Ministry of Education and Science of Ukraine
Black Sea Universities Network

ODESA NATIONAL UNIVERSITY OF TECHNOLOGY

International Competition of
Student Scientific Works

BLACK SEA SCIENCE 2022

PROCEEDINGS

Black Sea Science International Competition of Student Scientific Works by Odesa National University of Technology

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Proceedings of International Competition of Student Scientific Works «Black Sea Science 2022» contain the works of winners of the competition.

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INTRODUCTION

International Competition of Student Scientific Works “Black Sea Science” has been held annually since 2018 at the initiative of Odesa National University of Technology (formerly Odesa National Academy of Food Technologies) with the support of the Ministry of Education and Science of Ukraine. It has been supported by Black Sea Universities Network (the Association of 110 higher education institutions from 12 countries of the Black Sea Region) since 2019, and by Iseki-FOOD Association (European Integrating Food Science and Engineering Knowledge into the Food Chain Association) since 2020.

The goal of the competition is to expand international relations and attract students to research activities. It is held in the following fields:

- Food science and technologies
- Economics and administration
- Information technologies, automation and robotics
- Power engineering and energy efficiency
- Ecology and environmental protection

The jury includes both Ukrainian and foreign scientists. In the 4 years that the competition has been held, the jury included scientists from universities of 24 countries: Angola, Azerbaijan, Benin, Bulgaria, China, Czech Republic, France, Georgia, Germany, Greece, Israel, Italy, Kazakhstan, Latvia, Lithuania, Moldova, Pakistan, Poland, Romania, Serbia, Slovakia, Switzerland, Turkey, USA.

At the same time, every year the geography has expanded and the number of foreign jury members has increased: from 46 jury members representing 25 universities from 12 countries in 2018, to 73 jury members of the 46 universities from 19 countries in 2022.

More than a thousand student research papers have been submitted to the competition from both Ukrainian and foreign institutions from 25 countries: China, Poland, Mexico, USA, France, Greece, Germany, Canada, Costa Rica, Brazil, India, Pakistan, Israel, Macedonia, Lithuania, Latvia, Slovakia, Romania, Kyrgyzstan, Kazakhstan, Bulgaria, Moldova, Georgia, Turkey, Serbia.

The interest of foreign students in the competition grew every year. In 2018, the students representing 15 institutions from 7 countries have submitted 33 works. In 2021 the number of submitted works increased to 73, authored by the students of 40 institutions from 18 countries.

The competition is held in two stages. In the first stage, student research papers are reviewed by members of the jury who are experts in the relevant fields. In the second stage of the competition, the winners of the first stage have the opportunity to present their work to a wide audience in person or online.

All participants of the competition and their scientific supervisors are awarded appropriate certificates, and the scientific works of the winners are included in the electronic proceedings of the competition. Every year the competition receives a large number of positive responses from Ukrainian and foreign colleagues with the desire to participate in the coming years.

1. FOOD SCIENCE AND TECHNOLOGIES

DEVELOPMENT OF TECHNOLOGY FOR THE PRODUCTION OF NON-ALCOHOLIC BEVERAGE WITH NATURAL VINEGAR AS A NATURAL CONSERVANT

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Abstract. *White wine vinegar is characterized by various uses in household and cooking, but also has significant health benefits due to its acetic acid content, including blood sugar control, appetite control, weight management, reduced cholesterol and antimicrobial properties etc. Despite all the usefulness of vinegar, it is seldom used in the food industry. Although there is a current trend in the food and beverage market to diversify vinegar categories, to obtain new products with increased prophylactic properties that will be able to prevent diseases and better sensory characteristics compared to conventional products and beverages. The aim of this study is to develop a new soft drink technology based on local fruits/ berries, aromat herbs and natural white wine vinegar.*

The process includes the use of natural ingredients in the following ratio of components, in % mass: fruits or berries: 20%, sugar: 20%, natural white wine vinegar 6% acidity: 10%, aromatic herbs: 1% or spices: 0.2 %. The method of obtaining the drink includes the following steps: washing fruits / berries and herbs, adding and grind it with sugar, maturation for 5 hours at T = +2 ... 4± 1 °C, adding vinegar warmed up to T = +50±1 °C, homogenization, maturation for 3 days at T = +2...4±1 °C, filtration, dilution like commercial juices to 10-12° Brix and packaging.

As a result, a unique drink is obtained that maintains all the organoleptic properties of natural ingredients, as well as all the beneficial nutritional qualities, free of artificial additives (dyes, preservatives, sweeteners). This gives us the possibility to expand the range of natural drinks and to expand the consumers circle. This research is extremely useful not only by expanding the range of soft drinks produced, but also by using local agricultural resources.

Keywords: *non-alcoholic beverages, natural white wine vinegar, fruit, berries.*

I. INTRODUCTION

Recently, there has been growing recognition of the key role of functional vinegar drinks in both the prevention and treatment of disease. Thus, the production and consumption of functional drinks has become of great importance as they provide health benefits beyond the basic nutritional functions. Currently, such drinks are the most developed category of functional foods due to the convenience and ability to meet consumer requirements for content, appearance, and ease of use as long-term storage products. In addition, they are an excellent delivery vehicle for nutrients and bioactive compounds, including vitamins, minerals, antioxidants, natural acids, plant extracts, and more.

II. LITERATURE ANALYSIS

In addition to the growing public interest in natural fruit vinegars, vinegar drinks containing a combination of phytochemicals found in fruits have gained popularity in recent years [1]. Farmers in the Republic of Moldova produce a large number of local fruits and berries that are potentially of interest to the food industry [2]. The value of these agricultural products is mainly due to their nutritional and therapeutic properties. A huge amount of research is focused on their effects when consumed and health benefits, claiming that they are natural sources of bioactive compounds with antioxidant and anti-inflammatory properties [3]. In addition, when combined with vinegar, they have a positive effect on several chronic conditions such as obesity, diabetes, cardiovascular and neurodegenerative diseases [4].

In earlier studies, we have developed a technology for producing white wine vinegar by natural fermentation using walnut peel as a substrate [5, 6]. And also, for the production of one hundred percent local product, local acetic acid bacteria were isolated [7]. The result was a vinegar with very good taste characteristics that can be used not only as a condiment for salads, but also in the preparation of dishes and drinks, which is what this article describes.

The purpose of the study is to explore the possibility of using natural wine vinegar in the preparation of non-alcoholic beverages as a natural preservative, capitalization of local agri-food products, and obtaining natural drinks that can be a worthy replacement for commercial drinks containing artificial additives.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

All raw materials of plant origin (plums *Prúnus doméstica*, peaches *Prúnus pérsica*, apples *Malus domestica Jonathan*, strawberries *Fragária ananássa*, raspberries *Rúbus idáeus rubin*, dry lavender *Lavandula L.*, fresh mint *Mentha L.*and basil *Ocimum L.*) and non-plant origin (vanillin, cinnamon, sugar and drinking water) were purchased from a local large supermarket. White wine vinegar was obtained during the work on the innovation and technology transfer project 18.80015.5007.222T "Development of biotechnology and implementation of modern production line of natural, high quality seasoned inherited vinegar, competitive on the internal and external market" [8].

Sensory evaluation

In total, a sensory study was carried out on 5 samples of the obtained drinks, which were coded with random letters. The tasting was carried out in a special room with tasting panels and a space between them so that the tasters did not influence each other by conversation or facial expressions. The tasters, consisting of employees and students of the Department of Nutrition and Food, were given an evaluation sheet.

The samples were evaluated by grading (1-5, whereas 1 – minimal, 5 – maximal) was carried out for the following sensory parameters: aspect, colour, taste and after-taste (acidity, sweetness, bitter-sweet taste, harmonious taste, astringency, mouth-feel and overall sensation), consistency and aroma. Sensory evaluation was carried out in batches with appropriate pauses [9].

Bacteriological analysis

Microbiological analysis included enumeration and identification of potential

pathogens and total number of microorganisms using Nutrient Agar, Sabouraud media was used to detect mold fungi. All the selective media were purchased from local distributor Ecochimia SRL from one manufacturer HiMedia.

Samples without dilution in the amount of 0.1 ml were inoculated into the media and incubated. All plates were incubated under aerobic conditions at 36±1°C for 24 hrs. The mean number of colonies counted was expressed as log colony forming units (cfu)/100 ml [10].

Measurement of brix value

The Brix value of samples was calculated by refractive index using precision refractometer MASTER-53α (Atago, Honshu, Japan) [11].

Determination of pH and titratable acidity

The pH of each beverage (50 mL) was determined by using a H-meter laboratory inoLab® pH 7110 (WTW, Germany) - basic desktop pH/mV meter, previously calibrated with pH 4.0 and 7.0 buffers. The titrable acidity was then measured by adding 1.0-mL aliquots of 0.1 M NaOH to each beverage until the pH reached 7.0 [12].

Color measurements

CIELab chromatic parameters, L* (lightness axis), a* (red-green axis) and b* (yellow-blue axis) were obtained using a portable tristimulus colour analyzer Chroma Meter CR-400 (Minolta, Japan) [13].

IV. RESULTS

The aim of the present research is to develop the technology of soft drinks with the application of natural white wine vinegar and other local ingredients. In table 1 are presented recipes for beverages elaborate for 1 liter.

Table 1. Composition of non-alcoholic beverages prepared for 1 liter *

№	Name of beverages	Components, %					
		Fruits / Berries[1]	Sugar	Aromatic plants	Spices	Vinegar	Water
1.	Plum with lavender	20	20	0,2	-	10	70
2.	Peaches with cinnamon	20	20	-	0,2	10	70
3.	Apple with vanilla	20	20	-	0,2	10	70
4.	Strawberry with basil	20	20	1	-	10	70
5.	Raspberry with mint	20	20	1	-	10	70

*Note: * - developed by the author, [1]-fruit / berry norm is indicated for the net mass.*

The technology of obtaining the non-alcoholic beverage consists of two stages. The first stage involves the preparation of the concentrate, which consists of water base - natural vinegar with a concentration of 6%, obtained from white wine and solid - fruits or berries, herbs or spices and sugar. The fruits or berries are pressed and crushed with sugar. Leave until a syrup forms in 1-6 hours. The vinegar is pasteurized at +90 ± 2°C for 2 minutes, cooled to +50 ± 2°C, poured over the syrup formed and mixed. Maturation is carried out for 1 ... 3 days at a temperature of +2 ...+4°C, after which the liquid is filtered on the solid side, with the addition of drinking water in a ratio 1:1,

which is gradually poured through the solid side to reduce syrup losses.

The second stage consists in dissolving the concentrate obtained up to the value of the 12-15° Brix with drinking water and bottling it in appropriate and sterile packaging. The technological scheme for obtaining the elaborated drink is shown in figure 1.

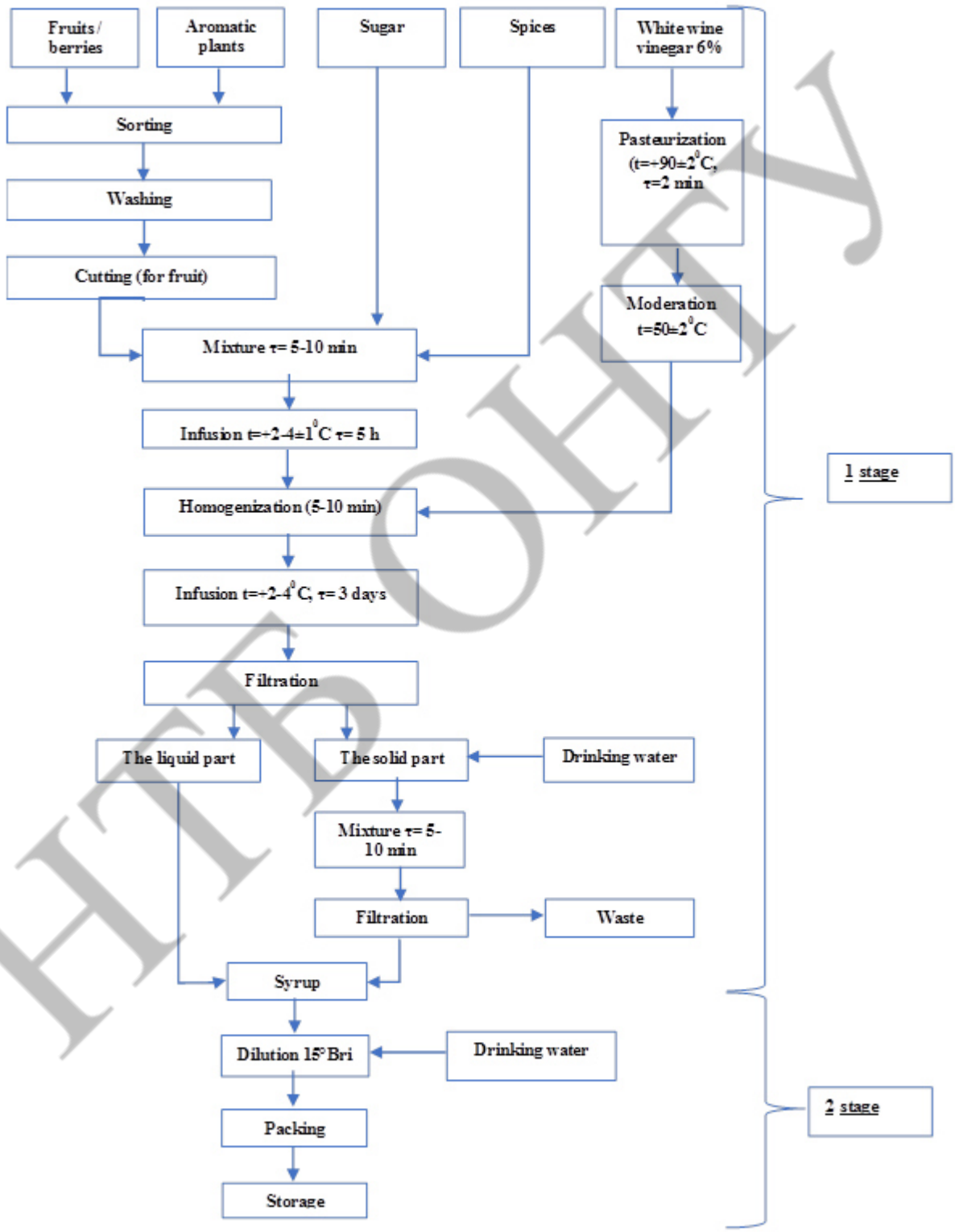

Fig. 1. Technological scheme for obtaining a non-alcoholic beverage

The consumer primarily pays attention to sensory characteristics such as appearance, taste and aroma. Thus, the second stage of the work was to determine the influence of the vinegar on the organoleptic indicators of beverages. The organoleptic evaluation of the quality of non-alcoholic beverages was performed by a group of tasters consisting of teachers and students of the Department of Food and Nutrition. The sensory qualities (appearance, consistency, taste, aftertaste, aroma, color) of the assortment of non-alcoholic beverages made were assessed according to the scoring scale, presented in the sensory analysis sheet. Based on the results of the average scores of the sensory analysis of five samples of non-alcoholic beverages made from various natural ingredients was built in Figure 2.

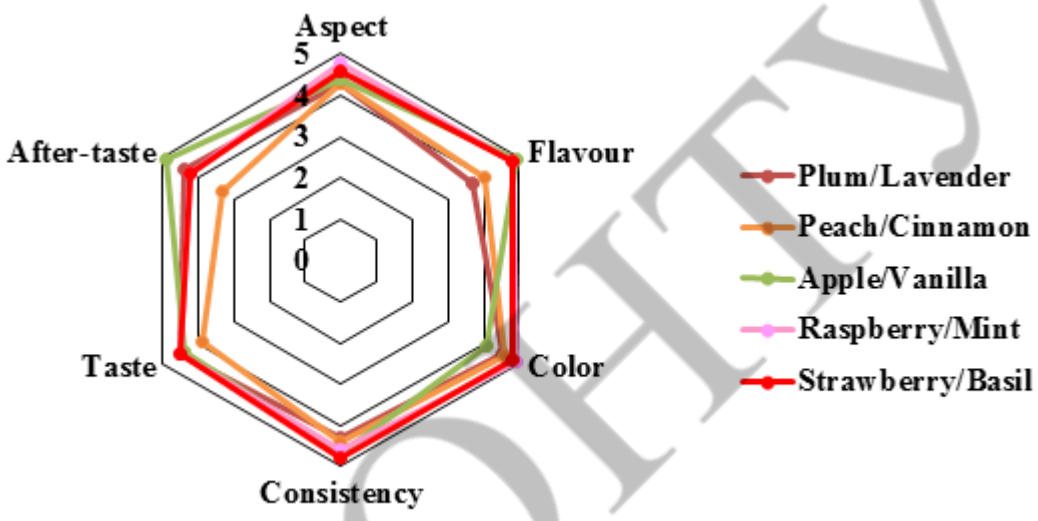

Fig. 2. Spider-graph for the sensory profile of beverages samples.

Based on the data obtained, we can conclude that all the non-alcoholic beverages analyzed had a sweet taste and aroma with a sour hue corresponding to the ingredients from which they were obtained. Some tasters noticed a hint of vinegar, but this did not negatively affect opinions about the quality of soft drinks. The tasters also assessed the ability of the drinks to give a feeling of lightness and freshness, which is especially important for summer soft drinks. The appearance and consistency of the non-alcoholic beverages made are similar to ordinary carbonated water, with a light color of the raw materials used (light yellow, light pink, etc.), figure 3.

Based on the data presented in the figure 2, the leaders of the non-alcoholic drinks appreciated were "Peach drink with cinnamon" and "Raspberry drink with mint", with a total rating of 5 points, in second place was placed "Strawberry drink with basil" with a score of 4.9, on the third place was established “Drinking apples with vanilla” with 4.85 points and on the fourth place was placed “Drinking plums with lavender” accumulating 4.7 points. "Plum beverage with lavender" has accumulated the fewest points because not all tasters like the taste of lavender. The overall average for all types of non-

Fig. 3. The visual aspect of the elaborated beverages

alcoholic beverages appreciated was 4.89 points out of a possible 5.0, which is an indicator high enough to meet the demand of a large number of consumers and become a competitive product with non-alcoholic beverages on the market.

Non-alcoholic beverages are, as mentioned above, are products of current consumption, appreciated by most consumers. For the human body they have a rehydrating action due to the high water content. Non-alcoholic beverages containing carbon dioxide and organic acids ensure proper gastric acidification.

During the summer, when the water intake is high, the gastric acidity decreases, which favors the appearance of bacterial and viral infections in the digestive tract. During this period, the consumption of soft drinks increases and obviously the demand for them in commercial establishments increases, in which some non-alcoholic drinks due to their high sugar content, high acidity, use of synthetic dyes, preservatives, etc. are not recommended by doctors.

Table 2 shows the calculated energy and nutritional value for elaborated beverages.

Table 2. The nutritional and energy value of processed beverages

Type of beverages	**Raw material**	**Mass, g**	**Protein, g**	**Fats, g**	**Carbohydrates, g**	**Energy value**	
						kJ/g	**kcal/g**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Plums	30	0,24	0,09	2,88	52,75	12,60
	Sugar	10	0,00	0,00	9,97	166,63	39,80
	White wine vinegar	10	0,00	0,00	0,30	13,39	3,20
	Lavender dry	0,2	0,00	0,00	0,00	0,00	0,00
	Potable water	70	0,00	0,00	0,00	0,00	0,00
		Total 100 g	**0,21**	**0,08**	**10,94**	**193,80**	**46,29**
	Peaches	30	0,27	0,03	3,39	57,77	13,80
	Sugar	10	0,00	0,00	9,97	166,63	39,80
	White wine vinegar	10	0,00	0,00	0,30	13,39	3,20
	Cinnamon	0,2	0,01	0,01	0,16	57,77	0,52
	Potable water	70	0,00	0,00	0,00	0,00	0,00
		Total 100 g	**0,23**	**0,03**	**11,5**	**199,66**	**47,69**
	Mere	30	0,12	0,12	2,94	59,03	14,10
	Sugar	10	0,00	0,00	9,97	166,63	39,80
	White wine vinegar	10	0,00	0,00	0,30	13,39	3,20
	Vanilla	0,2	0,00	0,00	0,03	2,42	0,58
	Potable water	70	0,00	0,00	0,00	0,00	0,00
		Total 100 g	**0,10**	**0,10**	**11,01**	**200,88**	**47,98**
	Strawberry	30	0,24	0,12	2,25	51,49	12,30
	Sugar	10	0,00	0,00	9,97	166,63	39,80
	White wine vinegar	10	0,00	0,00	0,30	13,39	3,20
	Fresh basil	1	0,03	0,01	0,04	1,13	0,27
	Potable water	70	0,00	0,00	0,00	0,00	0,00
		Total 100 g	**0,22**	**0,1**	**10,38**	**192,29**	**45,93**

1	2	3	4	5	6	7	8
	Raspberry	30	0,24	0,15	2,49	57,77	13,80
	Sugar	10	0,00	0,00	9,97	166,63	39,80
	White wine vinegar	10	0,00	0,00	0,30	13,39	3,20
	Fresh mint	1	0,04	0,00	0,08	2,05	0,49
	Potable water	70	0,00	0,00	0,00	0,00	0,00
		Total 100 g	**0,23**	**0,13**	**10,61**	**198,24**	**47,35**

The analysis of Table 2 shows that the beverages produced contain a significant amount of carbohydrates due to the components of sugar and fruit or berries, whose values are from 10.38 to 11.50g per 100ml. In order to correspond to the carbohydrate content (according to the norms) of the non-alcoholic beverages produced, it was resorted to compare the energy value with those selected from the trade shown in tab.3.

Table 3. The nutritional and energy value of commercial beverages

Product name	**Mass, g**	**Protein, g**	**Fats, g**	**Carbohydrates, g**	**Energy value**	
					kJ/g	**kcal/g**
CAPPY with grapefruit pulpy	100	0,00	0,00	12,10	**214,00**	**50,00**
PRIGAT, peach concentrate	100	0,00	0,00	14,00	**217,71**	**52,00**
OCHAKOVO, strawberry mojito	100	0,00	0,00	18,60	**320,00**	**75,60**
TEDDY, with apple and carrot juice	100	0,00	0,00	11,00	**188,40**	**45,00**
FANTA, strawberry and kiwi	100	0,00	0,00	10,20	**177,00**	**42,00**

The data presented in tables 2 and 3 demonstrates that the energy value of processed beverages is close to the energy value of the same amount of commercial sweet drinks. The difference is insignificant, but the advantage is that processed soft drinks are made from natural raw materials, while commercial ones contain artificial additives. Therefore, the drinks obtained can be offered as a healthy and natural alternative to commercial non-alcoholic beverages.

Table 4. Physico-chemical and chromatic characteristics of processed beverages

№	**Indices***	**Beverage samples**				
		Plum /Lavender	*Peach /Cinnamon*	*Apple /Vanilla*	*Strawberry /Basil*	*Raspberry/ Mint*
1.	pH	3,53±0,02	3,51±0,01	3,47±0,07	3,33±0,01	3,43±0,02
2.	Density, g/cm^3	1 056±0,03	1 045±0,05	1 050±0,03	1 047±0,05	1 047±0,01
3.	Brix^0	15±0,07	11±0,02	13±0,01	12±0,01	12,5±0,02
4.	Titratable acidity, %	15,2±0,15	14,2±0,23	14,1±0,05	15,4±0,14	15,1±0,11
5.	L*	15,46±0,02	26,95±0,32	28,93±0,31	17,94±0,06	14,27±0,03
6.	a*	5,41±0,03	4,31±0,19	5,73±0,14	15,17±0,10	9,89±0,05
7.	b*	2,78±0,03	13,53±0,52	19,26±0,38	7,71±0,05	2,97±0,05

** results are presented as mean ± standard deviation*

Analyzing table 4. similarity is observed in several parameters, such as: pH, density, acidity. The significant difference is observed in the color indices, determined by the CIELab method. For two samples "Peach beverage with cinnamon" (26.95) and "Apple beverage with vanilla" (28.93) the L-brightness value was obtained higher, which shows that the samples emit more light. The results of the "Plum beverage with lavender", "Strawberry beverage with basil" and "Raspberry beverage with mint" tests at the L value ranged from 14.27 to 17.94, which proves the darker color, ie the drinks emit less light. The values obtained at a * and b * are all positive, ie the color of the samples is in the range of red-orange-yellow. The dominant red color in the "Strawberry beverage with basil", "Raspberry beverage with mint" and "Plum beverage with lavender" samples is due to the extraction of anthocyanins from the fruit, at the same time the dominance of the yellow color in the "Apple beverage with vanilla" and "Peach beverage with cinnamon" samples is due to the extraction of carotenoids.

The microbiological characteristics were determined from the samples kept during the research in glass containers with airtight lids at a temperature of + 3 ± 1C. 2 types of media were used to determine the microbiological status of non-alcoholic drinkers: Sabouraud and Agar. The description of the cultural and morphological properties was performed after staining and microscopy of the colonies with the determination of the total number of microorganisms. The results of the analyzes are presented in Figure 4 depending on the dynamics of storage for up to 6 months.

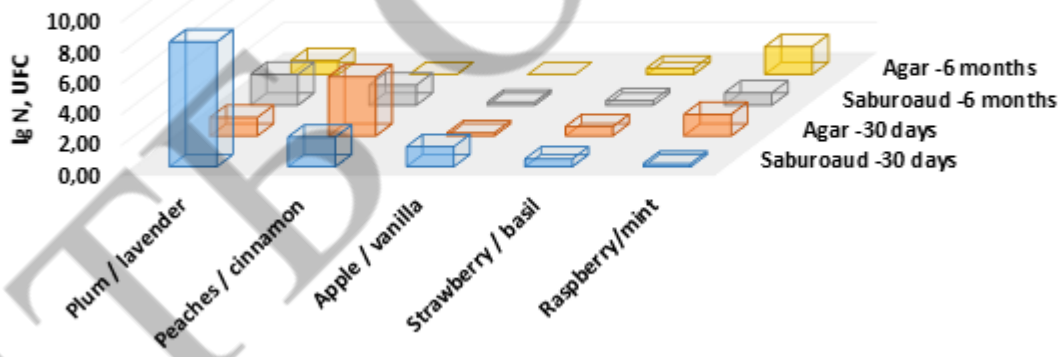

Fig. 4. Dynamics of microbiota development of beverage samples

It is known that fresh fruits and berries may contain various populations of bacteria and yeast. These microorganisms can be completely or partially removed by the washing process depending on the structure and surface condition of the product. Analyzing the evolution of the microbiota shown in Figure 4, it is observed that the samples are prepared in the correct hygienic conditions and plus the presence of acetic acid plays an important antimicrobial and preservative role. We can mention that during the preparation, under the action of acetic acid, some microorganisms in the drinks go into a state of anabiosis. Only after storage for 30 days at a temperature of 3 ± 1ºC is observed an insignificant increase in the number of microorganisms, but falls within the allowable limit according to the standards of RM - GD no. 934 [14]. In conclusion, we can state that the shelf life of beverages can be longer than 30 days. For

some samples, kept for 180 days, the development of unique micromycete colonies is observed. This phenomenon is due to the specific microflora and anatomical structure of the berries (strawberry, raspberry), which is more numerous and varied compared to the microflora of fruits (apples, plums).

V. CONCLUSIONS

In this paper, the recipes and the technological production scheme for five types of non-alcoholic beverages from local fruits/berries, natural white wine vinegar and aromatic plants were elaborated, with the determination of the organoleptic, physico-chemical and microbiological characteristics. At the same time, a new way was proposed to capitalize on the natural vinegar from white wine produced in the food industry and to diversify the assortment of non-alcoholic beverages from local natural products.

Following the comparative analysis of the energy value of elaborate the non-alcoholic beverages (from 45.93 to 47.98 kcal / 100ml) and of the commercial non-alcoholic beverages (from 42.00 to 75.60 kcal / 100ml), it was found that processed soft drinks could be offered as a healthy and natural alternative to commercial ones.

The quality of processed soft drinks (from plum with lavender, from apples with cinnamon, from raspberries with mint, from strawberry with basil) is due to the addition of wine vinegar obtained from natural components, which have a significant impact on the nutritional, physico -chemical and microbiological characteristics of drinks.

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MONITORING OF DIFFERENT PUMPKIN VARIETIES FOR PECTIN PRODUCTION

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Abstract: *One of the most important tasks of our time is to improve the supply of the country's population with high-vitamin, environmentally safe food throughout the year. To reduce the ingress and content of various heavy metals and radionuclides into the human body through food products, the population of the country needs to ensure the safety of food products. The need for inexpensive, ecological melon products with a high content of pectin substances, carotene, and dietary fiber has increased. The highest content of such substances is distinguished by pumpkin. One of the most important ways to reduce the negative impact of the environment on human health is the creation of pectin-containing food products that have detoxifying properties, which contributes to the elimination of toxic substances and radionuclides.*
Keywords*: pectin, dietary fiber, pumpkin, bread, pumpkin variety Karina, pumpkin variety Aphrodite, pumpkin variety Mozoleevskaya 10.*

I. INTRODUCTION

According to the Quarterly Review of Food Hydrocolloids, since 1991, the world market has seen a steady increase in pectin consumption by an average of 3-3.5% per year. The most extensive and free-market today is the market of therapeutic and preventive food products enriched with low-methoxylated pectin, which can remove heavy metals, radionuclides, and pesticides from the human organism. Especially attractive in this group are pectin preparations. Pectin is recognized by the World Health Organization as a toxicologically safe product and is recommended as a corrector of human health. By Article 321 of the Labor Code of the Republic of Kazakhstan, employees who come into contact with inorganic lead compounds must additionally give out 2 grams of pectin in the form of canned plant foods, fruit juices, and beverages enriched with it (the actual content of pectin is indicated by the manufacturer.).

The market for pectin and pectin products is growing rapidly every year by 3-4%. Pectin is a special component of dietary fiber.

Kazakhstan, Russia, and the Central Asian republics do not have their pectin production.

Kazakhstan has a sufficient raw material base for the production of pectin drugs, in particular secondary raw materials. One rational way to solve this problem is to create a scientific and technological base of deep processing of sugar beets, apples, and melons with competitive products [1].

Global pectin production is concentrated in Europe, South America, Iran, and China (Fig.1).

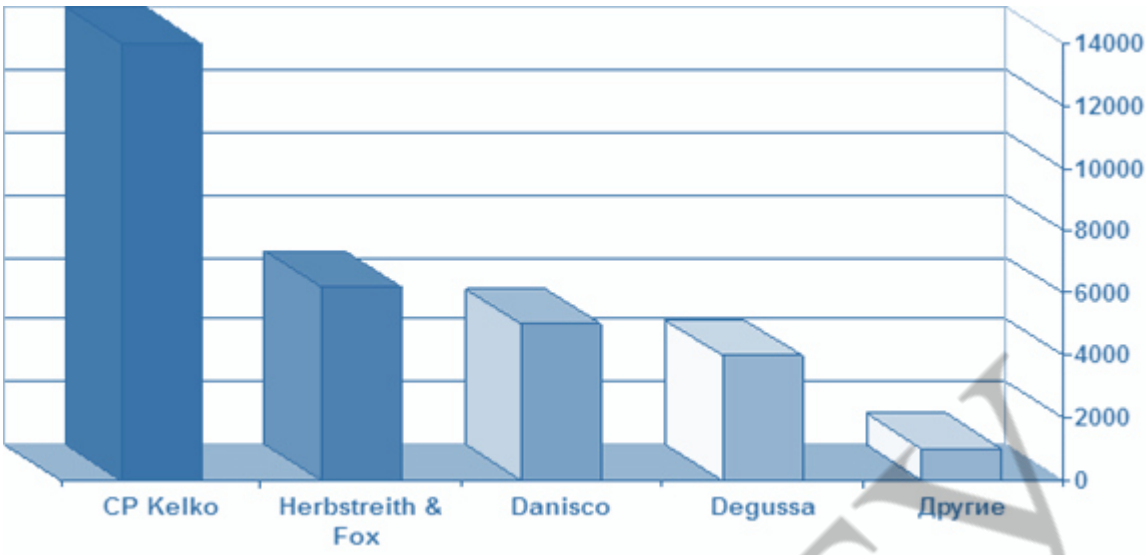

Fig.1. Major World pectin producers

II. LITERATURE ANALYSIS

2.1 The use of pectin's in the food industry

The use of pectin's in the food industry has reached enormous proportions. The main consumer of high-labeled pectin (about 80%) is the confectionery industry.

Compared to other gelling agents commonly used for confectionery, the use of pectin requires strict adherence to prescription and production parameters.

Pectin's are used as an additive to medicinal varieties of bakery and pasta; in the bakery - for baking non-stale varieties of bread.

Currently, pectin and its derivatives are increasingly used in baking as an anion-active, useful substance (PAV).

It has been established that the insertion of pectin into the dough affects the biological, colloidal, and microbiological processes of preparation of the dough. In addition, it has been found that the content of the petition of the finished bread is reduced in comparison with the original amount in the dough.

It should be noted that as the dosage of pectin increases, there is a decrease in the specific volume and decreases in the rest of the bread quality, which is due to the ability of the latter to bind the water, and in turn, has an impact on the dough's humidity and quality of bread.

The effect of pectin etherification on the quality of wheat flour bread has also been established.

The maximum improvement in the quality of bread with the addition of low-esterified pectin is associated with the presence in its molecule of a larger number of free carboxyl groups than that of high-esterified pectin. These groups are reactive, and, actively interacting with the components of the dough, form a large number of compounds, affecting the properties and quality of bread. Thus, in baking, it is possible to use highly esterified and low-esterified apple pectins, but in contrast to confectionery production, it is more appropriate to use low-esterified pectin.

The change in the parameters of the structural and mechanical properties of bread crumb with the addition of pectin in the amount of 0.05-1.0% of the flour weight

during storage indicates that bread with the addition of pectin becomes stale 1.04-1.9 times slower than bread without pectin, which is extremely important for increasing the sales period of bakery products [2].

The influence of apple pectins with a degree of esterification of 59-64, 76-78, and 38-44 % on the quality of custard cakes was studied.

The addition of high-esterified and low-esterified apple pectins improves the quality of gingerbread. The best quality is the gingerbread with the addition of low-etherified apple pectin in an amount of 0.1 % by weight of flour.

The main area of use of citrus pectins is dairy products (in particular, yogurts), where it is necessary to prevent the separation of milk proteins and whey at low pH values, as well as to provide a variety of textural properties, smoothness of structure and freshness of taste.

Low-esterified pectins are often used in fruit preparations for yogurt to create a soft, partially thixotropic texture of the jelly, sufficient to ensure a uniform distribution of the fruit, but still allow the free introduction of the fruit preparation into the yogurt. The texture of yogurt can be improved by adding small amounts of low-methoxylated pectin. However, it should be noted that low-methoxylated pectin does not prevent syneresis [3].

The introduction of pectin in fermented milk products can significantly increase their shelf life.

Pectin is also used in the production of ice cream, cheeses (to increase their moisture-absorbing capacity), and other products in the dairy industry [4].

Highly methoxylated pectin is used in concentrated fruit drinks to stabilize oil emulsions and suspensions of fruit particles.

The property of highly methoxylated pectins to change the consistency (viscosity) of products is used in recombined juices to restore the feeling of fresh juice in the mouth. Pectin is also used to create a natural consistency in instant fruit drinks. Based on pectins, a wide range of kissels, mousses, and gels have developed.

A wide range of functional properties: thickening, gelatinization, stabilization of food systems, complexation defines pectin as a biopolymer, valuable in many industries. Pectin is not only an effective, in some cases simply necessary, a food additive that forms the structure of food, but also a valuable medical drug.

2.2 Pumpkin is a source of pectin

Pumpkin (Cucurbita) is an annual plant in the pumpkin family. The fruits are large fleshy pumpkins with numerous flat yellowish-white seeds. It is worth noting the good resistance of the pumpkin to drought. The fruit pulp of pumpkin contains dry substances (15-18 %), sugars (8-10 %), pectin substances, nitrogenous compounds, salts of potassium, calcium, magnesium, iron, vitamins C, B, B2, PP and provitamin A; in seeds - fatty oil (36-52%), phytosterols, organic acids, resins, fiber (0.7%), a little organic acid.

The fruits of vegetable pumpkins contain up to 14% of sugars, especially a lot of easily digestible glucose. They also contain starch, pectin substances, and fats. The calorie content of a pumpkin is from 170 to 316 calories per kilogram of fruit. Of the

minerals in the pumpkin, there are especially many salts of potassium, phosphorus and calcium, which are vital for the human organism. They also contain a lot of copper, cobalt, and other trace elements [5].

The content of pectin in fruits and vegetables is (g/100 g of the product):

Beets 0,7–2,0

Watermelons 1,0–1,5

Melon.....1,0-1,5

Pumpkin 2,6–9,3

Pumpkin 2,2-2,4

Karina is a large-fruited pumpkin selected by the Kazakh Research Institute of Potato and Vegetable Farming. The variety is long-leaved, the fruits are round-flattened, medium-sized, gray and green, less often variegated, pinkish when stored. The flesh of the fruit is bright orange, dense, medium-thick, very sweet. The average weight of the fruit is from 2 to 10 kg. The seeds are cream-colored, leathery, with a dense rind. The variety is medium-ripe, yielding. Keeping quality and transportability are high.

Mozoleevskaya 10-hard-edged pumpkin of selection of the Kazakh Research Institute of Potato and Vegetable farming. The plants are long-leaved, the fruits are cylindrical, with ribbing at the peduncle, light orange when fully ripe. The pattern is in the form of wide mottled stripes, initially dark green, and when fully ripe - dark orange. The flesh is yellow or cream, 3-5 cm thick, medium-density, slightly sweet. The seed nest is large. The seeds are medium oval, yellowish-cream with a rim. The average weight of the fruit is 4.5-7.0 kg. The variety is medium-ripe (102-117 days), productive, with high commercial qualities and good taste. Keeping quality and transportability are high.

Aphrodite (nutmeg pumpkin) - TK-17, KON-898, selected by KazNIIKO, the sample was obtained from the originator. The fruits are elongated, with a swollen end, of the "intercept" type. The tail part of the fruit occupies up to 2/3 of its entire length and has no voids. The color of the fruit is orange with a pattern in the form of brown indistinct torn stripes. When fully matured, the pattern disappears. The flesh is thick orange, sweet, dense. The surface of the fruit is smooth, with a powdery-bluish waxy coating, the peduncle is ribbed. The average weight of the fruit is 5-8 kg. The variety is medium-ripe for table consumption.

2.3 The process of obtaining pectin

The process of obtaining pectin consists of several stages. To begin with, the preparation of pectin-containing raw materials is carried out, then – extraction-hydrolysis of raw materials with mineral or organic acids. Extraction is an important step in the production of pectin. By evaporation in a vacuum, the extract is filtered, the filtrate is clarified, and then the extract is concentrated. The precipitation of pectin substances reproduced using polyvalent metal salts of aliphatic alcohols. At the next stage, the raw pectin is cleaned with alcohol and dried, crushed and mixed with sugar to a standard degree of strength.

Raw materials for pectin production should contain a minimum amount of reducing sugars, since the reaction with amino acids produces colored products (melanoidins) (Fig.2) [6].

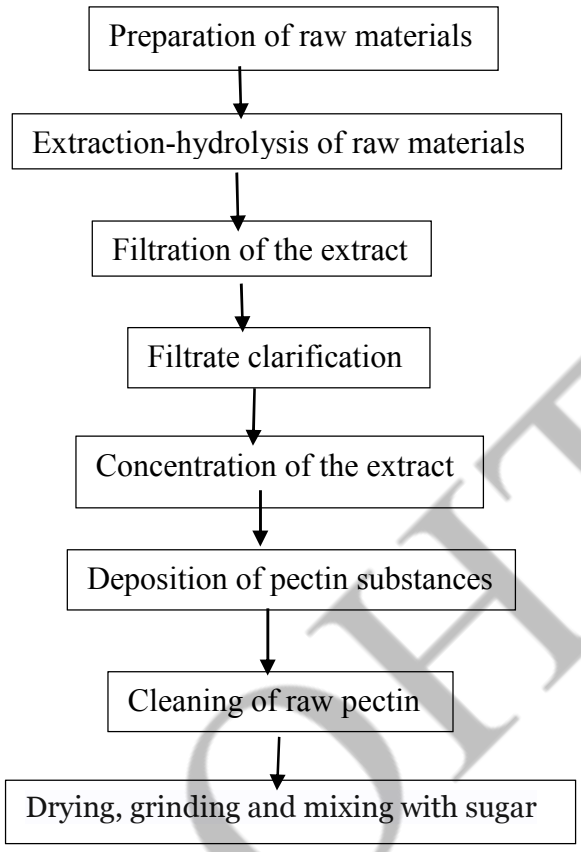

Fig. 2. Stages of pectin production

2.4 Detoxifying properties of pectins

Pectin not only forms a jelly consistency, but also has radioprotective and detoxifying properties, and, therefore, belongs to multifunctional additives.

Pectin has acquired particular importance recently, when it was found that it can form insoluble complexes, remove toxic metals from the human body and long-lived (with a half-life of several decades) isotopes of strontium, cesium, etc. In addition, pectin can absorb and remove from the body biogenic toxins, xenobiotics, anabolic, metabolic products and biologically harmful substances that accumulate in the body. It is recognized in most countries as a valuable food ingredient that has no restrictions on use [7].

In addition to radioprotective and detoxifying properties, clinical studies have shown the ability of pectin to reduce the allergic effects associated with the environmental situation, regulate metabolism and the functions of the digestive organs.

Pectin acts as a radioprotector and is recommended as an additive in food products to give them detoxication properties [8].

III. OBJECT AND METHODS OF RESEARCH

The main objects in the work are the most popular varieties of pumpkins: Aphrodite, Karina and Mozoleevskaya 10 (Fig.3).

a) Aphrodite variety b) Karina variety c) Mozolevskaya 10 variety

Fig. 3. Pumpkin varieties used in the work

Methods

We analyzed samples of melon crops and selected and determined the following quality indicators in pumpkin:

1 The content of pectin
2. Sugars
3. Acid content
4. Dry matter content
5. Degree of esterification

The main methods of analysis of pectins are related to their physical and chemical properties, as well as their structural features. For the characterization of pectins, the main indicators are total ash content, molecular weight, provide component, degree of esterification, the content of free carboxyl groups, binding capacity, etc.

Determine the total ash content of absolutely dry substance is carried out taking into account mass loss during drying of raw materials or subject to the humidity of raw materials, by ashing.

Determination of the mass fraction of dry substances was carried out by drying the suspension in the drying cabinet by the accelerated method.

The determination of the mass fraction of sugars was carried out by the cyanide method, which is based on the ability to reduce sugars to reduce potassium ferrocyanide in an alkaline medium to ferrocyanide:

$$C_6H_{12}O_6+6K_3[Fe(CN)_6]+6KOH \longrightarrow (CHOH)_4(COOH)_2+6K_4[Fe(CN)_6]+ 4H_2O$$

IV. RESULTS

The study of the anatomical composition of three varieties of pumpkin was carried out to select the most optimal variety from them, to recommend further production of pectin from secondary raw materials of pumpkin processing (pumpkin pulp).

Global consumption of pectin is growing rapidly. In the world, the potential reserves of raw materials (apple pomace and citrus peel) for pectin production allow

its main producers to plan an annual increase in pectin production by about 3.8 %, but the search for new sources of pectin-containing raw materials is an important task of science that provides the pectin industry [9].

According to figure 4, the safety indicators of domestic varieties of pumpkins do not exceed the permissible standards.

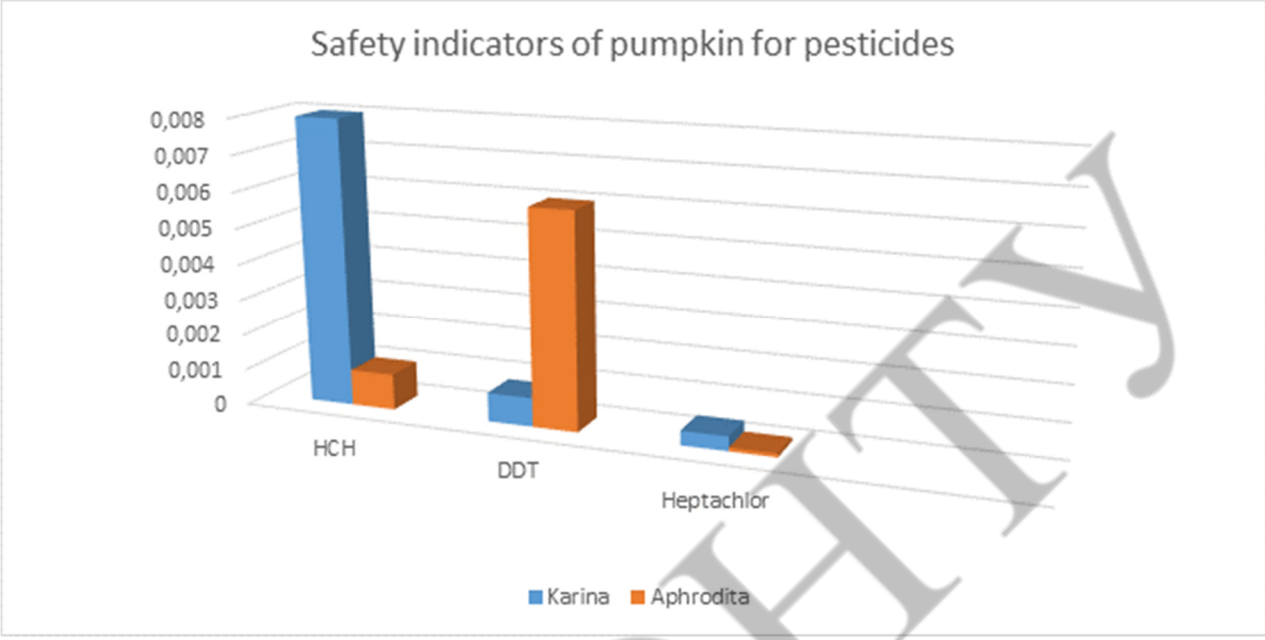

Fig. 4. Safety indicators of pumpkin varieties used in the work

According to GOST 30349-96, the indicators of pesticides do not exceed the norm. Hexachlorane in the Carina variety is 0.08%, and in the Aphrodite variety is 0.001%, which does not exceed the norm of 0.5%. Insecticide (DDT) was not found in both varieties of pumpkin, which also corresponds to regulatory documents. Heptachlor 0.0004% and 0.001%, respectively, in the varieties Carina and Aphrodite. The norm for this pesticide is less than 0.002%.

The functional orientation of the studied varieties is determined by the fractional composition of sugars (Figure 5).

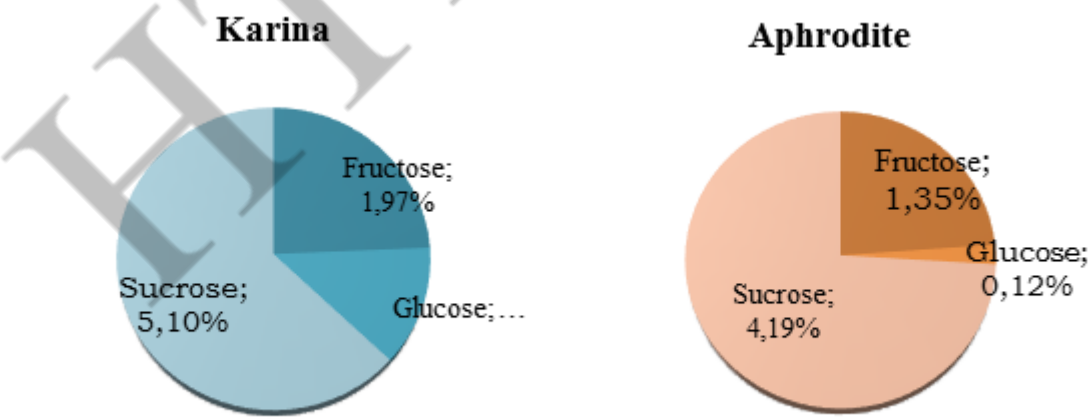

Fig. 5. Fractional composition of sugars in the studied pumpkin samples

It was found that the Karina variety is distinguished by the total sugar content (8.1%, against 5.7% - in Aphrodite). The fractional composition is dominated by sucrose (5.1 and 4.2%, respectively). The glucose content is 8.6 times lower in the Aphrodite variety (0.12%) than in the Carina variety (1.03%). At the same time, the fructose content in the Aphrodite variety is 31.5% less than in the Carina variety.

However, the study of the fractional composition of organic acids showed that the Carina variety has 3 times more tartaric acid than Aphrodite. Natural tartaric acid has antioxidant properties and has a beneficial effect on the metabolic and digestive processes in the body. Citric and lactic acids are absent in both varieties, and they do not differ in the content of malic acid (0.01%) and its content is very low. It is known that malic acid plays an important role in the metabolic processes of the human body. It promotes the full absorption of iron, interacts with vitamins, and is soluble in water.

As shown in fig. 6, relatively high content of succinic acid was found (0.027%-0.028%). The results of previous studies have shown that succinic acid is an adaptogen (increases the body's resistance to adverse environmental factors), which is a positive factor in the development of functional products [10].

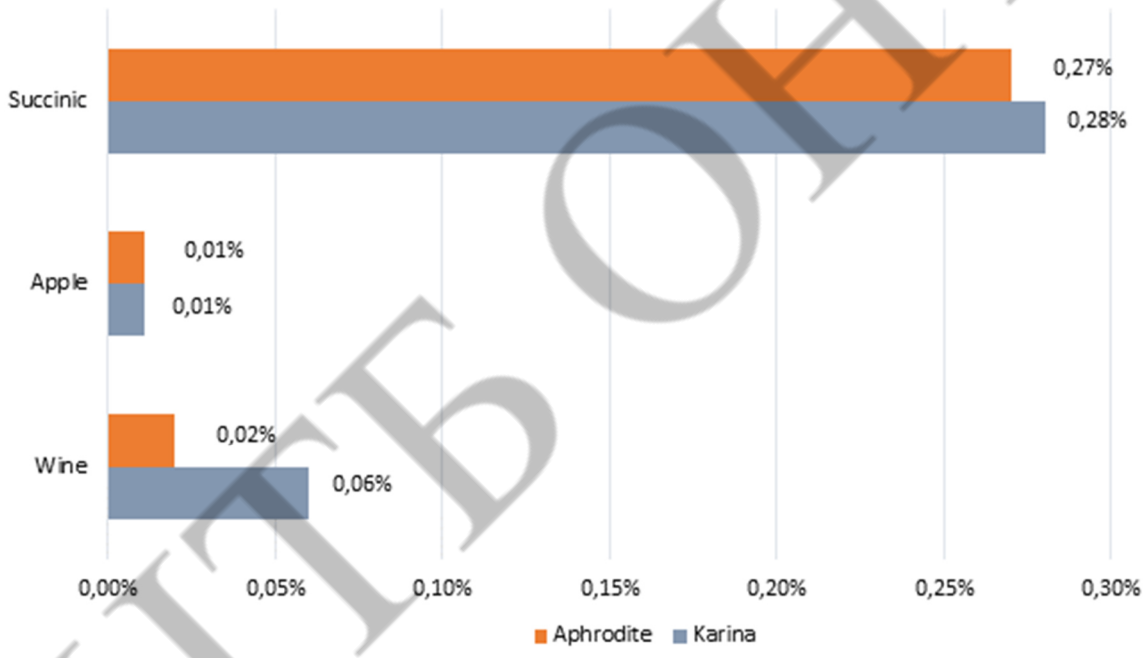

Fig. 6. Fractional composition of organic acids in the studied pumpkin samples

So, the total content of pectin in terms of absolutely dry matter in the Carina variety was 15.8%, Aphrodite-21.8 %. The studied pumpkin varieties (Carina and Aphrodite) were characterized by a high content of insoluble protopectin-11.88 and 15.5% and a lower content of soluble hydratopectin-3.96 and 6.30%, respectively (fig. 7).

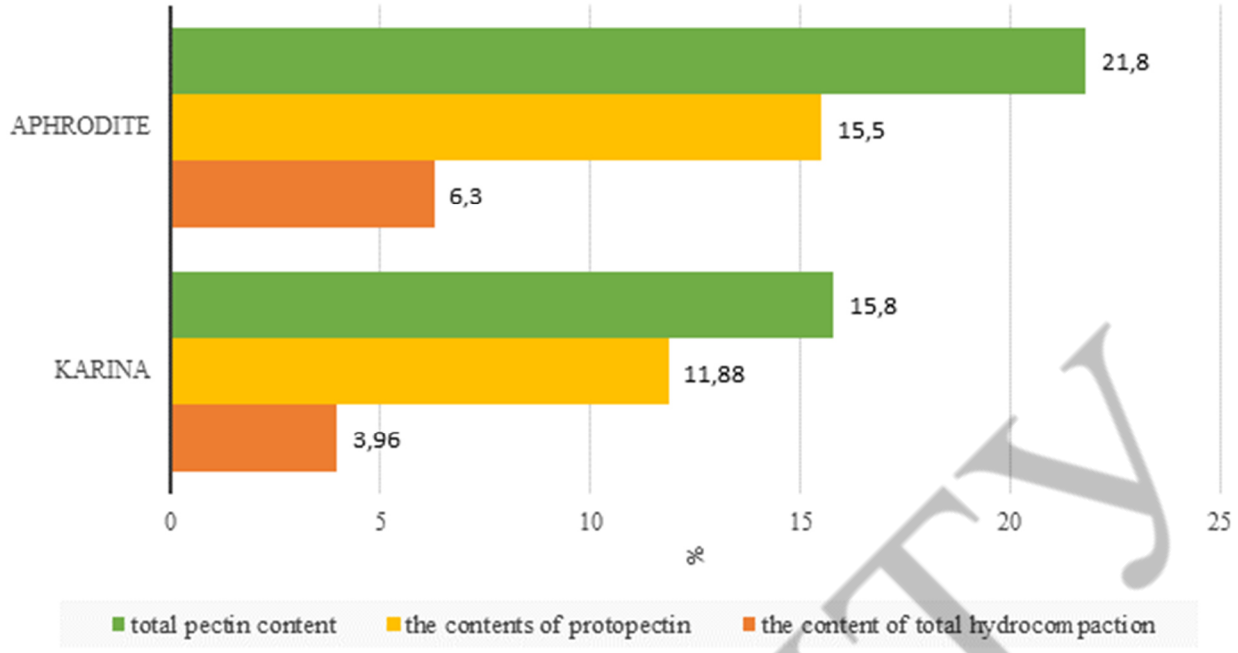

Fig. 7. Total content and fractional composition of pectin substances in the studied objects of research, % to absolutely dry matter

The results of studies of the analytical characteristics of the isolated pectins showed that the content of free carboxyl groups of pectin samples isolated from pumpkin pulp varieties Aphrodite and Karina practically do not differ. At the same time, the degree of esterification is slightly lower in the Karina variety (37.94%) in comparison with the Aphrodite variety (43.27%) (Figure 8). Thus, the isolated pectins from both studied pumpkin varieties should be classified as low-esterified (E less than 50%).

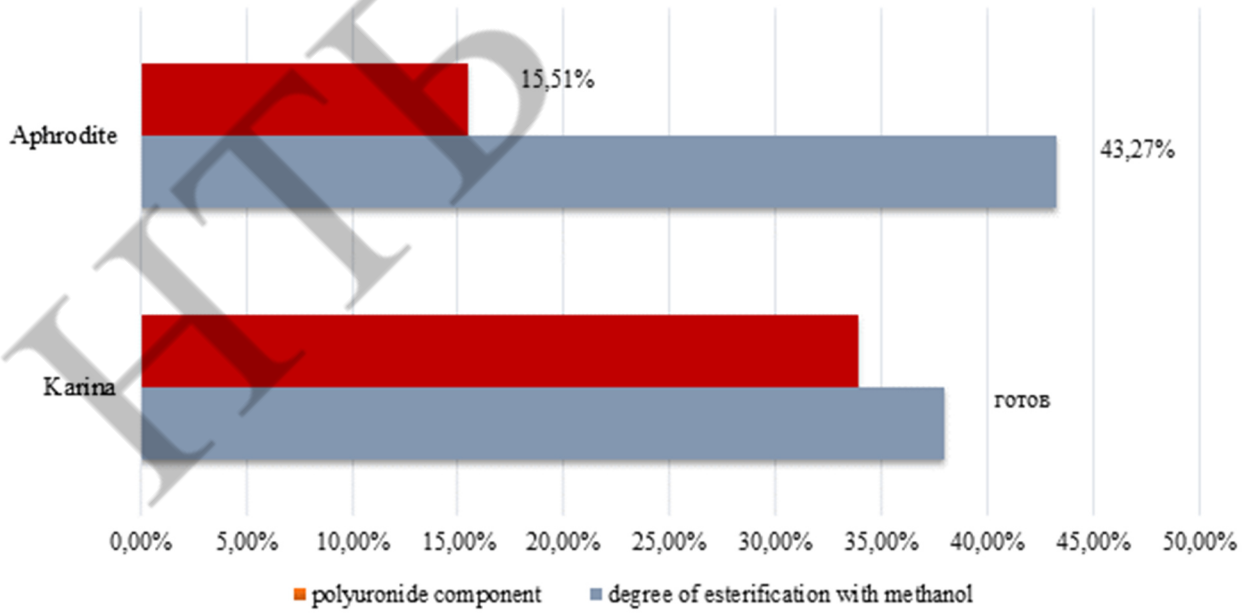

Fig. 8. Analytical characteristics of the pumpkin pulp varieties

It is known that the complexing properties of pectin substances depend on the content of free carboxyl groups, i.e., the degree of esterification of carboxyl groups

with methanol. The degree of esterification determines the linear charge density of the macromolecule, and, consequently, the strength and method of cation bonding.

With a decrease in the degree of esterification, that is, with an increase in the charge of the macromolecule, the bond of pectin substances with cations increases. Therefore, it is possible to predict a large complexing capacity for the Karina variety.

From the presented data, it follows that the total content of pectin substances is distinguished by the pumpkin of the Aphrodite variety (21.8%).

Thus, studies have shown that pumpkin can be used as an effective raw material for the production of pectin.

V. CONCLUSIONS

The state of the environment in many regions of the world, accompanied by pollution of the environment and food products with toxic substances, requires food safety and requires the expansion of the production of pectin and pectin-containing products as natural detoxifiers.

The demand for inexpensive melon-growing products, which are characterized by a high content of pectin substances, carotene, and dietary fiber, has significantly increased. The highest content of such substances is distinguished by pumpkin.

1. The results of studies of varietal characteristics of pumpkins in Kazakhstan have shown that the most promising and productive varieties are Karina and Aphrodite, which are characterized by a high content of mineral and biologically active substances, and in terms of food safety meet the requirements of regulatory documents.

2. The study of the fractional composition of organic acids showed that the Carina variety has 3 times more tartaric acid than Aphrodite. Citric and lactic acids are absent in both varieties, and they do not differ in the content of malic acid (0.01%) and its content is very low. Relatively high content of succinic acid was found in both varieties (0.027%-0.028%).

3. The pectin content in terms of absolutely dry matter in pumpkin pulp of the Karina variety was determined to be 15.8%, Aphrodite-21.8%, while their fractional composition of pectins was characterized by a high content of insoluble (protopectin) - 11.88 and 15.5% and a lower content of soluble (hydratopectin) - 3.96 and 6.30 %, respectively.

4. Studies have shown that the degree of esterification is slightly lower in the Carina variety (37.94%) in comparison with the Aphrodite variety (43.27%). Thus, the isolated pectins from both studied pumpkin varieties should be classified as low-esterified (E less than 50%). However, with a decrease in the degree of esterification, the complex-forming activity increases, which characterizes the Carina variety with higher detoxification properties.

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PSYLLIUM GEL AS A SUBSTITUTE FOR FAT IN THE COOKIES TECHNOLOGY

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Abstract. *The psyllium usage is of great interest for the value-added pastry production due to its functional and physiological characteristics. This raw-material is also characterized with some technological characteristics which will positively effect on their quality. The aim of the present study was to evaluate the effectiveness of psyllium usage for the reduced fat content cookies production. In the cookie`s recipe, 20 and 40 % of fat was replaced with psyllium gel using a combination of psyllium and water (P:W) in the ratio 1:8, 1:10 and 1:12. All samples were analyzed for moisture content, hardness, density, water absorption ability, spread ratio and sensory characteristics. It was found that the combine use of psyllium and water in ratio 1:12 leads to a negative effect on products quality, the denser structure formation compared with the control. The samples with 20 % fat replacement with psyllium (P: W -1:8) and 40 % (P: W -1:10) have showed the best results in all quality parameters – lower density and high overall acceptability. Density for these samples decreased by 14,8…9,0 %, spread ratio - by 2,07 ... 32,78 %, compared with the control. Thus, the psyllium use provides the consumer characteristics improvement of enriched products and their energy value decrease.*

Keywords: *psyllium, biscuits, pastry, fat content, quality parameters.*

I. INTRODUCTION

Pastry products are known to be in demand among the consumers. According to the State Statistics Service, in 2020 more than half of confectionery products on the market were pastry products, which confirm their potential for manufacturers [1].

Pastry products belong to the multicomponent foods. They contain a large amount of vegetable and animal fats, as well as fast carbohydrates, but essential amino acids, dietary fiber and micronutrients are present in very small quantities. The main disadvantage of pastry products, in particular butter cookies, based on the requirements of healthy diet, is the high energy value due to the high content of fast carbohydrates and saturated fats and lack of essential macro- and micronutrients in their content. At the same time, current trends in the development of the food industry are focused on chemical composition, energy and biological value improvement.

It should be noted that hydrogenated vegetable fats, which may contain trans fats, are often used for the production of pastry products. Their presence does not meet product safety requirements and is negatively perceived by modern consumers. Trans fats are characterized with negative effect on human health – disrupting metabolic processes, which can lead to weight problems, impaired immune function, and risk of diabetes and cardiovascular disease [2]. In particular, the World Health Organization in 2018 presented the REPLACE project, aimed at phasing out trans-fatty acids of industrial production from food around the world [3]. Recently, in our country there

are also initiatives aimed at limiting the content of trans fatty acids in food, in particular, a draft law banning the use of hydrogenated fats in foods consumed by children is prepared [4].

As a result, manufacturers are faced with the issue of finding safe alternatives to fat, the use of which will reduce the energy value of products and will not lead to a deterioration of final product`s quality.

A perspective ingredient for fat substitution is psyllium - the husk of the seeds of plantain (Plantago ovata). Psyllium contains about 2% proteins and a small amount of fats, about 85-88% carbohydrates, a significant massfraction of which is presented by water-soluble dietary fiber (arabinoxylan) [5, 6, 7]. Due to the high content of dietary fiber, psyllium is a promising substitute for fat, because this raw-material is able to form a gel with water, which is characterized by a stable structure.

II. LITERATURE REVIEW

Psyllium is the common name for several plant species of the genus Plantago. The psyllium husk is the outer shell of its seeds, which is separated by crushing them [6].

Detailed studies of the active fraction of psyllium husk showed that it is presented by the neutral arabinoxylan (22,6% arabinose, 74,6% xylose and a molar base) with branched structure [7]. Psyllium husk gums have a high molecular weight, which enhance the viscosity [8].

The gel-forming fraction of psyllium husk is about 55-60% and has not only a laxative effect, but also reduces blood cholesterol levels [9]. Psyllium has shown to be effective in the treatment of chronic constipation in patients [10]. According to another study, psyllium has a less pronounced effect than dried plums (prunes), but is still recognized as effective in the treatment of constipation [11].

Psyllium has been used in the treatment of mild to moderate hypercholesterolemia. During eight weeks of treatment of patients, the level of total cholesterol in the blood serum decreased by 14,8% and low-density lipoprotein (LDL) cholesterol by 20,2% [12, 13]. Psyllium has also been found to be a safe addition to the diet of patients with hypercholesterolemia (10 mg of simvastatin) and was effective in lowering cholesterol levels as 20 mg of simvastatin alone [14]. In addition, psyllium reduces the level of glucose in blood serum by 11% for the patients with type II diabetes mellitus, improves glycemic and lipid control [15-18].

Due to its chemical composition, psyllium is also recognized as an effective additive in food production. So, psyllium is used not only for therapeutic purposes, but also as a substitute for gluten in the production of flour products. Thus, the adding of the 3.0% psyllium in the starch mixture for the gluten-free bread production, provides to obtain a product with high sensory characteristics and a lower content of fat and calories [19]. Adding hydrated psyllium to bread recipes leads to increase the moisture content and thus the softness of the finished bread [20]. At the same time, when replacing wheat flour with psyllium, the volume of finished bread decreased with an increase in its content in the recipe. However, the samples with psyllium were close to the control in terms of weight, volume and rheological properties [21-23]. In addition, psyllium incorporation provides positive effect on the gluten-free pasta preparation,

which eliminates the stage of gelatinization of rice flour and increases the digestibility of finished products [24].

The use of psyllium makes it possible to increase the content of dietary fiber in the composition of the product, while not affecting the taste characteristics of finished products [25]. The addition of 7,5% psyllium to the recipe of a diet cake did not significantly affect the organoleptic and physicochemical properties of the product and is recommended for the overall quality improvement of the product [26]. By partial replacement of the flour with psyllium, a biscuit with a high content of dietary fiber was developed, consumption of which can effects on the glucose levels regulation in blood [5]. Psyllium is also used as a fat substitute in food technology. For example, cake samples with 75% vegetable oil substitution for psyllium gel were found acceptable [27].

Due to this, there is a need for further research on the use of psyllium in the production of pastry products. For nowadays there is not much research on replacing fat in the recipe of butter cookies with psyllium gel, which makes this topic promising for study.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Objects of research. The following raw materials were used for the production of buttery cookies: wheat flour (GSTU 46.004-99), margarine (spread) (DSTU 4465: 2005), white sugar (DSTU 4623: 2006), cocoa powder (DSTU 4391: 2017), egg products (DSTU 8719: 2017), table salt (DSTU 3583: 2015), vanillin (GOST 16599-71). Psyllium – husk of plantain seeds (NPE Shebanova L.O.) was also used in the research.

The subjects of research were dough, butter cookies.

The aim of the project is to study the possibility of reducing the fat content in the recipe of butter cookies by the use of psyllium. For this aim, rational conditions for its preparation for the production of butter cookies were also elaborated.

As a control sample buttery cookies "Vanilla Pretzel" with a significant proportion of fat in the recipe was chosen. During the study, psyllium gel (PG) was used to replace 20… 40% of fat, which was prepared with a ratio of psyllium and water 1:8, 1:10 and 1:12.

Research methods. In all samples, moisture and density for the dough were determined, as well as moisture, hardness, density, wetting, distribution coefficient and organoleptic characteristics for finished products.

Moisture content for the raw materials, semi-finished products and cookies was determined by drying method [27, 29].

The density of the dough was determined by volumetric method using the mass and volume measured, density of sample was calculated as mass to volume ratio, according to the generally accepted method [28, 29].

All statistical analysis was carried out in triplicate and average values were calculated. All data was statistically analyzed through analysis of variance (ANOVA) and Fischer test. Significance was accepted at $p<0.05$.

The cookie dough was prepared in two stages according to the functional diagram shown in Fig. 1.

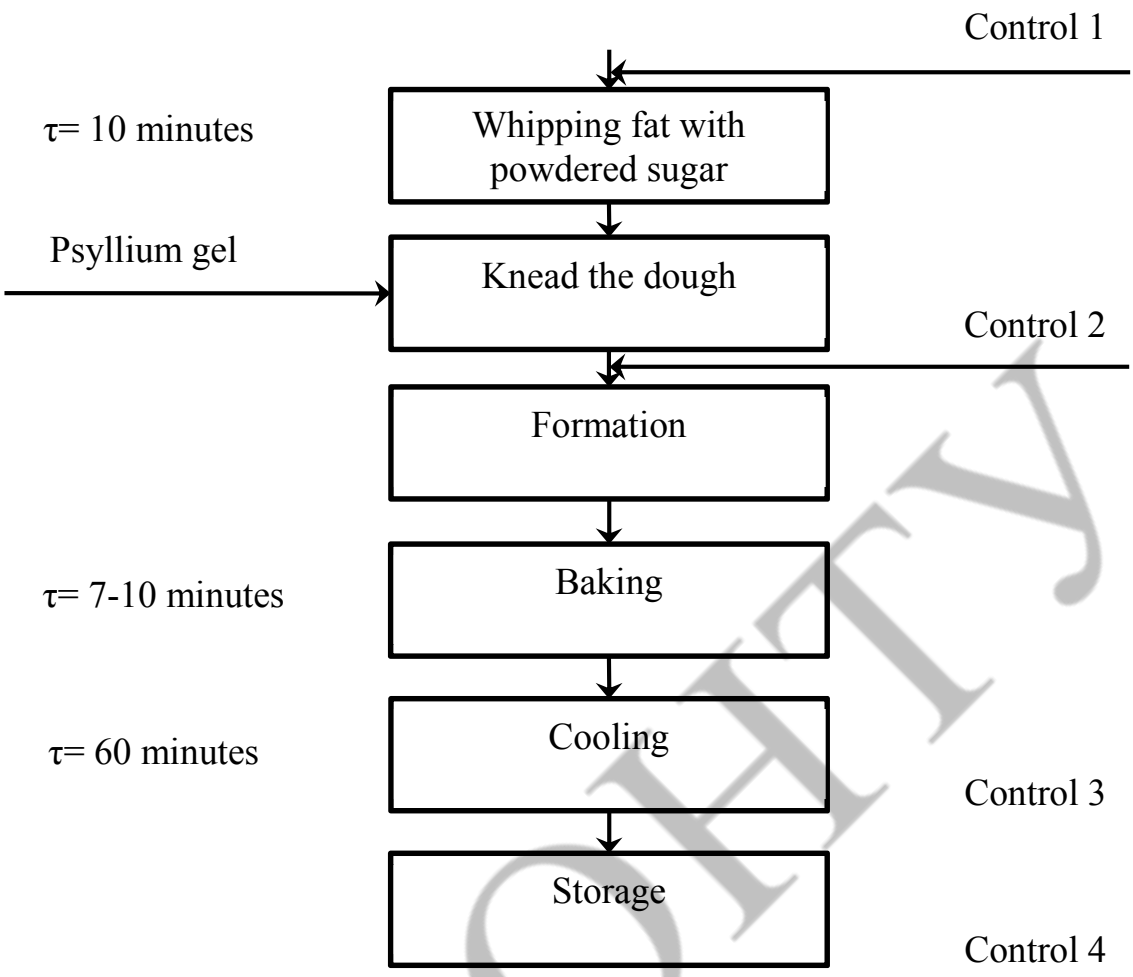

Fig. 1. Scheme of butter cookies production

The quality of cookies was determined after 24 hours after baking. Physico-chemical (hardness, density of cookies, water absorption ability, alkalinity and spread ratio) and sensory characteristics of cookies were determined according to the methods according to the standards. The hardness of cookies was determined by pressing the stamp to break the cookies [29]. The density of cookies was calculated as the ratio of pre-measured mass and volume of cookies [28, 29]. The spread ratio was determined by the ratio of the average diameter of the cookies to the average height [30].

Sensory evaluation of the product was carried out based on appearance, color, aroma, structure, and taste. A panel of 15 members was selected to evaluate the sensory properties of the cookies. Sensory evaluation was done using the preference ranking test method, in which the pre-coded samples were given scores on a five-point scale (1 – strongly dislike, 5 – strongly like).

Nutrition and energy values were calculated using a specific Excel spreadsheet according Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers.

All statistical analysis was carried out in triplicate and average values were calculated. All data was statistically analyzed through analysis of variance (ANOVA) and Fischer test. Significance was accepted at $p<0.05$.

IV. RESULTS

The experimental data has shown that the adding of PG has a negative effect on the color of the products. As the mass fraction of psyllium gel increased, the number of dark spots on the surface of the cookies increased, which leads to a deterioration in the consumer characteristics of the developed cookie. To avoid the mentioned negative effect we have proposed to add additionally of 5% cocoa powder by weight of dry matter of flour.

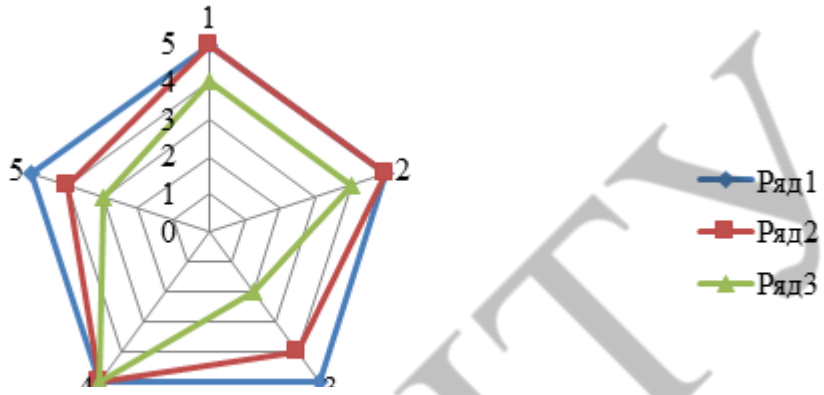

Fig. 2. Sensory characteristics of cookies

According to research results, the use of 20… 40% PG (a ratio of psyllium and water 1:12) to replace the fat has a negative effect on the quality of cookies. These samples with reduced fat content were characterized by an increase in hardness by 44-100% and reduced consumer properties compared to the control (Fig. 2). Cookies with PG were characterized with uneven and dense structure, with increasing the PG mass fraction (1:12) the color of the cookies became much darker. These samples were not evaluated in further studies.

Replacement of fat (20-40%) with PG (the ratio 1:8 and 1:10) had almost no effect on physicochemical parameters of dough (Table 1).

Table 1 – Physico-chemical quality indicators of dough for butter cookies

Quality indicators / Samples	**Control**	**PG (1:8)**		**PG (1:10)**	
		20%	**40%**	**20%**	**40%**
Moisture content,%	21,9	22,3	25,8	20,2	22,9
Density, kg/ m^3	636,88	701,55	741,42	692,05	737,2

The dough moisture content for samples with 20% PG remains almost at the level of control, which minimizes changes in the technological process. Density of dough for samples with replacement of 20… 40% fat increased by 10-16% for PG with the ratio 1: 8 and by 8-15% with 1:10 P:W ratio, compared with the control. This tendency is probably due to the increase in the content of dietary fiber contained in psyllium.

It was found that the reduction of 20… 40% of fat mass fraction with PG in the ratio of 1:8 and 1:10 provides to the formation of butter cookies with high quality and overall acceptability (Table 2).

Table 2 – Physico-chemical quality indicators of cookies

Quality indicators / Samples	Control	PG (1:8)		PG (1:10)	
		20%	40%	20%	40%
Cookies moisture content,%	2,8	2,5	3,2	3,5	3,4
Hardness, kg/mm²	4,5	4,0	7,5	3,6	7,5
Water absorption ability, %	134,0	149,42	119,56	148,06	120,5
Alkalinity, deg	0,7	0,4	0,5	0,4	0,6
Spread ratio	4,82	4,72	3,13	3,93	3,24

The spread ratio of cookies decreased when replacing fat with psyllium by 2,07… 32,78% in the selected samples compared to the control. The obtained results have shown that cookies enriched with psyllium are characterized with less melting process during baking and are able to hold their shape better. The density of cookies is no less important characteristic, as it allows you to characterize the structure of products.

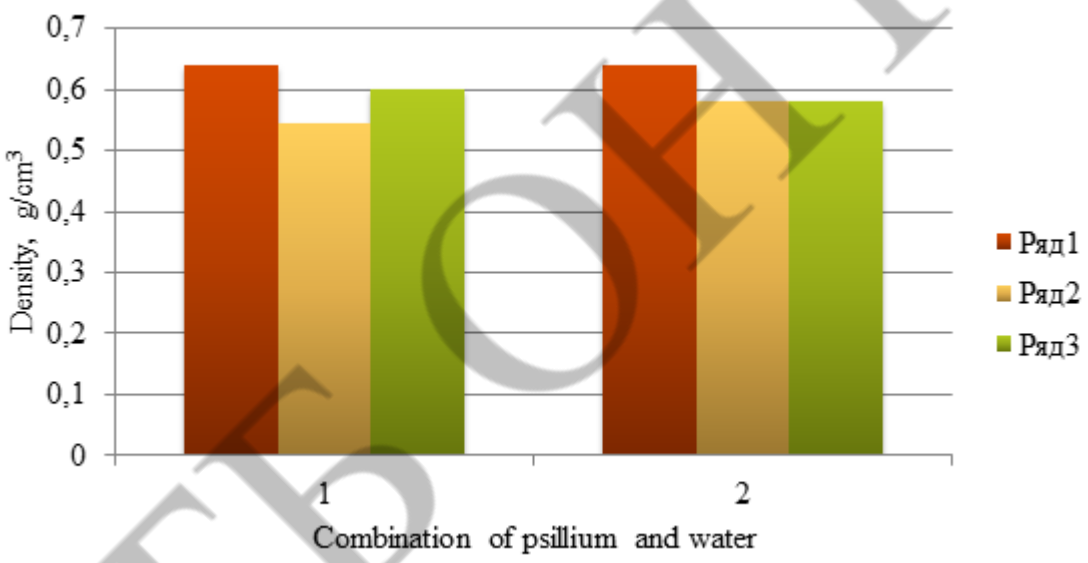

Fig. 3. Density of butter cookies

Thus, the density (Fig. 3) for samples with replacement of 20% fat by PG (1:8) and 40% fat by PG (1:10) decreased compared to the control by 14,8 and 9,0%, respectively. The obtained results have indicated the formation of a more porous structure of the final products.

According to the results of the sensory parameters evaluation (Fig. 4), the samples with 20 and 40% PG did not differ significantly from the control – the shape of the cookies was correct with a clear pattern on the surface with porous structure, pleasant taste and aroma.

Control 20% PG (1:8) 40% PG (1:10)

Fig. 4. Samples of butter cookies

In general, the quality of elaborated samples is in accordance with national standard requirements. According to the results of organoleptic evaluation, the samples with fat replacement by 20% PG (1:8) and 40% PG (1:10) were recognized as the best.

The nutritional value of these samples was investigated, too. The introduction of psyllium in the butter cookies recipe provides additionally the improvement of the nutritional value of the final product (Table 3).

Table 3 – Nutritional value of the cookies

Parameters	**per 100 g of final product**		
	Control	**20% PG (1:8)**	**40% PG (1:10)**
Protein, g	5,79	5,78	5,76
Fat, g	36,94	29,82	22,70
Carbohydrates, g:			
total	54,88	55,47	55,81
dietary fiber	0,83	1,45	1,85
Ash, g	1,28	1,26	1,24
Vitamins, mg:			
A	0,02	0,02	0,02
B_1	0,09	0,09	0,09
B_2	0,04	0,04	0,03
PP	0,87	0,85	0,83
Minerals, mg:			
Na	328,58	313,74	298,90
K	98,62	97,75	96,89
Ca	21,16	20,21	19,25
Mg	17,86	17,78	17,69
P	66,95	66,34	65,73
Fe	1,25	1,39	1,49
Energy value, kcal	563,17	501,59	438,99

The nutritional value of cookies with 40% fat replacement with PG in the ratio of 1:10 is significantly improved. There is an increase in the content of dietary fiber by almost 2,5 times, as well as a decrease in fat content by 38,5% compared with the control. As a result of replacing the proportion of fat with psyllium, there is a reduction in calories by 22%, which gives the product more dietary properties.

In addition, the replacement of 20… 40% fat with PG leads to the energy value reduction the of finished products by 11… 22% and increase the content of dietary fiber in cookies (Fig. 5), compared with the control.

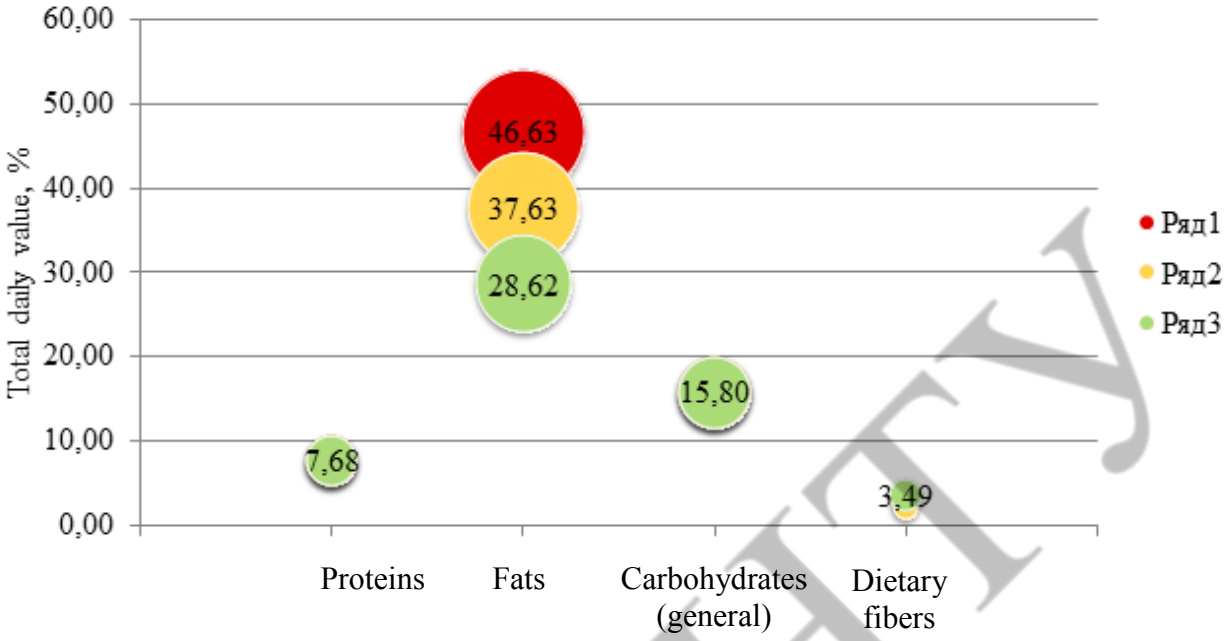

Fig. 5. The daily value of product

Based on these data, it can be seen that the consumption of 100 g of cookies with the replacement of 40% of fat with PG in the ratio of 1:10 leads to an increase in proteins and dietary fibers content to satisfy total daily value recommendations compared with the control sample.

V. CONCLUSIONS

Based on the experimental data, we can conclude that the use of psyllium gel in the technology of butter cookies has a positive effect and provides to:

- replace 20% fat on PG (1: 8) or 40% fat on PG (1:10) in cookies recipe;
- to obtain products with high consumer characteristics and consistently high quality;
- reduce the energy value of products by 11… 22%, respectively;
- to expand the range of pastry products with low energy value and high content of dietary fiber.

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IMPROVING THE EFFICIENCY OF THE FUNCTIONAL MECHATRONIC MODULE FOR LIQUID FOODSTUFFS

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Abstract. *Functional mechatronic modules of liquid food dosing systems are widely used at the stage of packing-dosing of liquid food products into consumer containers. The advantage of such modules is tightness and ease of operation. However, it is not possible to adjust the cost characteristics for continuous dosing without the formation of product residues.*

The study of liquid food flow control systems of functional mechatronic modules in order to ensure continuous processes of dosing and packaging of liquid food products with the properties of Newtonian fluids is an urgent task.

The object of study was selected locking element, control system, pneumatic actuator, positioner using an analog control signal. The aim of the research is to increase the efficiency of regulating the cost characteristics of functional mechatronic modules at the stage of dosing and packaging of liquid food products in consumer packaging. As a result of the calculations by the method of statistical and mathematical analysis, an experimental stand was developed on the basis of a pneumatic system and a product pipeline in order to modulate the process in food production. The process of control of flow characteristics and speed characteristics of the drive during dosing by means of an electropneumatic positioner and smooth change of section is theoretically investigated. The research results confirm the possibility of adjusting the flow characteristics at the outlet of the locking element.

Keywords: *liquid products, dosage, control, mechatronic module.*

I. INTRODUCTION

Due to the lack of scientific and technical material related to the study of the influence of the control system on the accuracy of dose formation to control the technical and technological parameters of functional mechatronic modules for liquid foods in this paper, attention was paid to mechatronic control systems.

To ensure high rates of scientific and technological progress, it is necessary to increase labor productivity in enterprises and equipment. To this end, they try to combine several processes or automate control processes by using mechatronic systems.

II. LITERATURE ANALYSIS

Based on the analysis of functional mechatronic modules of liquid food dosing systems, it was found that a number of functional mechatronic modules [7-8, 10-13] use pneumatic systems. In order to choose a rational design and modes of operation of the mechatronic control system taking into account the various physical and mechanical properties of food, packaging materials - it is necessary to be able to model the kinematic and dynamic characteristics of the working environment during process

emission [1, 11, 13, 14]. An effective method of modeling complex systems is modeling technology [16, 18, 20].

Analysis of the literature showed a lack of information on adjusting the accuracy of dose formation using the control system.

To increase the efficiency of the mechatronic functional module for liquid food products, it is important to expand the study of the optimal technological characteristics of taps, valves and dispensers. In this regard, the urgent goal is to modernize the mechatronic modules of packaging machines. Systematic analysis and synthesis of known literature sources were used in solving the problem [2-3], [4-6, 9, 17, 19]. Given this, it is important to develop new designs to control the cost of food.

A study was conducted to study the cost impact of various mechatronic modules, including the valve and ball valve.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Object of research. Regulatory elements of dosing and packaging systems for liquid food products.

Research methods. Statistical-mathematical, taking into account the general gas-dynamic theory, applied mathematical packages of software MathCad.

Research materials. Liquid food products with the properties of Newtonian fluids, control systems and locking elements.

Scientific novelty. Researches in the system of regulation of a stream of a product in dosing systems for the purpose of maintenance of continuous technological processes of work of functional mechatronic modules of dosing systems are executed.

The obtained results of experimental researches are processed and reduced to a graphic form for the purpose of demonstration of work of the dosing device, with application of the theory of gas-dynamic systems, in problems of regulation of a stream of Newtonian liquids.

On the basis of the conducted analysis and patent search of technical systems connected with the functional mechatronic module for dosing of packing of food liquid products the following tasks of carrying out research are formed:

1. Treated milk and condensed milk with the following characteristics were accepted for the study as the most characteristic product:

Table 1. Characteristics of condensed milk

Acidity, °T	Degree of purity according to the standard, group	Density at 20°C, kg/m3	Temperature, °C	Mass fraction of dry matter, %	Viscosity at 20°C, Pa · s
16	1	1027	10	11	0,0018

2. Develop a mathematical model for calculating the main functional mechatronic modules and their components, namely: ball valves, seat valves, pneumatic actuators of linear and rotary types, which are part of standard designs. Justify the choice of a typical drive to FFM.

3. Calculate and assemble an experimental setup for research related to adequacy assessment by pre-calculating a mathematical model.

4. Carry out statistical processing of the received statistical data.

5. To formulate conclusions and recommendations on the basis of the received statistical data, concerning possibility of use of system in industrial machines and devices.

IV. RESULTS

4.1. Dispenser pump for viscous dairy products

The pump-dispenser of viscous dairy products works as follows. During the rotation of the output shafts of the gear motor cranks with the help of collet bushings and cranks cyclically reciprocating in the guide bushings connected to the connecting rods, sliders-plungers. Moving the plunger sliders in the direction of the axis of rotation of the output shafts of the gear motor, in the working cylinders creates a discharge that ensures the opening of check valves and filling the working cylinders with product from the intake manifold. Moving the plunger sliders in the opposite direction, in the working cylinders creates a pressure that ensures the opening of the check valves of the discharge manifold and the supply of product from the dosing pump. In order to optimize the design, reduce metal consumption and increase the reliability of the reciprocating axis of the plunger sliders are shifted relative to the axis of rotation of the cranks in the direction of the trajectories of the spikes, creating injection forces. This allows to reduce the angles of pressure of the working strokes of the connecting rods, and to provide structurally the smoothest mode of operation of the mechanism during the working stroke, the injection trajectory, and relatively reduce the idling period, the suction trajectory.

4.2. Volumetric piston dispenser

The piston dispenser works this way. At the initial moment of the kinematic cycle, the rod of the pneumatic cylinder is in the lowest position.

The required amount of dose is adjusted by means of a movable stop, which is moved by means of a screw. The dosing cylinder is installed in the case. The dosing device is attached to the frame of the packaging machine by means of a support.

4.3. Dispenser of membrane-piston type with a vertical axis of movement of pistons

Dispenser membrane-piston type with a vertical axis of movement of the pistons is used for packing sour cream and mayonnaise in portions of 200 g. Packing sour cream can be made of different fat content at a temperature not lower than 18 ° C. The housing on which the entire dispenser is assembled, with the help of two brackets, is attached to the frame of the machine. The principle of operation of the dispenser is as follows. Sour cream is fed through a pipe into a container. At direct course of the piston of the pneumatic cylinder together with the rods of a traverse connected with it together with pistons rises. At this point, the membrane is in the middle position and the product from the tank through the channels enters the lower cavity of the cylinder. The valve, as a result of the pressure created by the air, stretches and closes the access of the

product to the outlet nozzles. When sucking the piston to the lowest position, a portion of the product is dosed, and then the operation is repeated. Dose adjustment of the drug is carried out by changing the stroke of the piston with a screw. The dispenser has four dosing cylinders mounted in the housing.

4.4. General characteristics of ball valves

Ball valves are a type of pipeline fittings in which the shut-off element has the shape of a body of rotation (ball) with a hole of circular cross-section to allow the flow of the working medium. The movement occurs around its own axis, due to the presence of a groove in the ball and the shaft when rotating which rotates the ball.

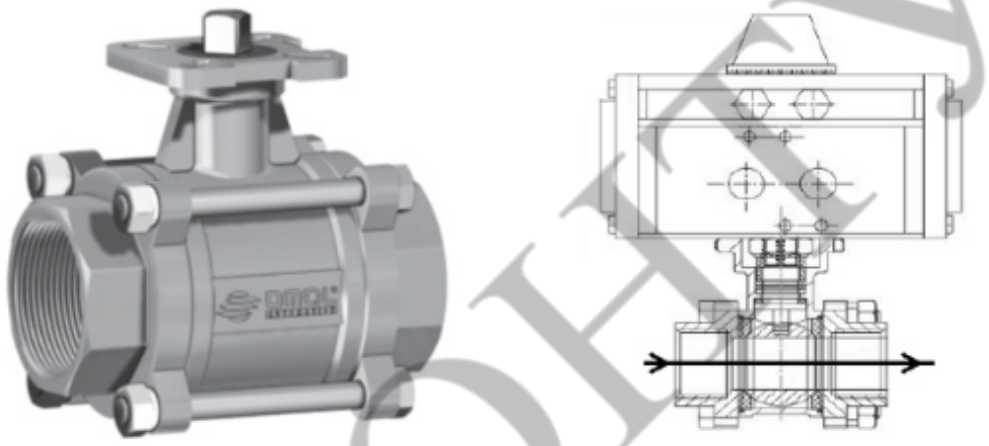

Fig. 1. Three-component ball valve: 1 – shaft; 2 – nut; 3 – disc spring; 4 – sealing ring; 5 – V-shaped shaft seal; 6 – sealing ring; 7 – antistatic ring; 8 – shaft seal; 9 – housing sealing; 10 – sealing the ball; 11 – nut; 12 – bolt; 13 – bullet; 14 – building; 15 – cover

Advantages of ball valves:
- low cost, compact design;
- low flow resistance in the open state;
- ease of manual operation;
- simple mechanical locking in any position.

Disadvantages:
- the complexity of the implementation of mechanical or electrical control;
- relatively long switching time.

4.5. General characteristics of shut-off siphon valves

Shut-off valve - shut-off valve, structurally made in the form of a valve, ie the shut-off element moves parallel to the axis of flow of the working medium.

Are intended as shut-off valves of overlapping of a stream as valves of this type have high indicator of tightness at rather simple design. Used for liquid and gaseous media with a wide range of operating parameters and connection types.

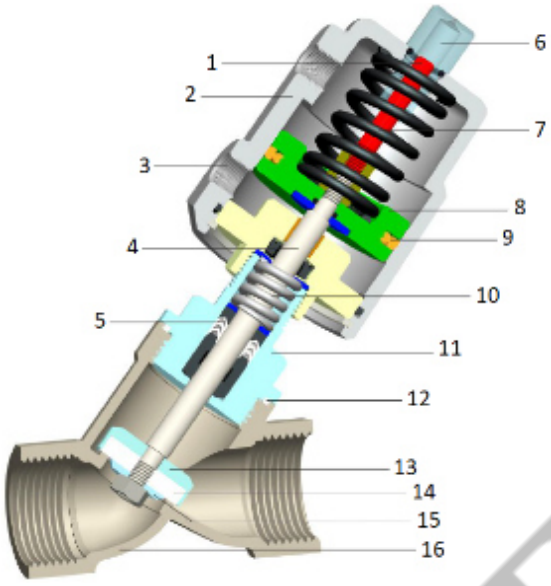

Fig. 2. Seat valve with pneumatic control: 1 – indicator; 2 – drive housing; 3 – air connection port; 4 – stock; 5 – rod seals; 6 – cap; 7 – spring; 8 – the piston; 9 – piston seal; 10 – spring; 11 – cover; 12 – sealing of the case; 13 – saddle; 14 – saddle seal; 15 – washer; 16 – housing

Advantages:

- small stroke of the shutter for full opening (usually not more than 0.25 nominal diameter, while the latches - not less than the diameter) and, accordingly, low construction height and weight;
- in valves it is much easier, than in latches, to provide necessary tightness of a gate (by application of sealing rings from various nonmetallic materials);
- when closing and opening the valve, in contrast to the latch, the friction of the shutter seal on the saddle is virtually eliminated, which significantly reduces the wear of the sealing surfaces;
- the possibility of using a bellows as a seal of the valve in relation to the external environment.

Disadvantages:

- high (compared to ball valves and latches) hydraulic resistance, which at large diameters and high speeds of the environment creates large energy losses and causes the need to increase the initial pressure in the pneumatic control system or more powerful electric drive;
- limiting the limits of application to the diameter mentioned above;
- the presence of stagnant zones in most structures, in which mechanical impurities from the working environment accumulate, sludge, which leads to intensification of corrosion processes in the valve body.

4.6. Calculation of the piston batcher

Imprint:

The product is condensed milk.

The specific density of the product is $\rho = 1.3$ t/m^3

The dose volume of the product is W = 0.25 l

Productivity – Z = 60 unitary enterprise / min

The air pressure in the hopper is P_1 = 0.2 MPa

The pressure that occurs before the piston at the stage of forming the dose – P_2 = 0.08 MPa

Air pressure in the container – P_4 = 0.1 MPa

The height of the product column in the hopper is H = 1.2 m

The length of the nozzle of the dosing device is l = 0.09 m

The value of the dynamic viscosity of the product is μ = 2 Pa · s

The diameter of the outlet hole is d_0 = 0.024 m

Piston diameter – D = 0.08 m

The diameter of the channel in the crane is d_1 = 0.015 m

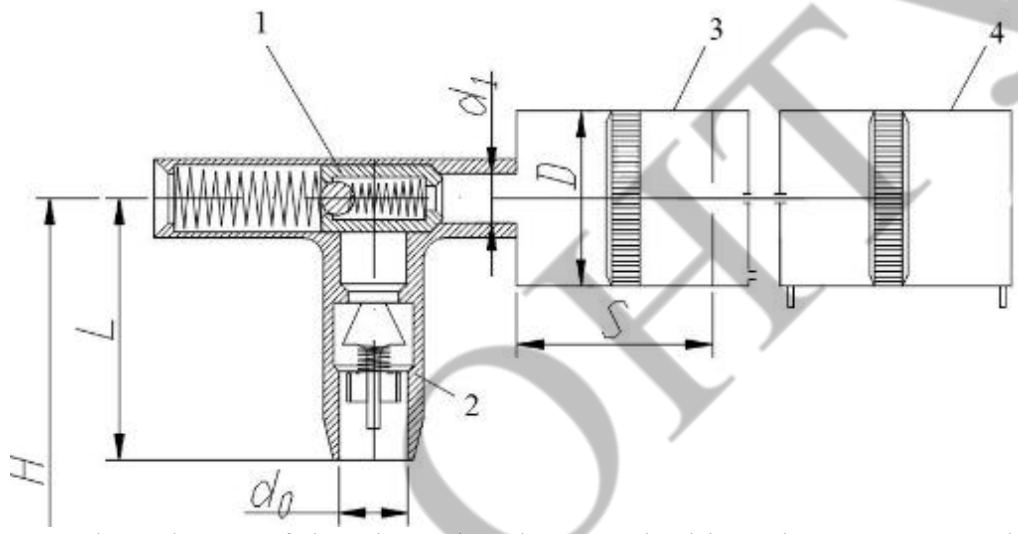

Fig. 3. The scheme of the piston batcher: 1 – locking element; 2 – outlet pipe; 3 – dosing cylinder; 4 – pneumatic cylinder

Based on the results of calculations of the main parameters, we will summarize the PTC MathCad and obtain the results in graphical form for different tube diameters and pressure.

Substitute the values of the pressure in the line = 5 bar, the diameter of the tube = 6 mm and present them in the form of graphs.

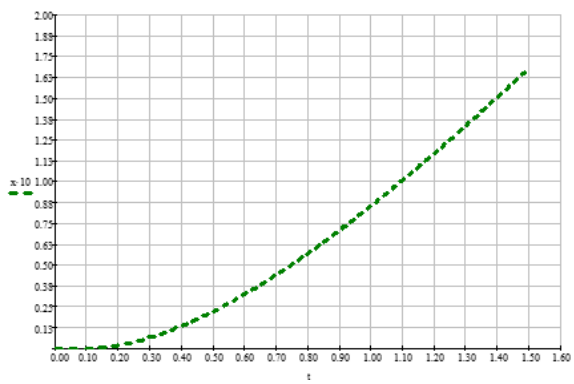

Fig. 4. Graph of the distance traveled over time for the output link of the rotary drive, m

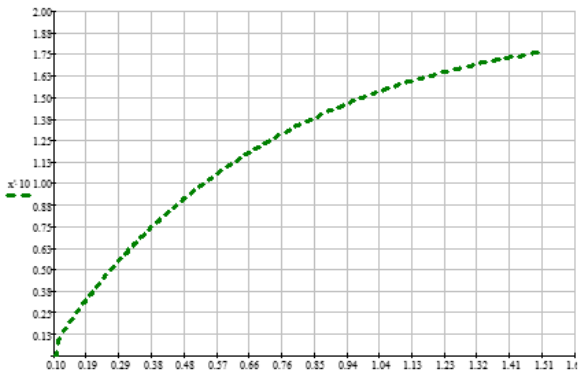

Fig. 5. Graph of the acquired speed when turning the output bench of the rotary drive, m/s

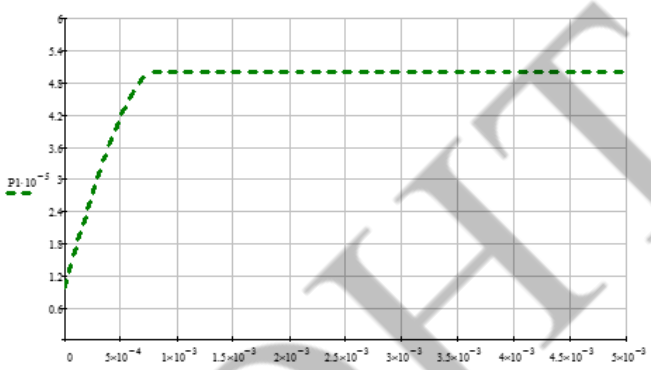

Fig. 6. Partially presented graph of the pressure at the time of pressure supply cavity S_1, bar

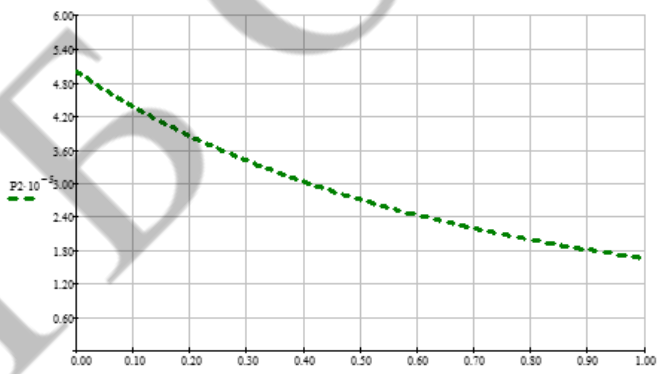

Fig. 7. Graph of pressure relief from the cavity S_2 pressure, bar

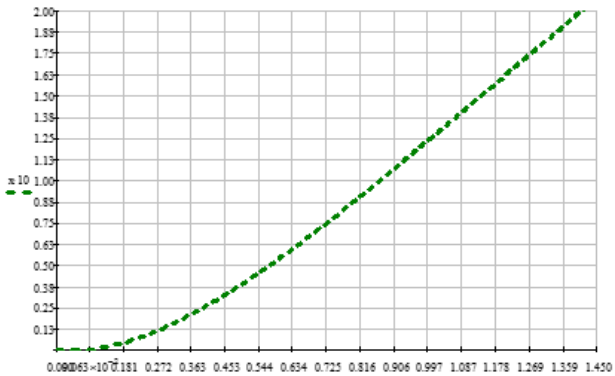

Fig. 8. Graph of the distance traveled over time for the output link of the rotary drive, m

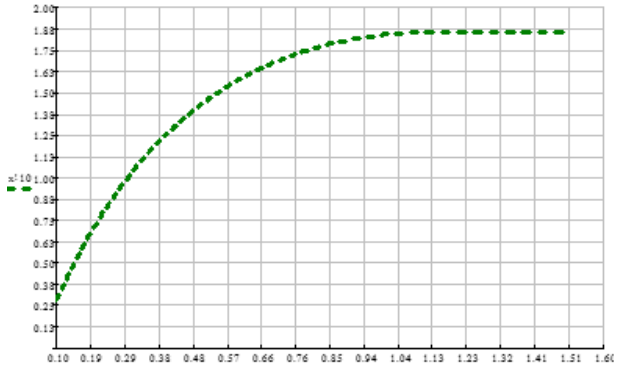

Fig. 9. Graph of the acquired speed when turning the output link of the rotary drive, m/s

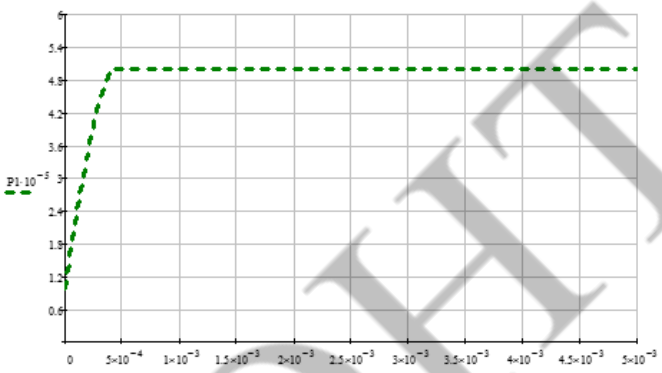

Fig. 10. Partially presented graph of the pressure at the time of pressure supply cavity S_1, bar

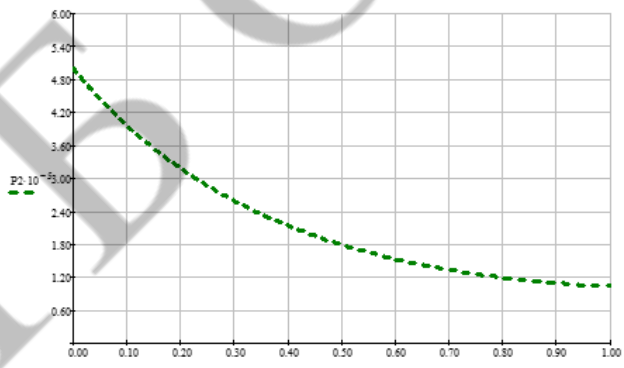

Fig. 11. Graph of pressure relief from the cavity S_2 pressure, bar

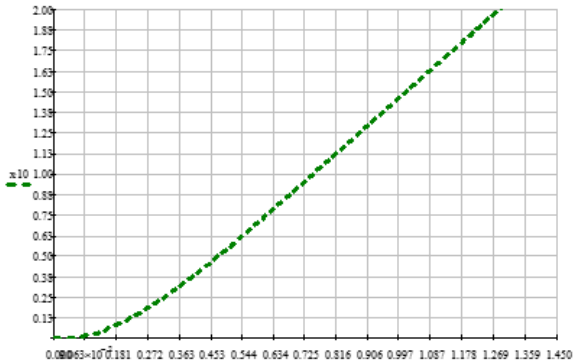

Fig. 12. Graph of the acquired speed when turning the output link of the rotary drive, m

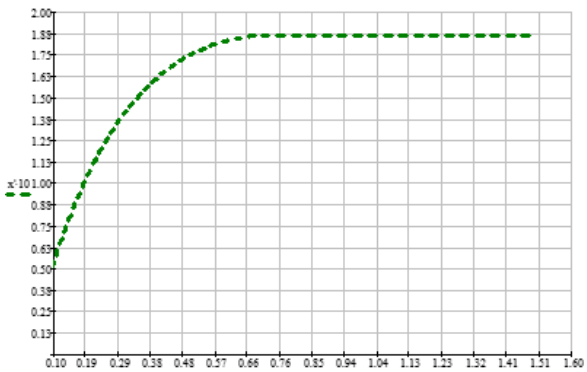

Fig. 13. Graph of the acquired speed when turning the output link of the rotary drive, m / s

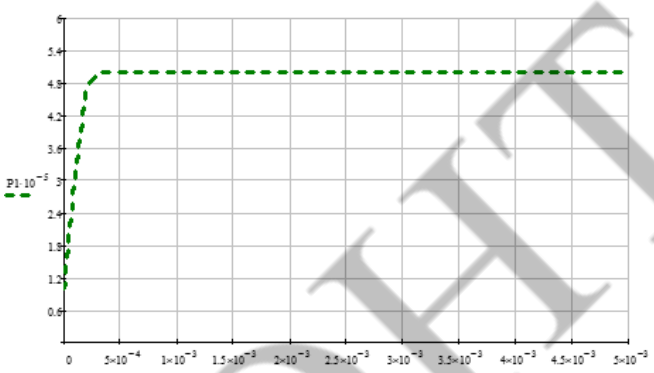

Fig. 14. Partially presented graph of the pressure at the time of pressure supply cavity S_1, bar

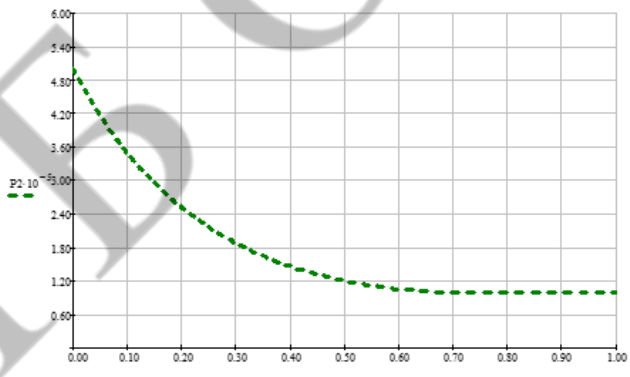

Fig. 15. Schedule of pressure relief from the cavity S_2 pressure, bar

Table 2. Comparison of the obtained values

Tube diameter, mm	**Turning time, s**	**Maximum speed at the end of the movement, m/s**	**Time of pressure supply to port S_1, s**
6	1,41	1,75	$7,5*10^{-3}$
8	1,14	1,79	$4*10^{-4}$
10	1,01	1,88	$2,5*10^{-4}$
Absolute error	0,4	-0,13	$7,25*10^{-4}$
Relative error	28,36%	7,42%	9,66%

Having considered and studied the graphs in detail, comparing them with each other, we can observe that due to the increase in the cross section of the air supply tube to the drive – speed characteristics and speed of filling / dropping cavities also increases.

As pneumatic actuators will control the opening process, it is not permissible to open or close the valves quickly, as this can lead to the destruction of seals, shut-off elements or damage to the environment as a result of leaks.

Therefore, the optimal pipe for air connection will be the tube with the smallest of the above, with a diameter of 6 mm.

4.6. Experimental study of the functional mechatronic module for liquid foods

An installation for filling plastic containers with liquids was found and studied, which was taken as a basis for modeling and construction of our own experimental installation:

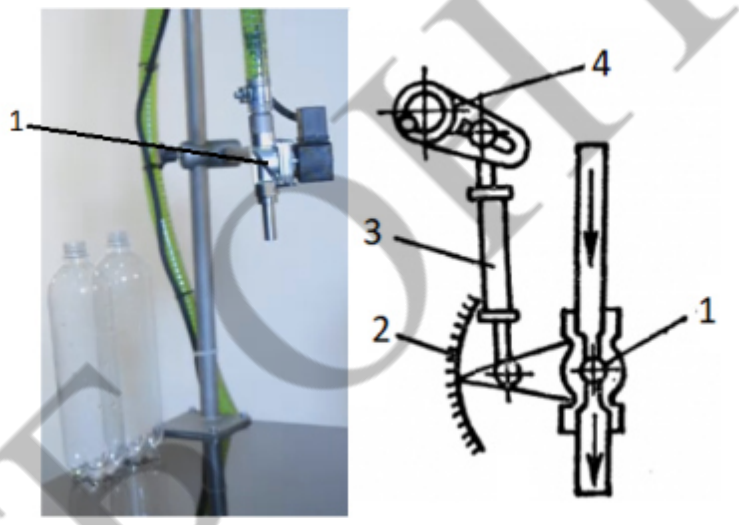

Fig. 16. Installation for the batcher of continuous action:
1 – the electromagnetic valve; 2 – scale; 3 – traction; 4 – rocker arm

The main shut-off element is a diaphragm-type solenoid valve that acts as a shut-off valve – "open" / "closed".

The main disadvantage is that abrasive inclusions are not allowed for diaphragm valves, as well as the impossibility of working with viscous media with a viscosity exceeding 37sSt, as well as the design and shape of the passage. At high speeds, the destruction of the pipeline or membrane may occur over time.

The main task is to develop a functional mechatronic module for food dosing using a ball valve and a valve.

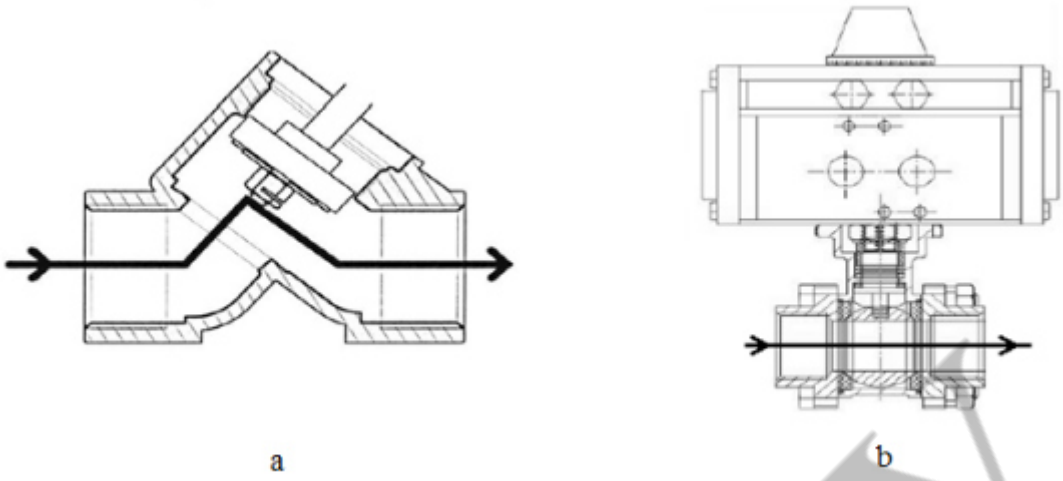

Fig. 17. The direction of the product when passing through: a – saddle valve, b – ball valve on the right

4.6. Description of the experimental setup

Conducted experimental and mathematical statistical analyzes are based on the installation that simulates the operating conditions of shut-off valves for a short period.

Since the task is to upgrade and improve the functional mechatronic module for dosing liquid food, the scheme will be the same, the main difference is the type of locking element and its drive, the control system is the same.

2 units were assembled to measure the cost characteristics by changing the position of the shut-off element: ball valve; seat control valve.

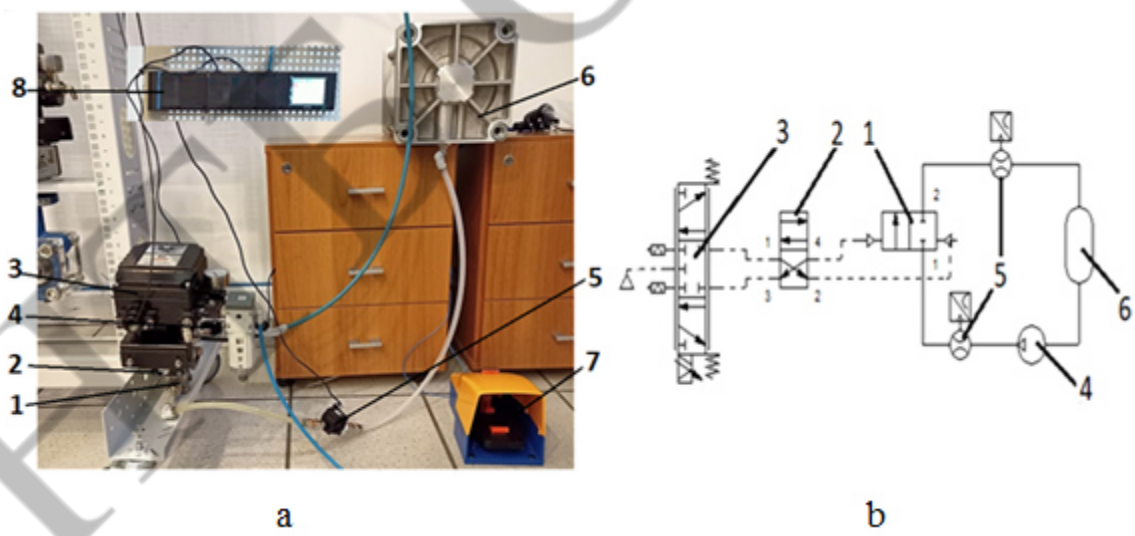

Fig. 18. Experimental installation №1 (a) and its scheme (b) for testing a ball valve: 1 – ball valve; 2 – pneumatic drive; 3 – electropneumatic positioner; 4 – pump; 5 – flow meter; 6 – receiver; 7 – the button; 8 – control and measuring device

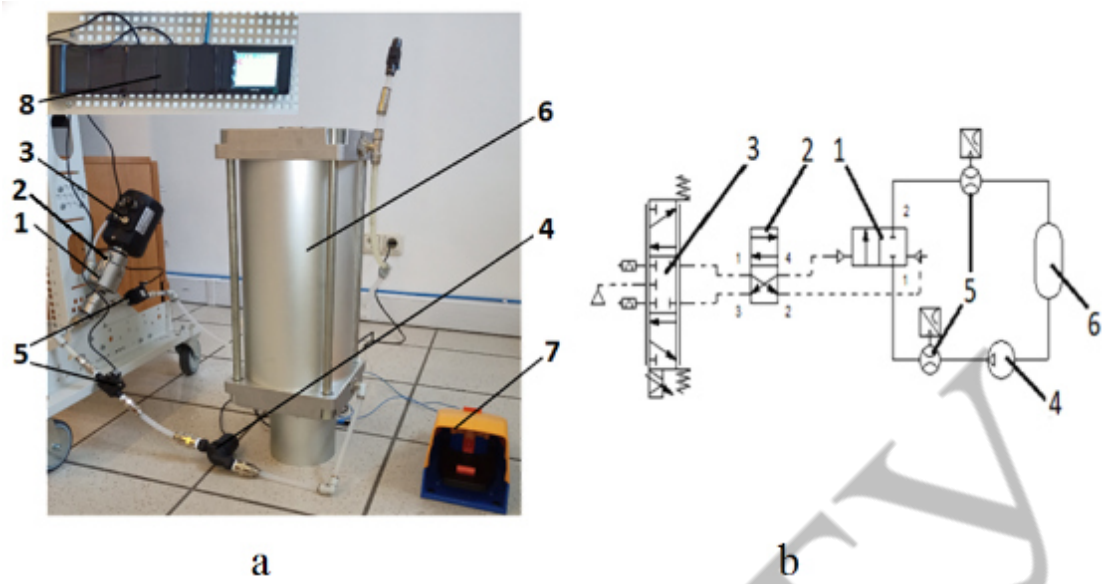

Fig. 19. Experimental installation №2 (a) and its scheme (b) for testing the seat control valve: 1 – seat valve; 2 – electropneumatic positioner; 3 – flow meter; 4 – pump; 5 – receiver; 6 – button; 7 – control and measuring device

4.6. Description and methods of the experiment

Compressed air was used to supply the electropneumatic positioner, and the pressure in the pneumatic line was 4 bar.

A 12V DC power supply was used to power the pump.

Pedal toggle switch to control and transfer power to the pump.

A controller with an analog output of 4...20 mA was used to supply the control analog current signal.

To conduct the experiment and obtain the results of control and measuring instruments, you must perform the following instructions:

1. Power the pump - press the button.
2. Apply power to the positioner.
3. Start the controller with the specified law of simulation of the analog signal;
4. Record data from control and measuring instruments.

Table 3. Simulations of analog signal

Locking element	Law of management	Time of one cycle	Output signal
Ball valve	Sinusoidal Linear Linear is inversely proportional	10 seconds	4..20 mA

According to the received and processed statistical data it is possible to draw some conclusions:

1. The best graph of the flow rate at the output from 0 to 100% of the cost was obtained using a seat valve with pneumatic control and electropneumatic positioner,

according to the linear control law as a result of processing experimental data polynomial 5th degree obtained approximation coefficient is 0.99.

2. The ball valve is also suitable for flow control, but the cross section has changed very sharply, so it is necessary to use in such cases ball valves with V-shaped cross section with an angle of 60°, 30°, 20°, to obtain a smoother cross-sectional change and respectively smooth flow curve, to obtain a smooth flow.

3. The disadvantage of the rotary positioner is the constant discharge into the atmosphere, and due to the principle of positioning (pressure difference in the pilot valve which is achieved by throttling the discharge pressure by means of an armature in the solenoid coil).

4. The linear type positioner has more options, better accuracy and repeatability compared to the rotary type positioner.

V. CONCLUSIONS

Based on the analysis and patent search of technical systems related to the functional mechatronic module for dosing and packaging of liquid food products, the following research tasks were formed and performed:

1. The mathematical model of calculation of the main functional mechatronic modules and their components is developed, namely: ball valves, seat valves, pneumatic drives of linear and rotary types which are a part of standard designs. The choice of a typical drive to the FFM was justified and appropriate calculations were performed.

It was determined that the optimal diameter of the tube for air supply to the drives to maintain optimal speed characteristics and filling speed - 6mm;

2. The experimental setup was calculated and mounted, research was conducted, a mathematical model was built on the basis of the calculation and an experiment was conducted.

After processing the experimental data, it was determined that the optimal cost characteristics were obtained during the operation of the valve and identified its advantages over the ball valve, namely:

- lower cost characteristics of the positioner;
- high adjustment accuracy;
- greater optional options.

3. The received statistical data from control and measuring devices were processed and the statistical and mathematical analysis was carried out.

4. Conclusions were formulated in accordance with each section at the stage of scientific work and recommendations based on the obtained statistical data on the possibility of using the system in industrial machinery and apparatus.

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ISOLATION OF BIOACTIVE COMPOUNDS FROM HEMP (*Cannabis sativa* L.) BY CONVENTIONAL AND NOVEL EXTRACTION TECHNIQUES

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Abstract: *Industrial hemp (Cannabis sativa L.) is a source of valuable bioactive compounds which is used as a highly valuable product in food, pharmaceutical and cosmetic industries. Bioactive composition of hemp contributes to the prevention and treatment of some diseases, so it can be widely used in medicine. The main goal of this paper was to investigate the most convenient extraction approach for isolation of bioactive compounds (cannabinoids and phenols) from dry inflorescence of three hemp varieties. Modern extraction techniques were applied and compared with conventional techniques in order to obtain maximum yield. Essential oils were obtained by hydrodistillation (HD), microwave-assisted hydrodistillation (MWHD) and supercritical fluid extraction (SFE). Extracts from the primary raw material of hemp and SFE raffinate were processed by microwave-assisted extraction in order to isolate polyphenolic fraction. The obtained results showed that SFE provides the highest yield of hemp oil compared to HD and MWHD. The highest yield of lipid extract was obtained from variety Fedora 13 (14.01%), while the lowest yield was obtained from variety Marina (5.33%). The high content of phenols and flavonoids obtained from SFE raffinates indicates that the by-products of supercritical fluid extraction could be used as potential natural antioxidants.*
Keywords: *Cannabis sativa L.; supercritical fluid extraction; microwave assisted extraction; essential oil; polyphenols*

I. INTRODUCTION

Industrial hemp (*Cannabis sativa* L.) is one of the oldest medicinal plants that is a source of valuable bioactive compounds (fiber, protein, oil, cannabinoids, polyphenols, etc.). Due to the uniqueness of its composition, hemp is used as a highly valuable product in the food, pharmaceutical and cosmetic industries. The nutritious and bioactive composition of hemp contributes to the prevention and treatment of some diseases, so it can be used in medicine as: analgesic, antiepileptic, anticonvulsant, anti-neurodegenerative, antibacterial and anticancer agent [1]. Hemp is used to treat conditions, such as, rheumatoid arthritis, cardiovascular diseases, hormonal disbalance, psychological and psychiatric disorders, Alzheimer's, Parkinson's disease and schizophrenia [2]. In the past two decades, many countries have legalized the production of industrial hemp, which encouraged further studies focused on its health benefits. Without doubt, the huge interest in hemp cultivation is a consequence of the ability of this plant to biosynthesize various organic compounds called cannabinoids. In addition to cannabinoids, this plant also contains terpenes, polyphenols and fatty acids, which have also shown significant biological activity. Due to the presence of delta-9-tetrahydrocannabinol (Δ-9-THC), which is considered to be a psychoactive and

toxic substance for humans, cannabis is still a central topic of many legislative debates [3]. The main difference between industrial hemp and marijuana is primarily in the levels of Δ-9-THC production. Industrial hemp contains less than 0.3% Δ-9-THC, while marijuana contains more than 0.3% which causes psychoactive effects [4].

As the interests for the use of this plant grow, it is necessary to intensify research on the chemical composition of hemp, as well as the methods of extraction of bioactive compounds. High energy and solvent consumption and low yield of the desired compound are the biggest problems that can occur. Today, solutions that will enable reduction in the usage of organic solvents are being examined, and at the same time, these findings will be able to ensure the intensification of the process and cost-effective production of high-quality extracts. Novel techniques correspond to green chemistry concept that reduce the time of usage and energy consumption, lowers down the temperature, avoid usage of organic solvents. They should provide a high yield of targeted compounds by using alternative solvents (mainly water-based), preserves the high quality of extracts and reduce the number of operations in the production process [5].

Industrial hemp originates from central and northeastern Asia. *C. sativa* belongs to the family *Cannabaceae* and includes three species: *Cannabis sativa* L., *Cannabis indica* and *Cannabis ruderdalis*. The plant is considered dioecious (dicotyledonous) and female inflorescences are densely covered with glandular trichomes containing resin, one of the most valuable cannabis products with various psychoactive and healing properties [6]. Historically, many products come from the seeds, fibers and trees of the hemp plant [7].

All ingredients of hemp can be divided into two groups: cannabinoids and non-cannabinoids [3]. Hemp is a plant known for its content of bioactive cannabinoids from the group of secondary metabolites unique to the genus Hemp. These compounds are produced in specialized glands in the leaf epidermis. Non-cannabinoid ingredients are: terpenes, carbohydrates, flavonoids, simple alcohols, aldehydes, ketones, acids, and esters. All these pharmacologically active ingredients of hemp are responsible for a wide range of its effects. Hemp contains four main groups of compounds with pronounced pharmacological activity: polyunsaturated fatty acids, cannabinoids, terpenes, and polyphenols. Olis from hemp seeds contain 70-80% of polyunsaturated fatty acids. Two essential fatty acids, linoleic and linolenic acid, are the most common. The ratio between fatty acids is 3:1, which is the optimal balance for people's diet and is unique in common herbal olis [8]. Canabinoids are species of terpenophenols mostly synthesized in glandular trichome of female inflorescens. Canabinoids interact with human endocanabinoid system, but those are different for their effects. For example, CBD is not psychoactive, whereas Δ-9-THC is psychoactive compound. As a result, these compounds are of great interest when it comes to their terapeutical potential in neurological disorders [9]. Typical and unique scent and aroma of this plant come from terpenes and polyphenols. Hemp essential oils are rich with monoterpenes (myrcene and pinene) and sesquiterpenes (β-caryophillene and its derivatives) [10]. The greatest importance of phenolic compounds is their role as antioxidants. Antioxidants participate in hydrogen atom release reactions and free radical scavenging reactions. The most common flavonoids identified in cannabis are apigenin and quercetin [9].

II. LITERATURE ANALYSIS

Given that the demand for cannabis-derived compounds is constantly growing, despite strict regulations in some countries, the global market needs appropriate technologies to isolate the target compounds. Therefore, the subject of many studies was the isolation of bioactive compounds from hemp, using conventional (maceration, Soxhlet extraction (SOX), hydrodistillation (HD)), but also novel extraction techniques (microwave-assisted hydrodistillation (MWHD), ultrasonic-assisted extraction (UAE), microwave-assisted extraction (MAE) and supecritical fluid extraction (SFE)). Detailed research of innovative extraction techniques is indeed crucial for the extraction of phenolic compounds and terpenes from cannabis.

According to Naz et al. [11], the isolation of essential oils was examined from industrial and Indian hemp herb by different extraction methods (hydrodistillation and steam distillation) and supercritical fluid extraction. The content of essential oil in industrial hemp was higher than in Indian hemp, and the highest essential oil yield was obtained by HD. Drinić [12] researched the essential oil content of variety Helena which was determined by the HD. The essential oil content was 0.08% (v/m), which classifies this plant species in the group of plants poor in essential oil. The use of microwave technology in the extraction of bioactive compounds offers a number of advantages: fast heating, shorter processing time, reduced solvent consumption, higher reproducibility and improved yield [7]. Microwave-assisted hydrodistillation (MWHD) can be an effective alternative for isolation of terpenes from cannabis. Recently published studies have shown that microwaves can even improve oil extraction, reducing process time and increasing productivity, compared to conventional extraction methods [13]. In the work of Gunjević et al. [14], *C. sativa* flowers were used and conventional HD was performed to compare the yield of essential oil with MWHD. The optimized MWHD procedure gave a significantly higher yield of essential oil, compared to conventional (HD). Furthermore, Micalizzi et al. [6] applied MWHD to isolate cannabis essential oil from dried flowers of four different varieties of hemp. This study also showed that MWHD is an effective technique for isolating cannabis essential oil.

Currently, SFE as a modern extraction method attracts a lot of attention due to its unique supercritical properties, which offer the advantages of liquid and gas phase, at the same time. Various authors have adopted this process for the isolation of cannabinoids from different parts of industrial hemp [15] as well as for the isolation of aromatic compounds from industrial hemp [8,11]. In the work of Moreno et al. [3], extracts were obtained from the buds of New Zealand varieties of industrial hemp with the help of SFE. The composition of the extracts and the influence of different extraction parameters and the addition of 5% co-solvent (ethanol) which improves the extraction of acidic forms were determined. According to Rovetto and Aieta [15], SFE has been shown to allow efficient extraction of cannabinoids. The total yield of the process under different extraction conditions and the effect of co-solvent (ethanol) were examined for four different variaties of *C. sativa*. It was concluded that the extraction results largely depend on the characteristics of the plant material. The addition of co-solvent improves the extraction process and the extraction speed. This

work demonstrates the efficacy of SFE cannabinoids with high yields of extracts. The use of extraction techniques such as UAE, MAE or SFE are good solutions for increased extraction efficiency with the shortest extraction time [9]. Marzorati et al. [16] investigated developed an extraction process that can provide cannabidiol-enriched products (CBD) from *C. sativa* inflorescences. They concluded that SFE enables selective extraction of cannabis oil without the use of toxic organic solvents. Although many works applied different extraction processes: maceration, SOX, UAE, etc., none satisfies all aspects in terms of efficiency and cost-effectiveness. Therefore, Devi and Khanam [17] investigated different processes of hemp oil extraction from techno-economic perspective at industrial level. Economic analyses for various processes revealed that SFE was the most useful extraction technique for recovery of hemp oil.

Several studies have reported that MAE was far better than the conventional method due to low solvent and energy consumption, shortened process time and higher yield of bioactive compounds [13, 19]. Maceration and SOX are considered to be the predominant methods with relatively low cost and high yield of essential oil. Despite this, they need more time to extract the oil and they also need chemical solvents. Some new methods have emerged such as MAE and UAE together with SFE for extraction of hemp oil from seeds [8,18,13] as a solution for these limitations. These methods offer large amounts of oil yield (especially in terms of microwave and ultrasound) and also significantly shorter extraction times compared to conventional ones [13]. MAE is a method proposed for the extraction of essential oils and hemp seeds due to its advantages in the production of high quality oil. Matešić et al. [19] extracted phenolic compounds from hemp with the help of microwaves and high yields of these compounds were observed.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The main objective of this paper was to investigate the most convenient extraction techniques for isolation of bioactive compounds (cannabinoids, phenols and fatty acids) from dry inflorescence of three *Cannabis sativa* L. varieties. In this research, modern extraction techniques (MWHD, MAE and SFE) were applied and compared with conventional technique (HD) in order to obtain of maximum yield. Since the chemical composition of the extracts depends on the extraction techniques and the applied conditions, this will enable a comparison of the examined techniques and the definition of the best extraction technique for the target group of compounds.

As a subject of research in this paper, dry inflorescence of three different varieties of *Cannabis sativa* L. were used: Helena, Marina and Fedora 13. Commercial crops were cultivated in the field in Bački Petrovac that belongs to the Institute of Field and Vegetable Crops in Novi Sad, Serbia.

Hydrodistillation was used as a conventional extraction technique in order to isolate the essential oil from dried inflorecsens of the industrial hemp. The Clevenger apparatus (Figure 1a), was used in experimental work. Sample (50 g) was weighed into a 1 L flask and 400 mL of distilled water was added. The distillation lasted 2 h, at a power of 205 W. A continuous supply of water and heat was provided. The distillation

yield is expressed as the percentage of essential oil isolated from the plant material we used as (%; v/m). The obtained essential oil was stored in glass bottles in the refrigerator. The procedure was repeated three times for each variety of *C. sativa*.

Microwave assisted hydridistillation was applied as modern extraction technique, which uses microwaves for distillation of essential oil. The heating of the vessel in which the plant material and water are located, takes place due to the action of microwaves. For microwave distillation, a modified microwave oven (MM817ASM, Bosch, Germany) was used, in which a glass flask with an Unger distillation apparatus was placed, (Figure 1b). Sample (50 g) was weighed into a 1 L flask and mixed with 400 mL of distilled water. All experiments were performed at a constant frequency and power of 600 W microwave radiation for 2 h. Experiments were performed in triplicates and the oil yield was expressed as (%; v/m). The distillate was stored in glass bottles in the refrigerator at 4 °C.

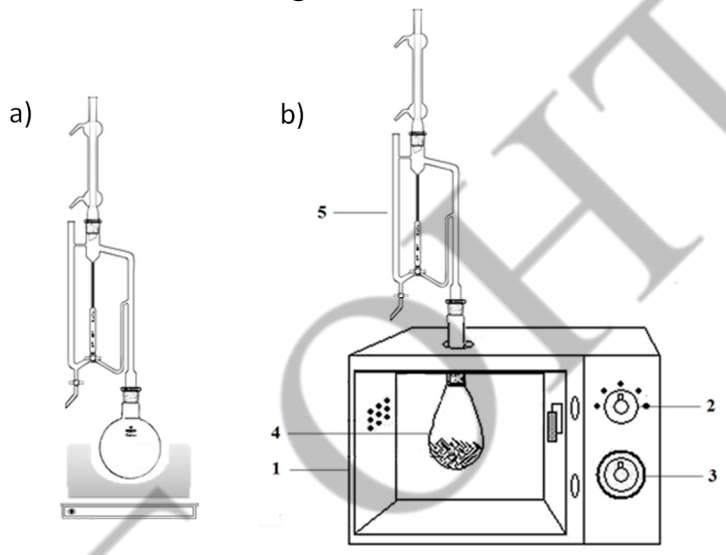

Figure 1. Schematic diagram of a) HD and b) MWHD apparatus: 1. microwave oven (MW); 2. irradiation power controller; 3. time controller; 4. glass flask; 5. Unger apparatus

Supercritical fluid extraction (SFE) is an environmentally friendly extraction technique that uses a fluid in its supercritical state for extraction of lipid compounds. Extraction with supercritical CO_2 was performed at the laboratory device for high-pressure extraction (HPEP, NOVA - Swiss), whose scheme is shown in Figure 2. The extractor was first filled with the measured mass of plant material (50 g). The plant material in the extractor was first released of the present air by blowing CO_2 from the bottle (GC) in the gaseous state, after which the valve (V5) and the control valve (RV2) were closed. The heated temperatures in the ultrathermostats (UT1) and (UT2) maintained the operating temperatures in the extractor and separator (S), while the valve on the CO_2 bottle was closed (V1). Then, after opening the valve from V1 to V5 (V4 is closed), the compressor on which the roughly set operating pressure is started and the operating pressure is set to the set value by the control valve (RV1). After passing through the heat exchanger (IT1), carbon dioxide was introduced into the extractor by opening the valve (V5), while the control valve (RV2) was closed. By opening and adjusting the control valves (RV2) and (RV3), the desired pressure in the

separator was achieved, as well as maintaining the working flow of the extractant. Supercritical fluid extraction was performed under extraction conditions: temperature of 65 °C, flow of 0.3 kg CO_2/h and constant pressure of 400 bar [20]. The extraction process lasted for 3 h, and the extraction yield was determined after 15, 30, 45, 60, 90, 120 and 180 minutes, and was expressed in % (m/m). Two replicates were performed for each *C. sativa* variety. The obtained extracts were transferred to plastic bottles which were closed and stored in the refrigerator at 4 °C. With SFE, first the essential oils were extracted from the primary raw material, then the SFE raffinates were stored and used to obtain total polyphenols by MAE.

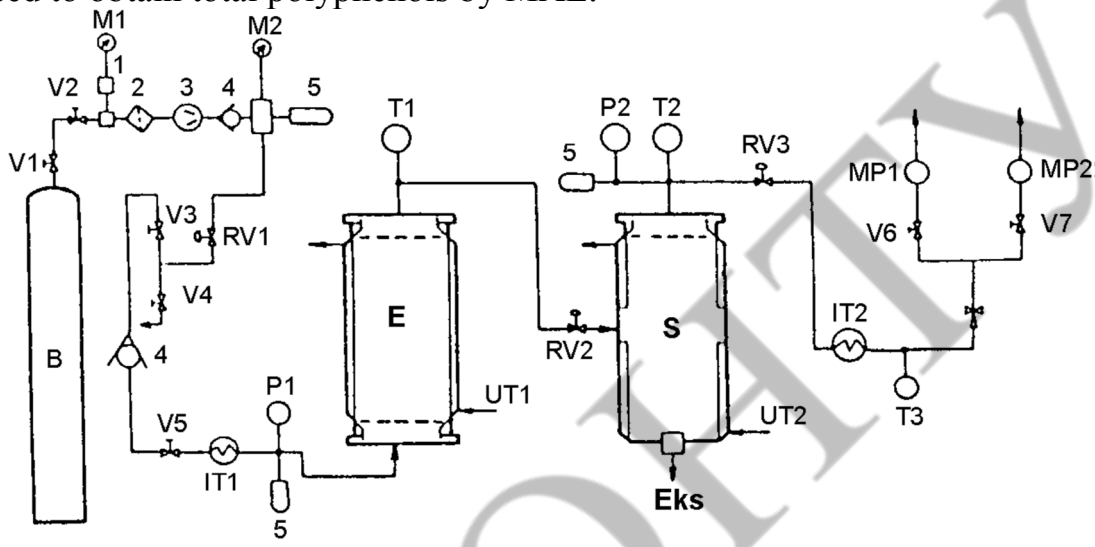

Figure 2. Schematic representation of the supercritical fluid extraction device:
1. Measuring connector; 2. Filter; 3. Diaphragm compressor; 4. Control valve: 5. Safety valve; B - Bottle with carbon dioxide; V - Valve; M - Manometer; RV - Control valve; IT - Heat exchanger; P - Pressure gauge; E - Extractor; T - Thermometer; UT - Ultrathermostat; S - Separator; Ex - Extract; MP - Flow meter.

Extracts from the primary raw material of hemp and SFE raffinate were processed by microwave-assisted extraction in order to isolate total phenol and flavonoids. MAE was performed on a modified microwave oven (MM817ASM, Bosch, Germany) in which a glass balloon with a reflux condenser was placed (Figure 3). Sample (2 g) was weighed and mixed with 60 mL of 25% ethanol, 30 mL/g was solvent-sample ratio [19]. The extraction was performed at a microwave power of 600 W for 25 minutes. When the extraction was completed, the obtained extracts were filtered through filter paper. MAE was performed with the primary raw material and SFE raffinate, twice for each variety of *C. sativa*. The obtained extracts were subjected to a dry evaporation process on a rotary vacuum evaporator to remove the solvent from the extract, after which the extraction yield was determined (%; m/m). The obtained extracts were stored in glass vials in a refrigerator at 4 °C.

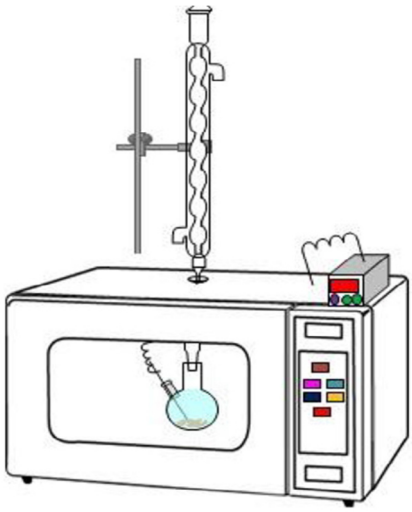

Figure 3. Schematic diagram showing vacuum assisted MAE model

The content of total phenols (TP) in liquid hemp extracts was determined by the Folin-Ciocalteu spectrophotometric method [21]. This method is based on measuring the reduction capacity of polyphenolic compounds. Appropriate dilution of the liquid extract or dry hemp extract solution (0.1 mL) was mixed with 7.9 mL of distilled water, 0.5 mL of Folin-Ciocalteu reagent and 1.5 mL of 20% Na_2CO_3. In the preparation of the trial, 0.1 mL of distilled water or an appropriate ethanol-water mixture used as an extractant in MAE extraction was added instead of 0.1 mL of sample. The reaction mixture was incubated for 1 h at room temperature and the absorbance of the sample was measured on a VIS spectrophotometer at 750 nm. All measurements were performed in triplicate. TP yield in extraction procedures is expressed in g of gallic acid equivalents per 100 g of sample (g GAE/100 g of sample).

The content of total flavonoids (TF) in hemp extracts was determined by the Markham colorimetric method [22]. The determination of the content of total flavonoids is based on their ability to build appropriate metal-organic complexes with metals. The reaction mixture was prepared by mixing 1 mL of sample (appropriate dilution of liquid extract or dry hemp extract dissolved in distilled water) with 4 mL of distilled water and 0.3 mL of 5% $NaNO_2$. The mixture was then incubated at room temperature for 6 minutes and 0.3 mL of 10% $AlCl_3$ x 10 H_2O was added thereto and 5 mL of 1 M NaOH 5 minutes later. The resulting mixture was made up with distilled water (3.4 mL) to a total volume of 10 mL. The absorbance of the sample was measured on a VIS spectrophotometer at a wavelength of 510 nm and all measurements were performed in triplicate. TF yield is expressed in g of catechin equivalents per 100 g of sample (g CE/100 g of sample).

Data was analyzed by using analysis of variance (ANOVA) with Tukey's multiple comparison test at $p<0.05$. Statistica 10.0 (StatSoft, Inc.,Tulsa, OK).

IV. RESULTS

4.1. Hydrodistillation (HD) and microwave-assisted hydrodistillation (MWHD)

After hemp hydrodistillation of all three verieties we obtained golden to pale yellow color essential oil. The yield of essential oil obtained in the process of HD and MWHD, is shown in Figure 4.

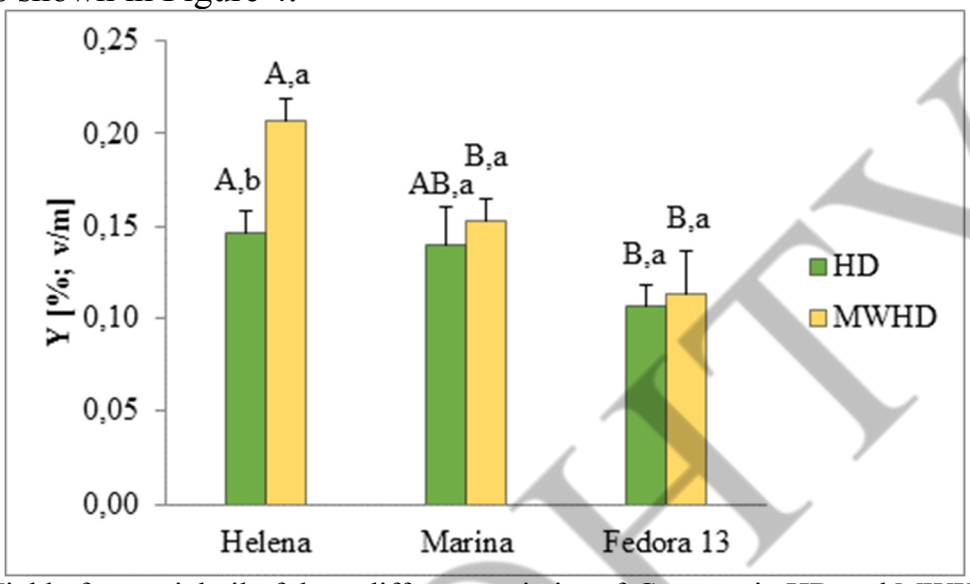

Figure 4. Yield of essential oil of three different varieties of *C. sativa* in HD and MWHD. Results were expressed as mean ± standard deviation (SD) and different uppercase letters represent statistically significant differences ($p<0.05$) among hemp varieties, while different lowercase letters represent diffences among applied techniques according to Tukey's test.

From the Figure 4, it can be seen that the highest yield of essential oil was achieved in the process of HD, in the variety Helena (0.15%), while Marina (0.14%) and Fedora 13 (0.11%) gave a lower yield ($p<0.05$). In MWHD, the highest yield of essential oil was given by the variety Helena (0.21), and the lowest yield was given by the variety Fedora 13 (0.11%) ($p<0.05$), while the variety Marina gave a yield of 0.15%. Optimized MWHD provided higher essential oil yields than conventional HD. Unlike Helena and Marina, the yields of essential oil obtained with the Fedora 13 variety are the same using HD and MWHD.

According to Drinic [12], the content of essential oil of industrial hemp herb was determined by the HD, where it was determined that the content of essential oil was 0.08% (v/m). Comparing the results obtained in this work, it can be seen that the yield of essential oil in the HD process was slightly higher than the results obtained in the aforementioned study [12]. MWHD has been optimized for the isolation of cannabis essential oil from dried flowers of four different varieties of hemp [6]. The variety Kompolti gave the highest yield of 0.27%. This study showed that MWHD is an effective technique for isolating cannabis essential oil from dried hemp flowers. Generally, the use of MWHD could facilitate extraction and increase the yield of essential oil. In the work of Gunjević et al. [14], conventional HD was performed to compare the yield of essential oil with MWHD. The optimized MWHD procedure gave 0.35±0.02% (v/v) of essential oil, while the HD yielded 0.12±0.01% (v/v). The yield

of essential oil obtained in HD is therefore about three times lower than that obtained in optimized MWHD. The yield of essential oil in this work in the variety Helena obtained by MWHD (0.21%) is significantly higher than the yield obtained by HD (0.15%). It can be concluded that MWHD provides certain advantage in terms of yield.

4.2. Supercritical fluid extraction (SFE)

SFE was ised to islolate the lipophilic fraction from industrial hemp varieties. The extraction yield depended on the initial composition of the plant material and the yild increased linearly with the ectraction time, when non-polar and easily volatile compounds were isolated. Extraction yields (Y) for three different varieties of *C. sativa* are shown in Figure 5.

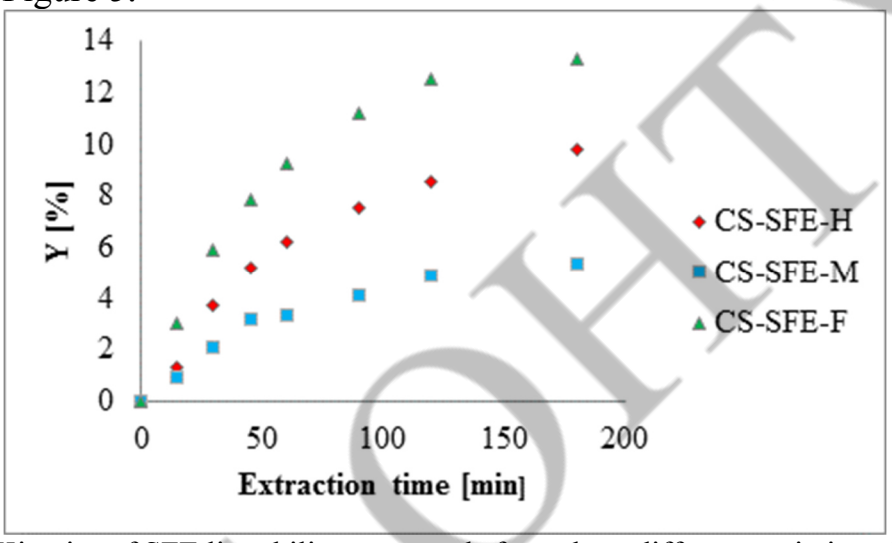

Figure 5. Kinetics of SFE lipophilic compounds from three different varieties of *C. sativa*

The highest yield of essential oil was given by the variety Fedora 13 (14.01%), while Helena achieved a slightly lower yield (9.77%), and the variety Marina had the lowest yield of essential oil (5.33%). When we compared SFE with traditional HD and MWHD to isolate essential oils from *C. sativa*, it was noticed that SFE provided better oil yield. Low temperature, increased pressure, and the use of supercritical CO_2 increased the yield of essential oils from *C. sativa*. So SFE at previously defined optimal conditions [19] has given preference to the use of modern extraction techniques over conventional approach.

Naz et al. [11] compared SFE with traditional steam distillation and HD for isolation of volatile aromatics from *C. indica* and *C. sativa* leaves. SFE was able to provide better oil recovery comparing to applied distillation techniques, while SFE at low pressure (85 bar) and temperature of 45 °C provided the highest oil yield (0.031 and 0.039%). By comparing the results obtained in this paper, it can be concluded that the parameters used were better in the process of isolating essential oil from the literature parameters. SFE has been established method for production of CBD-rich oil from *C. sativa* inflorescence. Marzorati et al. [16] applied heat treatment (100 °C, 6h) of Finola variety inflorescence for decarboxylation of CBDA to CBD which was followed by SFE at 380 bar and 60 °C to obtain 14% of total extraction yield with ≈50% CBD content. The yield of essential oil obtained in this work in the variety Fedora 13 is in accordance with the literature data.

4.3. Microwave-assisted extraction (MAE)

MAE was performed under optimal conditions, which predict the maximum yield of the extract. The yields of extracts from the primary raw material and SFE raffinates were compared and shown in Figure 6.

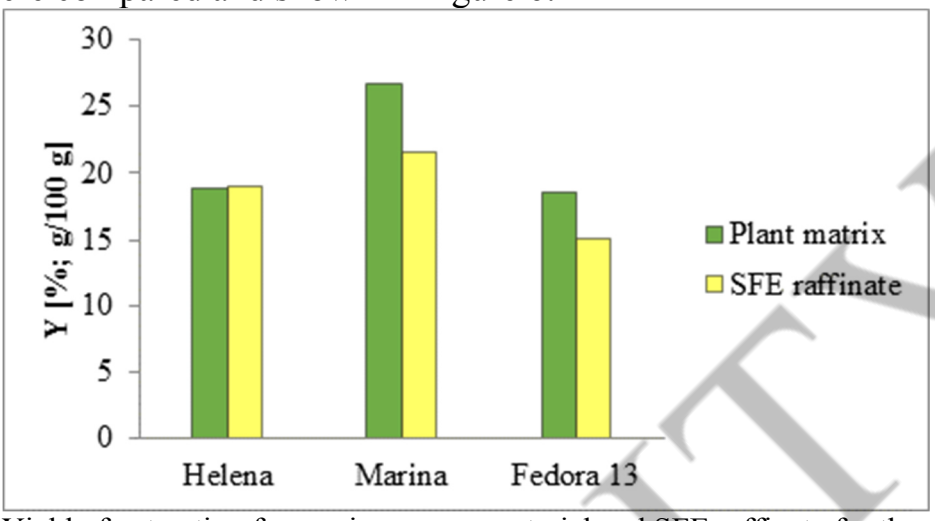

Figure 6. Yield of extraction from primary raw material and SFE raffinate for three different varieties of *C. sativa*

The yield of the extract is higher from the primary raw material than from the SFE raffinate, which is expected, but the amount obtained from SFE raffinate is not insignificant. The highest yield of primary raw material was given by the variety Marina (26.76%), and the lowest Fedora 13 (18.57%). The highest yield of SFE raffinates was given by the variety Marina (21.63%), and the lowest Fedora 13 (15.15%). From the obtained results it can be concluded that the highest yield of extract was in the primary raw material and in SFE raffinate at variety Marina. It is interesting that in variety Helena SFE raffinate has the same extraction yield as the primary raw material.

A recent study investigated efficiency of MAE in recovery of linoleic acid and linolenic acid oil from hempseed [13]. Oil yield obtained under MAE optimal conditions (33.91% w/w) was lower comparing to SOX (37.93% w/w). However, oils obtained with MAE exhibited higher tocopherol content and oxidative stability comparing to SOX due to shorter extraction procedure and lower temperatures used in MAE. In this paper, slightly lower yields of extracts were obtained in relation to the literature. Another study compared performance of MAE, UAE, heat reflux extraction (HRE), SOX and SFE in isolation of cannabinoids from hemp seeds [23]. The highest total CBDs yield was obtained with MAE (6.09 µg/g) comparing to all other extraction procedures (3.61-5.81 µg/g). This was supported with morphological observations on microstructure level, whereat hempseed cell wall breaking was significant after MAE which allowed easier diffusion of target compounds towards extraction medium. Furthermore, MAE was the fastest technique and required the smallest solvent to plant ratio indicating that MAE is rapid and cost-effective technology for CBDs isolation.

4.4. Content of total phenols (TP) and total flavonoids (TF)

The values of total phenols content (TP) in hemp extracts by MAE from primary raw material and SFE raffinate were the result of experiment. Figure 7 shows the yield of total phenols expressed in g GAE/100 g for three different varieties of *C. sativa*.

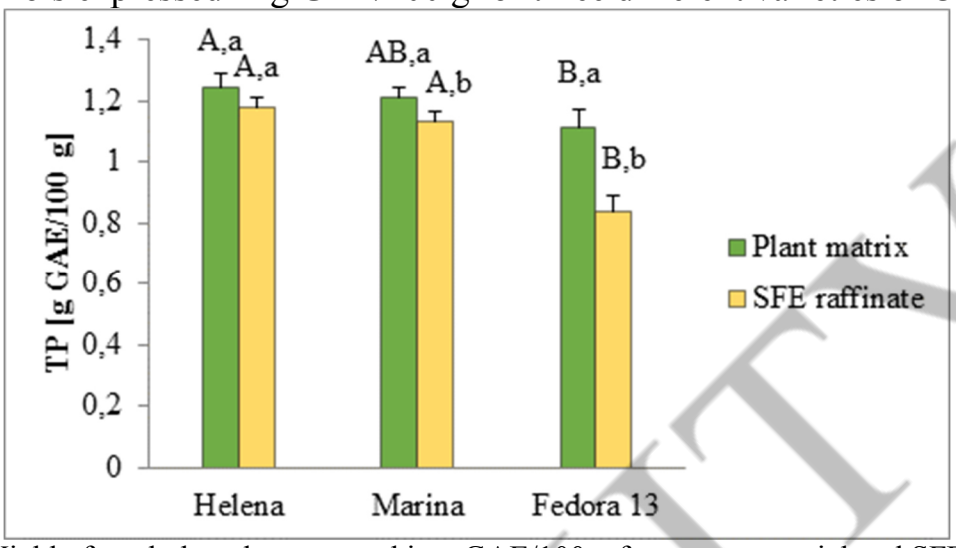

Figure 7. Yield of total phenols expressed in g GAE/100 g from raw material and SFE raffinate. Results were expressed as mean ± standard deviation (SD) and different uppercase letters represent statistically significant differences ($p<0.05$) among hemp varieties, while different lowercase letters represent diffences among applied techniques according to Tukey's test.

It can be observed that the highest yield of TP was recorded in the sample of the variety Helena (1.24g GAE/100 g) from the primary raw material (Figure 7). The highest yield of total phenols from SFE raffinate was recorded in the variety Helena (1.17g GAE/100 g), while the lowest yield was achieved with the Fedora 13 variety (0.84 g GAE/100 g) ($p<0.05$).

Figure 8 shows the yield of total flavonoids (TF) expressed in g CE/100 g from the primary raw material and SFE raffinate for three different varieties of *C. sativa.*

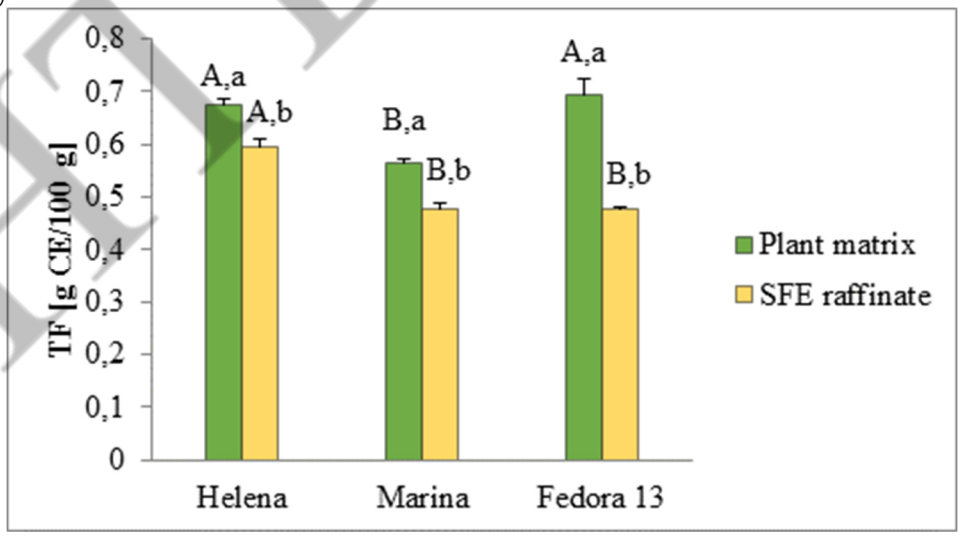

Figure 8. Yield of total flavonoids expressed in g CE/100 g from primary raw material and SFE raffinate Results were expressed as mean ± standard deviation (SD) and different uppercase letters represent statistically significant differences ($p<0.05$) among hemp varieties, while different lowercase letters represent diffences among applied techniques according to Tukey's test.

As for flavonoids, the yields of these compounds in hemp extracts were obtained using MAE. The highest yield of total flavonoids (TF) was obtained in the variety Fedora 13 (0.69 g CE/100 g) from the primary raw material, in contrast to the variety Marina in which the lowest yield of (0.56 g CE/100 g) was recorded ($p<0.05$). In case of SFE raffinates, the obtained results showed that the highest TF yield was achieved in the Helena variety (0.60 g CE/100 g), while the yield in Fedora 13 was significantly lower (0.48 g CE/100 g) ($p<0.05$).

Matešić et al. [19] extracted phenolic compounds from *C. sativa* using microwaves. The effect of each parameter separately on the yield of total phenols and flavonoids was determined. The highest amount of polyphenols (35.514±1.289 mg GAE/ g) was measured for hemp extract. The maximum yield of total flavonoids was 3.04±0.62%. Comparing the results from the literature, it is concluded that a lower content of phenols and flavonoids was obtained in this paper. The results of the content of TP and TF were compared with the study of Drinić [12]. The content of total phenols (2.71 g GAE/100 g) and flavonoids (1.42 g CE/100 g) was observed to be significantly higher than the content of phenols (1.24 g GAE/100 g) and flavonoids (0.69 g CE/100 g) determined in this study.

V. CONCLUSIONS

Although the interest of the scientific community for investigation of the hemp is constantly growing, there is still room for further improvements. Therefore, it is very important to improve the extraction techniques to obtain a product enriched with bioactive compounds in an optimal ratio that ensures maximum biological activity of the product. This step may include further investigation of the extraction processes, application of different solvents, optimization of the extraction, and improvement of the downstream processes (isolation and purification of/from the crude extract). Based on the conducted experiments and the obtained results, it can be concluded that supercritical fluid extraction is the best technique for obtaining essential oil from *Cannabis sativa*, when compared to HD and MWHD. The high content of phenols and flavonoids obtained from SFE raffinates indicates that the by-products of supercritical fluid extraction are a good natural source of antioxidants that can be used in the pharmaceutical and cosmetic industries. It is also very importan to elaborate the mass production of the products and making them available to the customers. This step includes scaling-up the production processes which have to be in accordance to the good manufacturing practices (GMP) and HACCP, as well as good laboratory practices (GLP). This includes intensive funding and further investigations and market analysis which will provide necessary data for accomplishing mentioned goals. Finally, hemp-based extracts exhibited significant health benefits against the different types of diseases and disorders. Therefore, the required large-scaled studies and investments will be justified by development of the different products which will help people to fight these diseases.

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RESEARCH OF INDICATORS OF QUALITY AND SAFETY OF MAYONNAISE ON THE BASIS OF HEMP OIL AND PROTEIN ISOLATE

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Annotation. *Sauces are an integral part of most dishes, which are prepared from a variety of products: meat, fish, seafood, vegetables. They give the dishes juiciness, add variety to the aesthetic appearance of the dish and complement their taste, increase calories and nutritional value. The most common sauces are culinary sauces of the emulsion type, in particular mayonnaise and their derivatives. Today, the oil and fat industry produces a whole "line" of mayonnaise products with various additives that improve the taste, structure and increase the shelf life. The oil and fat industry is at a stage when its development can no longer be carried out by traditional methods, new approaches and solutions are needed. Trends in a balanced and healthy diet are forcing producers to look for new approaches to the production of classic mayonnaise with high biological value and high quality characteristics. The problem of nutrition optimization in terms of the content of essential nutrients, such as fatty acids, can be solved by introducing into the recipe composition, as an oil-fat base, vegetable oils are rich in polyunsaturated fatty acids ω -3 and ω -6. One of the promising areas of production of emulsion products, such as mayonnaise sauce is the introduction of standard recipes for full or partial replacement of sunflower oil with hemp oil in order to improve biological value, while maintaining high organoleptic, structural and mechanical properties and safety. Among the essential nutrients needed to maintain homeostasis of the human body are polyunsaturated fatty acids, the source of which is hemp oil. Hemp oil contains natural antioxidants, which give it increased resistance to oxidation, despite the natural high content of ω -3 and ω -6 fatty acids. One of the ways to implement the innovative idea is the partial or complete replacement of the oil-fat fraction of the emulsion-type mayonnaise sauce with hemp oil with a mass fraction of introduction into the recipe (50%, 75%, and 100%) and complete replacement egg powder on protein isolate of hemp seed.*

The aim of the work is *to study the quality of mayonnaise sauce with partial or complete substitution of oil and fat fraction for hemp oil and protein isolate of hemp seed, namely their organoleptic, physicochemical (effective viscosity, emulsion stability, acidity, acid and peroxide value) indicators, to investigate the fatty acid composition developed samples of mayonnaise sauce based on hemp oil and investigate the change in microbiological parameters during storage. This will expand the range of quality foods enriched with essential nutrients. The following research methods were used in writing the article: standard methods of organoleptic profile analysis, structural-mechanical, standard methods of research of fatty acid composition and methods of determining microbiological parameters. The results of these studies were processed using modern computer programs. Results. The expediency of using mayonnaise-based*

mayonnaise sauce technology during the development of hemp oil sauce technology has been theoretically and experimentally substantiated and formulations of these mayonnaises have been developed. Based on the organoleptic analysis, it was determined that the use of hemp oil in the technology of mayonnaise sauce has a positive effect on its organoleptic characteristics. A study of the fatty acid composition showed that the optimal ratio of fatty acids of the groups ω-3: ω-6, as 1: 4, has a sample of mayonnaise sauce (M2), containing 75% hemp oil in its composition. Analysis of the fatty acid composition also confirmed the functionality of all developed samples of mayonnaise. It was found that all developed samples of mayonnaise based on hemp oil, fully comply with the normative indicators of structure (effective viscosity and stability of the emulsion) and quality indicators (pH, acid number and peroxide value). It was investigated that the microbiological parameters of the control sample of mayonnaise and experimental samples with partial or complete replacement of the oil and fat fraction with hemp oil during storage (28 days) indicate that opportunistic and pathogenic microflora are within acceptable values.

Conclusions and discussions. *The studied quality indicators make it possible to substantiate the technology of mayonnaise sauce based on hemp oil and protein isolate of hemp seed with increased biological value.*

Key words: *emulsion type sauce, mayonnaise, hemp oil, fatty acids, oil and fat fraction*

I. INTRODUCTION

The biologically active components of vegetable oils, in particular hemp oil, which normalizes lipid metabolism, primarily include polyunsaturated fatty acids (PUFA) - linoleic (ω-6) and linolenic (ω-3) PUFA are involved in the body as structural elements cell biomembranes [1-3]. They help regulate metabolism in cells, normalize blood pressure, affect cholesterol metabolism, stimulate its oxidation and excretion from the body, participate in the metabolism of B vitamins, increasing resistance to infectious diseases and other factors [4].

Mayonnaise sauce is one of the main products of the oil and fat industry, which is present in the mass daily consumption of the population [5, 6].

The multi-component composition of mayonnaise provides opportunities to create products that prevent deficient conditions in essential fatty acids, vitamins and other physiologically functional ingredients [7].

One of the main components of mayonnaise emulsions is refined deodorized oil. In order to create mayonnaises with high biological value in terms of essential fatty acids, samples of mayonnaise sauce with partial or complete replacement of oil-fat base with deodorized hemp oil were investigated, thus providing the necessary balance of PUFA and emulsifier. [8-10].

The idea of adding hemp seed protein isolate to mayonnaise sauce technology is due to several factors. One of them is the desire to reduce the fat content by replacing the egg yolk in the recipe, which will allow you to get a product perfectly balanced for daily nutrition. On the other hand, protein isolate obtained from waste oils (cakes) is a valuable source of protein, the use of which in turn solves the problem of food conservation and waste-free production [11-12].

The positive point of using the protein isolate is that it, along with significant biological value, has high functional properties - emulsifying, structuring, moisture-retaining. It enhances the structure-forming properties, which exhibits each component separately, which improves the technological characteristics of mayonnaise emulsions [13].

In the domestic concept of healthy eating an important place is occupied by the use of plant proteins in food production. In general, foods using plant proteins are healthy foods with an improved balance of nutrients compared to traditional foods [14].

Products derived from hemp seeds are divided into three groups that differ in protein content: protein-fat flour (45-50% protein content), protein concentrate 65-70% protein, protein isolate (more than 90% protein content). The most high-protein products - isolates - are the most purified from non-protein components product. They have a neutral taste, smell and color, ranging from light cream to white. Isolates are well soluble in water. When heating solutions and concentrated suspensions, hemp isolates form non-synergistic storage-resistant gems, which in turn have high moisture-retaining properties. Isolates well stabilize fat emulsions in water, which is technologically necessary in the manufacture of mayonnaise sauces [15].

The use of protein isolates as emulsifiers in the industrial production of mayonnaise does not involve changes in technology. The protein isolate forms a suspension in water, is sterilized and, after cooling, enters the emulsifier together with other prescription ingredients. The use of protein isolates in the production of mayonnaise instead of egg powder provides the required consistency of the low-fat product through the ability of hemp protein isolates to form high-viscosity solutions [16-18].

II. LITERATURE ANALYSIS

2.1 The state of study of the problem

Many studies of domestic and foreign scientists have been devoted to the determination of organoleptic, microbiological, physicochemical and functional-technological properties, research of fatty acid composition of mayonnaise sauces, vegetable oils and development of emulsion-type sauces based on them [11,12].

A number of scientists continue to work in this direction, as this problem has not lost its relevance today.

2.2 Unresolved issues

Analysis of the market for mayonnaise sauces shows that in modern society they have become one of the most popular products. However, these products do not meet the characteristics of physiology and biochemical processes of the human body due to the increased amount of saturated fatty acids, as well as the presence of flavoring and technological food additives that are not safe for health [13]. Ease of consumption, high organoleptic characteristics contribute to the fact that emulsion-type sauces are quite popular among consumers, with the greatest demand for mayonnaise sauce classic "Provencal". The analysis of the sauce market in Ukraine shows that the share of mayonnaise production is about 49% of the total number of sauces. About 80% of consumers prefer this type of sauce, and 40% of the population use mayonnaise sauce at least two or three times a week [14].

Increasing the production of biologically complete multicomponent sauces (including mayonnaise) is relevant in light of the concept of a balanced diet, according to which the daily diet should be sufficient polyunsaturated fatty acids [15]. The main advantage of sauces is the potential to enrich the recipe with ingredients for one or more factors in order to most fully comply with their formula for a balanced diet [16].

However, despite the high nutritional value of sauces, including mayonnaise, they have their drawbacks, one of which is the low content of essential nutrients, including polyunsaturated fatty acids, essential amino acids. The main fat fraction of mayonnaise sauce contains a large amount of saturated fatty acids and is not resistant to oxidation, so the classic mayonnaise is not able to meet human needs for essential micronutrients and cannot maintain its quality for a long time [17].

Partial introduction (50%, 75%) of hemp oil mayonnaise or complete replacement of refined deodorized sunflower oil causes high biological value [15]. Therefore, the development of mayonnaise based on hemp oil, enriched with polyunsaturated fatty acids, biologically active components (cachetin, flavones and flavonoids), which will be important both for proper nutrition and to ensure high quality and safety of the sauce [18].

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The aim of the article is to study the quality of mayonnaise sauce with partial or complete substitution of oil and fat fraction for hemp oil and replacement of egg powder with protein isolate, namely their organoleptic, physicochemical (effective viscosity, emulsion stability, acidity, acid and peroxide value) indicators, study of the fatty acid composition of the developed samples of mayonnaise sauce based on hemp oil and study of changes in microbiological parameters during storage.

The methodological basis of the study is the process of developing the recipe for mayonnaise sauce using hemp oil and protein isolate and the study of its quality and safety.

Research methods - standard organoleptic, structural-mechanical, methods for determining the fatty acid composition and microbiological methods and processing of data using modern computer programs.

Information base of the research - scientific articles, materials of international congresses and symposiums, scientific-practical conferences, normative and technical documentation, patents.

The object of the study is mayonnaise sauce with partial (50%, 75%) or complete substitution in the recipe of the oil-fat fraction for hemp oil and replacement in the recipe of egg powder for protein isolate.

The subject of the research is the technology of mayonnaise sauce with partial (50%, 75%) or complete substitution in the recipe of the oil-fat fraction for hemp oil and replacement in the recipe of egg powder for protein isolate.

The scientific novelty of the obtained results lies in the theoretical substantiation and experimental confirmation of the expediency of using hemp oil and protein isolate in mayonnaise sauce technology and its effect on organoleptic, physicochemical, microbiological parameters and fatty acid composition.

IV. RESULTS

The recipe of mayonnaise is selected in accordance with the requirements: DSTU 4487-2015 "Mayonnaise". The recipe of Provencal mayonnaise sauce with a mass fraction of 67% fat was chosen as a control sample. In parallel, three samples of mayonnaise were prepared on the basis of hemp oil with a mass fraction of 50%, 75% and 100%. (Table 1).

Table 1 - Mayonnaise recipes based on hemp oil with a mass fraction of 25%, 50% and 100% in the recipe (in kg per 1000 kg of product excluding losses)

Name of ingredients	**Control**	**Samples of mayonnaise**		
		Prototype 1 (50%)M1	**Prototype 2 (75%)M2**	**Prototype 3 (100%)M3**
Refined deodorized sunflower oil	65.40	49.05	32.7	-
Refined deodorized hemp oil	-	16.35	32.7	6540
Egg powder	5.0	-	-	-
Protein isolate	-	5.0	5.0	5.0
Skimmed milk powder	1.6	1.6	1.6	1.6
Mustard powder	0.75	0.75	0.75	0.75
Sodium bicarbonate	0.05	0.05	0.05	0.05
Sugar sand	1.5	1.5	1.5	1.5
Cooking salt	1.0	1.0	1.0	1.0
Viniger acid	0.55	0.55	0.55	0.55
Water	24.15	24.15	24.15	24.15

The next stage of the study was to determine the organoleptic characteristics of the developed samples of mayonnaise.

Organoleptic characteristics of mayonnaise must meet the requirements (DSTU 4487-2015 "Mayonnaise"), which are presented in table 2.

Table 2 - Characteristics of organoleptic characteristics of mayonnaise based on hemp oil and protein isolate

Indicators	**Characteristic**
Consistency and appearance	Homogeneous creamy product
Taste and smell	The taste is slightly sharp, sour
Colour	White with a yellowish tinge, uniform throughout the mass

Organoleptic evaluation was performed on a 5-point scale. The results of organoleptic evaluation of experimental samples are presented in the form of a profilogram (Fig. 1).

The use of hemp oil and protein isolate in the technology of mayonnaise sauce has a positive effect on its organoleptic characteristics. The consistency, appearance, color and odor of all samples (M1 and M2) were marked with the highest score (5 points), except for the mayonnaise sample with complete replacement (100%) of the oil-fat fraction with hemp oil. Sample (M3) was marked with the lowest taste score (4.8) because it had some deviations from the norm. The highest score (5 points) was a sample of mayonnaise, which contained 75% (M2) of hemp oil.

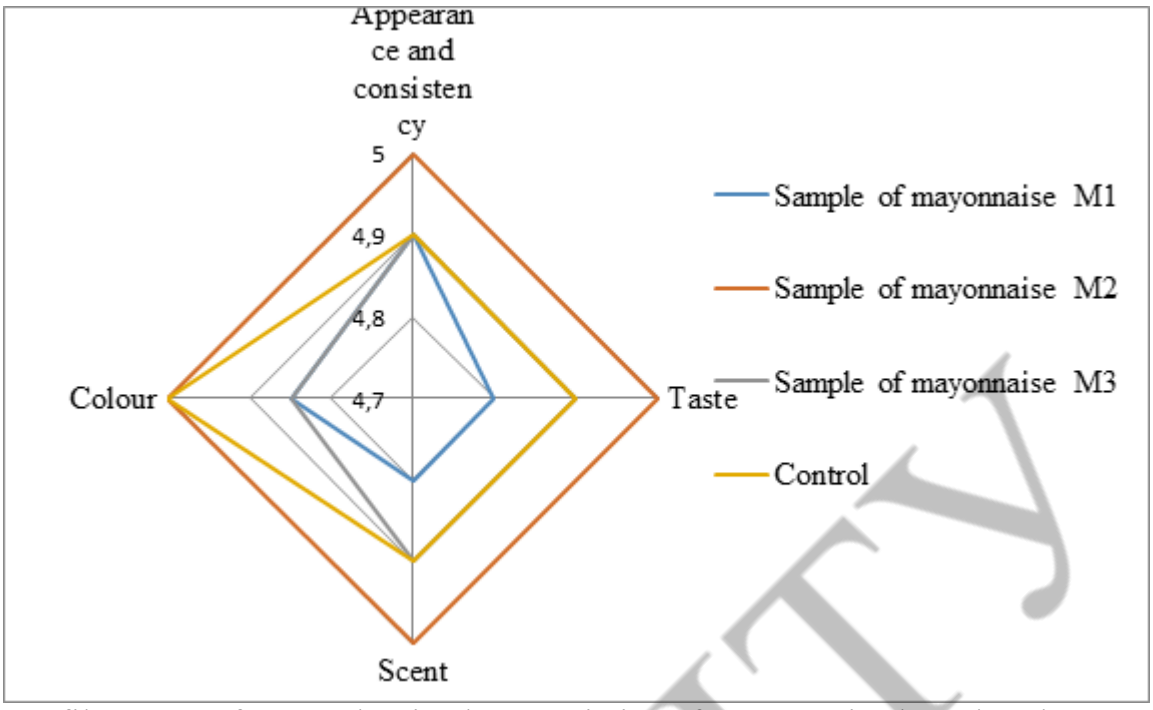

Fig. 1 - Profilograms of organoleptic characteristics of mayonnaise based on hemp oil and protein isolate

To confirm the enrichment of the biological value of mayonnaise sauce based on hemp oil and protein isolate, a study of the fatty acid composition of the developed samples with control - mayonnaise "Provencal" (Table 3).

Table 3 - Fatty acid composition of mayonnaise based on hemp oil and protein isolate

Indicator	**Content g per 100 g of product**			
	Control	**Prototype 1 (50%)M1**	**Prototype 2 (75%)M2**	**Prototype 3 (100%)M3**
Saturated fatty acids	7.96	8.337	13.895	16.674
14:0 Myristic	0.01	0.050	0.084	0.101
16:0 Palmitic	4.48	4.774	7.956	9.547
17:0 Heptadecanoic		0.036	0.060	0.072
18:0 Stearic	2.79	2.521	4.201	5.041
20:0 Arachinic	0.2	0.696	1.160	1.392
22:0 Behenic	0.46	0.166	0.277	0.332
24:0 Lignoceric	-	0.094	0.157	0.188
Monounsaturated fatty acids	16.88	18.636	31.06	37.272
16:1 Palmitoleic	0.08	0.175	0.291	0.349
17:1 Heptadecenoic	-	0.019	0.032	0.038
18:1 Oleic	16.8	16.876	28.127	33.752
20:1 Gadoleic	-	0.059	0.099	0.119
22:1 Erucic	-	1.507	2.511	3.013
Polyunsaturated fatty acids	39.27	33.027	55.045	66.054
18:2 Linoleic	39.24	14.473	24.122	28.946
18:3 Linolenic	0.03	18.554	30.923	37.108
18:3 γ- linolenic	-	6.517	10.862	13.034
18:3 α- linolenic	-	12.037	20.061	24.073

The ratio of fatty acids of the ω-3: ω-6 groups for the sample of mayonnaise sauce (M2) was 1: 4 (Table 3), which is the recommended ratio for functional nutrition. The ω-3 fatty acids include α-linolenic fatty acid. To ω-6 - linoleic and γ-linolenic. The optimal overall ratio of ω-3 to ω-6 in the diet is 1: 3/1: 6, and it must be maintained. It is undesirable to exceed the value of 1:10. It stimulates the development of inflammatory processes in the body. The control sample of Provencal mayonnaise contains ω-6 and ω-3 fatty acids. Monounsaturated fatty acids are contained in the control sample of the sauce twice as much as in the sample of mayonnaise sauce (M2) and 2.2 times more than in the sample of mayonnaise sauce (M3). The data on the qualitative characteristics of the developed samples of mayonnaise sauce based on hemp oil, show that the best indicators for the ratio of fatty acids of groups ω-3: ω-6, received a sample of sauce (M2). It should be noted that the highest levels of fatty acids of groups ω-3 and ω-6 received a sample of mayonnaise (M3). However, the ratio of fatty acids of the ω-3: ω-6 groups in the mayonnaise sample (M3) is 1: 7/1: 9, which does not correspond to the optimal one. Analysis of the fatty acid composition also confirmed the functionality of all developed samples of mayonnaise.

The stability of mayonnaise emulsion depends on the composition of the oil-fat base and emulsifying ability of the protein used as emulsifier: hemp seed protein isolate, milk powder, egg and mustard powder involved in creating the structure of mayonnaise, as well as compliance with optimal process parameters. all - homogenization.

Important quality indicators for emulsion-type sauces are structure indicators (effective viscosity and stability of the emulsion) and quality indicators (pH, acid number and peroxide value), which characterize the product's resistance to mechanical impact and storage stability. The results of the study of these indicators are presented in table 4.

Table 4 - Physico-chemical parameters of mayonnaise based on hemp oil and protein isolate

Indicator	**Samples of mayonnaise**			
	Control	**Prototype 1 (50%)**	**Prototype 2 (75%)**	**Prototype 3 (100%)**
Effective viscosity, Pa × s^{-1} (at a shear rate of 3 s^{-1})	9.5	9.5	9.5	9.3
Emulsion stability, %	99	100	100	99
pH	4.5	4.5	4.5	4.6
Acid number, ml KOH/kg	0.2	0.2	0.2	0.2
Peroxide number,½O_2, mmol / kg	2.3	2.5	2.6	2.9

The results of the research (Table 4) confirm the possibility of producing all samples of mayonnaise based on hemp oil and protein isolate, as they fully meet the physico-chemical parameters established by the requirements of regulatory documentation.

The percentage of undamaged emulsion for test samples of mayonnaise (M1) and (M2), with a mass fraction of hemp oil of 50% and 75% was 100%, which is 1% less than the control and experimental sample of mayonnaise (M3). As a result of the research, the stability of the emulsion corresponds to the norm for all samples of

mayonnaise. The effective viscosity for the control and test samples of mayonnaise (M1, M2 and M3) is within normal limits. However, the effective viscosity of the mayonnaise test sample (M3) with complete replacement of the oil-fat fraction with hemp oil was 0.2 Pa × s^{-1} less than that of the other mayonnaise test samples (M1 and M2). The results obtained on the indicators of active acidity, however, indicate that the pH for all developed samples of mayonnaise was within normal limits. Acid values did not differ for control and experimental samples of mayonnaise (M1, M2, M3). The peroxide value for the mayonnaise sample (M3) almost reaches the limit value for this type of product 3.1 mmol of active oxygen / kg.

To control the safety indicators for the developed samples of mayonnaise was determined by the change in microbiological parameters during storage (28 days) (table 5).

Table 5 - Change in microbiological parameters of mayonnaise based on hemp oil and protein isolate during storage

Indicator	**Permissible level**	**Prototype**	**Shelf life, days**			
			0	**10**	**14**	**28**
Bacteria of the Escherichia coli group (coliforms), 0.01 g of mayonnaise	Not allowed According to DSTU 6003: 2008	Control	–	–	–	–
		Prototypes	–	–	–	–
Pathogenic microorganisms, including bacteria of the genus Salmonella, in 25 g of mayonnaise	Not allowed	Control	–	–	–	–
		Prototypes	–	–	–	–
Staphylococcus aureus, in 1 g of mayonnaise, no more than	$5{,}0\times10^2$	Control	2.7×10^2	2.7×10^2	2.7×10^2	2.7×10^2
		Prototypes	2.7×10^2	2.7×10^2	2.7×10^2	2.7×10^2
Listeria monocytogenes, in 25 g of mayonnaise	Not allowed	Control	–	–	–	–
		Prototypes	–	–	–	–

Studies of microbiological parameters of the control sample of mayonnaise and test samples with partial or complete replacement of the oil-fat fraction with hemp oil during storage (28 days), indicate that opportunistic and pathogenic microflora are within acceptable values. Determination of Bacteria of the Escherichia coli group (coliforms) in 0.01 g of experimental and control samples of mayonnaise indicate their absence in the studied products. The number of bacteria of the Staphylococcus aureus group in the control sample of mayonnaise and experimental samples during the entire shelf life is the same and is 2.7×10^2.

V. CONCLUSIONS

Thus, the following conclusions can be drawn:

The expediency of using mayonnaise sauce based on hemp oil and protein isolate during the development of the technology of mayonnaise sauce was theoretically and experimentally substantiated, and formulations of these mayonnaises were developed.

Based on organoleptic analysis, it was determined that the use of hemp oil and protein isolate in the technology of mayonnaise sauce has a positive effect on its organoleptic characteristics. The consistency, appearance, color and odor of all samples were positively evaluated. The highest score (5 points) was a sample of mayonnaise, which contained 75% (M2) of hemp oil.

The study of fatty acid composition showed that the highest indicators of fatty acid content of groups ω-3 and ω-6 received a sample of mayonnaise (M3). However, the ratio of fatty acids of the ω-3: ω-6 groups in the mayonnaise sample (M3) is 1: 7/1: 9, which does not correspond to the optimal one. The sample of mayonnaise sauce (M2) has the optimal ratio of fatty acids of the ω-3: ω-6 groups, as 1: 4. Analysis of the fatty acid composition also confirmed the functionality of all developed samples of mayonnaise.

It was found that all developed samples of mayonnaise based on hemp oil and protein isolate, fully meet the regulatory structure (effective viscosity and stability of the emulsion) and quality indicators (pH, acid number and peroxide value), which characterize the resistance of the product to mechanical influences and storage stability for emulsion-type sauces.

It was studied that the microbiological parameters of the control sample of mayonnaise and test samples with partial or complete replacement of the oil and fat fraction with hemp oil during storage (28 days), indicate that opportunistic and pathogenic microflora are within acceptable values. The number of bacteria of the Staphylococcus aureus group in the control sample of mayonnaise and test samples throughout the shelf life is the same and is 2.7×10^2.

The studied quality indicators make it possible to substantiate the technology of mayonnaise sauce based on hemp oil and protein isolate with high biological value.

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FUNCTIONAL FOOD INGREDIENTS BASED ON ORGANIC COMPLEXES OF BIOMETALS WITH COMPOUNDS OF POSTBIOTIC ORIGIN

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Abstract. *Functional food ingredients based on complexes of biometals, products of postbiotic origin and dietary fiber of wheat bran were obtained in the work. Products of postbiotic origin were obtained by ultrasonic treatment and enzymatic conversion of peptidoglycans of Lactobacillus delbrueckii subsp. Bulgaricus B-3964. As a result of these transformations, a mixture of amino acids, low molecular weight peptides and muropeptides was obtained, the concentration of which is 10.24 mg/cm^3, 6.45 mg/cm^3 and 2.25 mg/cm^3, respectively. This hydrolyzate was used as a mixed ligand system to obtain complexes of +.Fe^{3+}, Ca^{2+} and Mg^{2+}. The progress of complexation was monitored using nephelometry. It has been established that the studied system of bioligands binds Fe^{3+} ions in quantity 32 mol/dm$^3 \cdot 10^{-2}$, Ca^{2+} – 28 mol/dm$^3 \cdot 10^{-2}$ ma Mg^{2+} – 24 mol/dm$^3 \cdot 10^{-2}$. The behavior of complexes at different pH and temperature values was studied. They are found to be stable in the pH range inherent in most food and digestive systems. The differential scanning calorimetry method shows that the obtained complexes are stable in the temperature range of 44–180 °C, which allows to recommend them as functional food ingredients for food products whose technology requires high-temperature processing. The feasibility of the obtained biometals complexes immobilization at dietary fibers is substantiated. It is proved that immobilization occurs only by physical sorption, which contributes to the complete release of the active components in environments that mimic the pH of the small intestine, where the absorption of biometals is been. The presence in the investigated ingredients composition of the bimetals in organic form, low molecular weight muropeptides with immunotropic activity, dietary fibers, allows to classify these preparations in the category of polyfunctional.*

Key words: *functional food ingredients, biometals, postbiotics, chelate complexes, muropeptides, dietary fiber.*

I. INTRODUCTION

Recently, theories of nutrition, which would satisfy all aspects of physiological activity and the need for alimentary nutrients, are being transformed and improved in parallel with changes in scientific and technological progress. The optimal theory of nutrition is replaced by the theory of functional nutrition [1]. Functional nutrition allows to individualize the needs of each person, prevent the lack of essential components of food, which may occur due to certain dietary restrictions associated with diseases of various etiologies, allergic conditions, intense lifestyle that prevents regular and complete nutrition.

Today the problem of hypoelementosis is quite acute [2-3]. Lack of essential bimetals, in particular, calcium, magnesium, iron, etc., can lead to irreparable consequences: metabolic disorders, iron deficiency anemia, disorders of the

cardiovascular, nervous system, immunity, etc. [2-5]. The use of functional nutrition to overcome this problem by introducing easily digestible and safe forms of biometals into the diet is very important.

II. LITERATURE ANALYSIS

There are three main approaches [2] to solving the problem of deficiency of macro- and micronutrients: the first – the consumption of products high in minerals; the second – the use of drugs and dietary supplements; third – purposeful enrichment with deficient elements of food for mass consumption. The most optimal for the prevention of food-dependent hypoelementosis is the enrichment of essential bioelements of food.

USA, England, Sweden, Holland, etc. adopted national programs for the enrichment of food with macro- and micronutrients. The experience of these countries shows that the use of inorganic compounds for these purposes does not provide the required level of their assimilation, can lead to physiological side effects, adversely affect the sensory characteristics of the product [2-4]. Therefore, it is important to develop safe and effective food ingredients based on biogenic metal compounds. It is known that organic and chelated compounds of biometals are more effective and safe compared to their inorganic forms [2-5].

Of particular interest for the prevention of trace elementosis are chelated compounds of biogenic elements with organic ligands, because in the metabolism of all minerals involved proteins, peptides, amino acids, phospholipids, carbohydrates, carboxylic acids, etc. [2,6]. Despite some advances in the development of chelated forms of biometals, the search for new, more advanced forms of functional food ingredients for the prevention of microelementosis continues, [7-11].

The use of postbiotics – products of metabolism and processing of probiotic bacteria to obtain mixed ligand chelate complexes of biometals is promising[12,13]. These systems contain a number of compounds that can be attributed to potential organic ligands for complexation with biometals, namely: organic acids, amino acids, low molecular weight peptides, muropeptides. In addition, the use of compounds of the muropeptide series for complexation with biometals will create multifunctional tools, because muropeptides have powerful immunotropic properties [14,15]. The use of postbiotics in functional nutrition is widely discussed today [16,17].

The purpose of the work is to obtain and characterize multifunctional food ingredients based on complexes of essential biometals, namely, calcium, magnesium and iron with low molecular weight degradation products of cell wall peptidoglycans and metabolites *Lactobacillus delbrueckii subsp. Bulgaricus* B-3964.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The next materials were used for research: biomass (BM) of lactic acid bacteria *Lactobacillus delbrueckii subsp. Bulgaricus B-3964* with concentration $4.8 \cdot 10^9$ CFU/cm^3 (SPI "Ariadna, Odesa, Ukraine); papain with a proteolytic activity of 10 U/mg (Swanson Health Products, USA); $FeCl_3 \cdot 6H_2O$ (China); $CaCl_2$, $CaMg_2$ (STAB, Netherlands); dietary fiber of wheat bran (DFWB) (Farmakom, Kharkiv, Ukraine).

Obtaining the destruction products of peptidoglycans Lactobacillus delbrueckii subsp. Bulgaricus B-3964. Isolation of cells from the culture fluid was performed by centrifugation for 15 min at 8000 min^{-1}. The cell pellet was washed with distilled water, resuspended and sonicated using PSB-1335-05 ultrasonic baths with an operating frequency of 40 kHz and a treatment duration of 300 s. Enzymatic destruction of BM cell walls was performed by treatment with papain at a temperature of 37°C and pH=7.4. The ratio of enzyme: substrate (dry matter content BM) was 1: 200, the incubation time of the reaction mixture was 300 minutes. The enzymatic hydrolysis was stopped by emergency heating to 100 ° C., the mixture was cooled, and the liquid phase was separated from the solid by centrifugation for 10 min at 8000 min^{-1}. In the liquid phase, the content of free amino acids was controlled by formol titration [18]. The content of low molecular weight peptides (LMWP) was determined by the Benedict method [18] after precipitation of high molecular weight proteins with 10% solution of trichloroacetic acid (TCA), the content of muropeptides was determined after purification of hydrolysate on Anthrone method [18].

Obtaining organic complexes of biometals. The complexes were obtained by combining solutions of the hydrolysate of *Lactobacillus delbrueckii subsp. Bulgaricus* B-3964 and biometals with vigorous stirring for 180 s, the temperature of complexation was 40°C. The complexing ability of metal ions in relation to bioligands was determined by nephelometric method in the presence of Na_2CO_3 on a spectrophotometer SF-2000 at a wavelength of 450 nm [19,20].

Study of the complexes pH stability. The behavior of the complexes was studied in the range of pH values of 1–10 units. The required pH value was achieved using standard solutions of NaOH and H_2SO_4. The concentration of free Fe^{3+} was determined by the thiocyanate method [21], the concentration of magnesium and calcium complex was determined spectrophotometrically at wavelengths λ = 340 nm [20]. The stability of chelate complexes was calculated by formula (1):

$$C = \frac{a-b}{a}100 \text{ , \%} \quad (1)$$

where *a* – initial concentration of the complex, mg/cm^3;

b – the concentration of the complex after incubation at certain pH values, mg/cm^3.

Investigation of heat resistance of the obtained complexes. The studies were performed using the method of differential scanning calorimetry (DSC) in dynamic mode. DSC thermograms were obtained in the temperature range 25–250°C at a constant heating rate of 5°C/min on a calorimeter Derivatorgaph Q1500-D. In order to determine the conditions under which the complete decomposition of the samples will take place, the heating was continued to a maximum temperature of 450°C. A portion weighing 500 mg was placed in a ceramic crucible. The accuracy of determining the temperature was ± 1°C, the thermal effect – ± 3%.

Functional food ingredients (FFI) obtaining. FFI was obtained by immobilization of organic complexes of biometals on DFWB, which were previously removed from water and salt-soluble protein residues by three treatments with physiological NaCl solution at a hydromodule (HM) 1:20 (the mixture was stirred for 10 min at room temperature). DFWB was washed with distilled water and dried in a convective dryer

at 70°C to a humidity of 10–12%. Immobilization was performed by combining a solution of an organic complex of biometal with DFWB (HM 1: 5). The mixture was kept for 120 min and dried in a convective dryer at a temperature of 50°C until a humidity of 10–12% was reached.

Determination of the degree of complexes desorption from the matrix DFWB. The degree of desorption of organic complexes of biometals from the matrix was determined by indicating the amount of protein substances transferred to the external environment of the extractant from the total content of these substances in the complex (%) by reaction with ninhydrin [18]. To determine the degree of biometals complexes desorption from DFWB as extractants where used distilled water (HM 1:5, process duration 300 min) and buffer systems corresponding to the pH of the of the gastrointestinal tract medium, namely the stomach (pH 1.2) and the small intestine (pH 7.4). FFI was incubated for 120 min in a solution with a pH of 1.2 at a GM of 1: 5, after which the liquid phase was separated, buffer with a pH of 7.4 was added and the mixture was incubated for 180 min with stirring. The concentration of protein in the liquid phase of the mixture was determined every 30 minutes

The absolute error of the measurements was determined using the Student's test, the confidence interval P = 0.95, the number of repetitions in the definitions 3–4, the number of parallel samples of the experimental samples – 3.

IV. RESULTS

For the formation of biometals chelated complexes used bioligands of probiotic origin, namely, the destruction products of peptidoglycan *Lactobacillus delbrueckii subsp. Bulgaricus B-3964*. Destruction of peptidoglycan of BM cell walls was performed according to the procedure described above. As a result, a mixture of amino acids, LMWP and muropeptides was obtained, the concentration of which was 10.24 mg/cm^3, 6.45 mg/cm^3 and 2.25 mg/cm^3, respectively. The complexing capacity of mixed ligand organic systems with respect to metal ions was investigated by nephelometry, namely by detecting insoluble forms of carbonates / metal hydroxides formed by the interaction of free metal ions with sodium carbonate after saturation of the ligand system with biometals. Free metal ions provoke turbidity after interaction with sodium carbonate. Determining the complexing capacity of the ligand system in relation to a particular biometal will allow to obtain a complex in which the presence of metal in an undesirable inorganic form is impossible. The results of the study are shown in Fig. 1.

As can be seen from Fig. 1, the turbidity of mixed ligand systems in the presence of biometal ions and Na_2CO_3 is minimally stable (0.05 opt. units) until a certain metal concentration is reached in the mixture. For the studied systems, this value has a significant difference. Thus, a rapid increase in the turbidity of the system containing Mg^{2+} ions occurs at their concentration in a mixture of 24 mol/dm^3·10^{-2}, Ca^{2+} – 28 mol/dm^3·10^{-2}, Fe^{3+} – 32 mol/dm^3·10^{-2}. This behavior of the studied systems indicates that before reaching these concentrations, the metal is in a bound state in mixed ligand complexes, which prevents its interaction with sodium carbonate presented in the system and the appearance of insoluble particles of iron hydroxide or magnesium / calcium carbonate, which cause turbidity of the system.

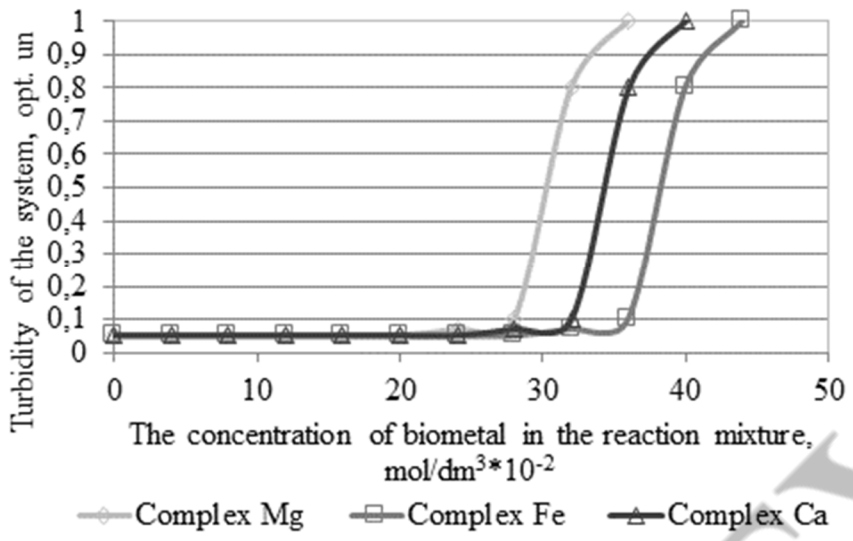

Fig. 1. Dependence of turbidity of mixed ligand system of probiotic origin on the content of biometal ions in the presence of Na_2CO_3

Since chelated complexes of biometals with the processing products of BM *Lactobacillus delbrueckii subsp. Bulgaricus* B-3964 is planned to be used as a dietary supplement and functional food ingredients, it is advisable to study their behavior at different pH values and temperatures. Figure 2 shows the dependence of the complexes stability on different pH values.

Based on the data of Fig. 2, the greatest stability at different pH values has a complex formed with the participation of Fe^{3+}. Complexing agent Fe^{3+} has d^2sp^3 hybridization of atomic orbitals and can cause the formation of an octahedral shape of the complex with bioligands, which explains the significant stability of the complexes in mediums with different ion activity. The stability of the obtained complex in the pH range 8–10 allows us to predict the possibility of the presence of ferric ions in the dissolved state in the small intestine, where it is absorbed by enterocytes.

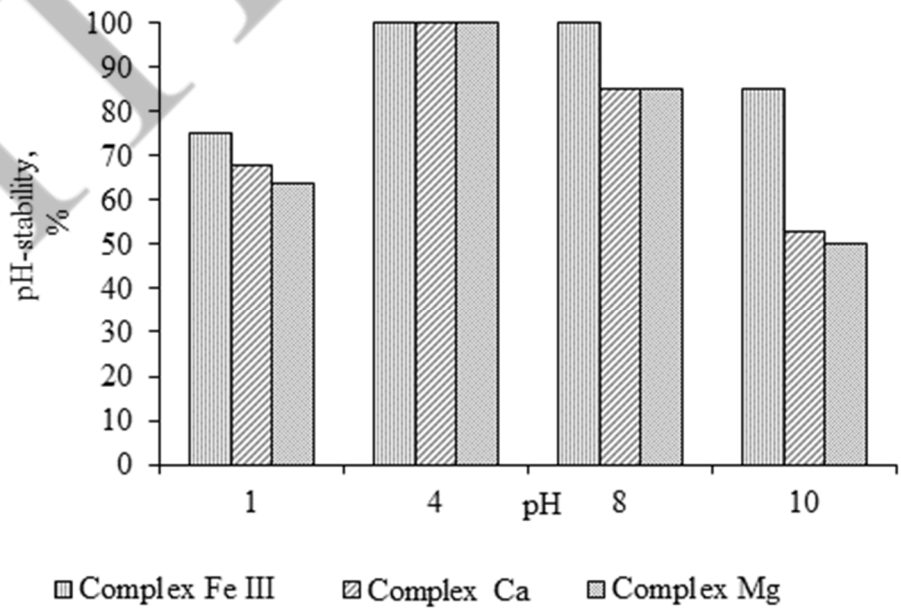

Fig. 2. Complexes pH-stability

The Ca and Mg complexes are also quite stable over a wide pH range. Thus, at the most aggressive values of pH 1 and pH 10, the stability of the Mg complex is 64 and 50%, Ca – 68 and 53%, respectively. The rather high stability of the obtained complexes can be explained by the fact that mixed ligand polydentant systems cause a stable "chelate effect", because the complexation of metals with polydentant ligands is more advantageous from a thermodynamic point of view than monodentant ligands. The stability of chelates at elevated pH values is also due to competition between metal ions and the proton of the solution for the anion of the chelate ligand. Thus, the obtained chelated structures are stable in the range of pH values of the environment, inherent in most food systems and digestive systems of the body, which determines the prospects of their use as components of dietary supplements and functional food ingredients.

In order to predict the behavior of the obtained chelate complexes in the composition of food systems that can be subjected to heat treatment, their analysis was performed by the DSC method (Table 1).

When comparing the DSC analysis data, it can be stated that the initial weight loss of the complexes begins at a temperature of 44–52 ° C, samples of the mechanical mixture – at 55–60 ° C. The first weight loss is not accompanied by thermal effects, which indicates that at these temperatures there is no destruction of the chelated bonds of the complexes, which can provoke a change in the enthalpy of the process and the appearance of thermal effects. In the temperature range 118–180 ° C, an endothermic reaction is observed during heat treatment of complexes, and no thermal effects are observed during treatment of the mechanical mixture. The presence of endothermic thermal effects on the thermograms of the complexes may indicate the presence in their structure of chelated bonds, the destruction of which changes the enthalpy of the process.

Table 1 – Thermal effects and weight loss in thermogravimetric study of samples

Samples	Temperature range, °C	Maximum, °C	Thermal effects	Weight loss, %
Complex Ca	49–122 122–178	– 140–145	– endothermic	3.00 18.50
Mechanical mixture of components of the complex Ca	59–122 122–178	– –	– –	7.00 16.00
Complex Mg	44–118 118–173	– 139–143	– endothermic	4.00 17.80
Mechanical mixture of components of the complex Mg	55–120 120–173	– –	– –	6.25 16.40
Complex Fe (III)	52–125 125–180	– 140–145	– endothermic	3.80 19.60
Mechanical mixture of components of the complex Fe (III)	60–125 125–180	– –	– –	7.30 17.50

The results of the research allow us to state that the obtained metal complexes are promising components of dietary supplements and functional food ingredients intended for the prevention of hypoelementosis, as they contain metal in safe organic (chelated) form, are stable in a wide range of pH and temperature.

Since the conditions for obtaining complexes involve the use of dilute solutions of their components, in the development of technologies for dietary supplements and food ingredients based on them, there are problems of concentration and drying of such systems. Upon receipt of soluble chelate complexes according to the proposed scheme, the moisture content can be up to 95%. These systems are difficult to dry and are quite hydrophilic after drying, which complicates their storage and possible dosing when added to food systems. In addition, due to the fact that the effective daily intake of the complexes is quite low, there may be a problem of even distribution of such a functional food ingredient throughout the product. In order to get rid of such shortcomings, it is proposed to immobilize the obtained complexes on classical matrices – dietary fiber of wheat bran. Modes of immobilization are shown above, and Figure 3 shows the regularity of desorption of the Fe (III) complex from the DFWB matrix during extraction with water and solutions corresponding to the pH of the gastrointestinal tract (regularities of desorption of Ca and Mg complexes correspond to those for the Fe (III) complex).

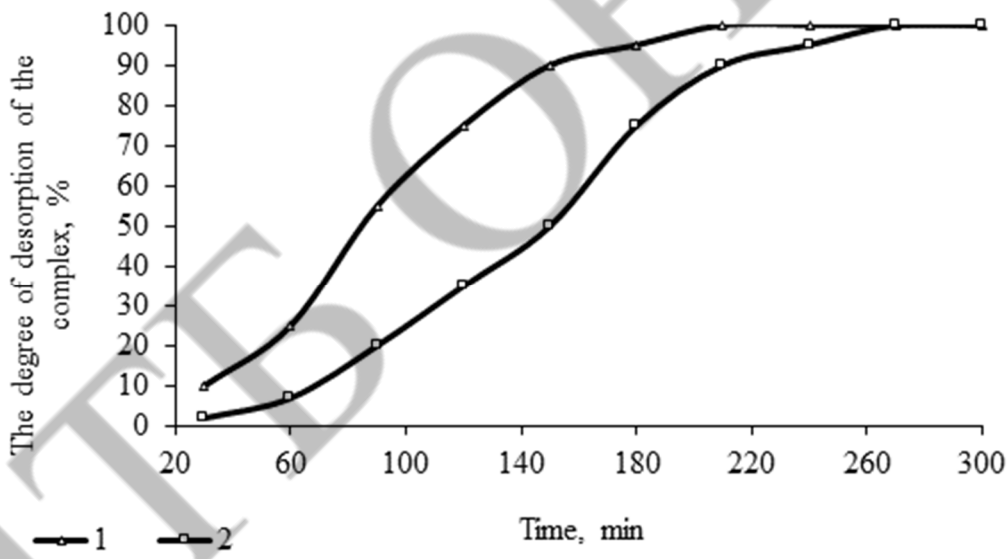

Fig. 3. Desorption of Fe (III) complex from DFWB matrix, depending on time and type of extractant

The nature of the release of the complex from the DFWB matrix during extraction with distilled water and solutions corresponding to the pH of the gastrointestinal tract is slightly different. The desorption of the complex is more intensive during the incubation of FFI with water, its complete release takes place after 210 min of extraction. Desorption of organic form of Fe (III) during extraction with solutions corresponding to the pH of the gastrointestinal tract, in the first 120 min of incubation is quite slow (only 35%, in contrast to the experiment with water – 75%). Complete release of the complex occurs after 270 minutes of extraction. The slow desorption of the complex at low pH values (the first 120 min of the experiment) can be explained

by the low water-binding capacity of DFWB under these conditions, which is a certain obstacle to the free extraction of the complex. Complete release of the complex from the matrix suggests that immobilization occurs only through physical sorption. The time of complete desorption of the biometal complex from the DFWB matrix in both experiments corresponds to the idea of the duration of the process of transporting food lumps from the upper gastrointestinal tract to the site of absorption of bimetals by enterocytes of the small intestine.

V. CONCLUSIONS

1. The results of research indicate the effectiveness of the use of polydendant mixed ligand systems of postbiotic origin for complexation with biometals.
2. According to research, the resulting complexes are stable in the pH medium inherent in most food systems and digestive systems, which determines the prospects of their use as components of dietary supplements and functional food ingredients.
3. The DSC method proved that the obtained complexes are stable in the temperature range 44–180 ° C, which allows to recommend them as FFI for food products, the technology of which provides for high-temperature processing.
4. The expediency of immobilization of the obtained biometals complexes on DFWB is substantiated. It is proved that immobilization occurs only by physical sorption, which promotes the complete release of active ingredients in media that mimic the pH of the small intestine, where the absorption of biometals takes place
5. The presence in the composition of the studied FFI biometals in organic form, low molecular weight muropeptides with high immunotropic activity, DFWB, allows to refer these tools to the category of multifunctional.

The prospect of further research is to study the physiological activity of the obtained FFI in animal experiments.

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TECHNOLOGY OF MOUSSE PRODUCTS FROM HYDROBIONTS

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Abstract. *The expediency of improving the technology of shrimp mousses is substantiated in the work. Based on the analysis of literature sources, the priority areas of processing of fish raw materials and expanding the range of fish products have been identified. The analysis of existing technologies of mousse products from aquatic organisms has been carried out. The prospects of production of mousses from fish and shrimps have been established. The expediency of using shrimp to create food products with improved organoleptic characteristics and increased nutritional value has been theoretically substantiated. The effectiveness of combining crustaceans with fish, animal and plant raw materials has been experimentally confirmed. New mousse recipes based on shrimp meat with cream cheese, cream, olive oil, salmon fillet, avocado, apples, spices and condiments have been developed. A study of organoleptic, physico-chemical indicators of quality and nutritional value of finished products has been conducted. Based on the research results, the compliance of the indicators with the requirements of the standard has been established. Results of study on the chemical composition indicate the high nutritional value of the developed mousses. Based on theoretical and experimental researches the technological scheme of production of mousses on the basis of shrimps with use of animal and vegetable components has been developed. The main technological operations are preliminary preparation of raw materials, fine grinding of the mixture and packaging of the finished product.*

Keywords: *mousse, shrimps, technological scheme, recipe, nutritional value.*

I. INTRODUCTION

Pasty products from aquatic organisms are gaining popularity in the global market of fish products and are in great demand among consumers. This is due to their organoleptic characteristics, ease of consumption, high nutritional value and degree of assimilation, as well as the spread of low-waste industries. The technology of pasty products allows to obtain products enriched with various flavoring additives, functional ingredients, using raw materials with mechanical damage. The range of these products includes fish pates, pastes, oils, creams and mousses.

Despite the great popularity of pasty products from aquatic organisms abroad, in Ukraine their range is quite limited and is represented by fish pates and pastes from fresh or salted fish using a large number of synthetic flavors and aromatic additives [1].

One of the main conditions for the functioning of the human body is the mandatory presence of essential nutrients in the diet, which must be taken into account when choosing food ingredients. Therefore, the issue of expanding the range of pasty products based on valuable raw materials and natural ingredients that improve not only organoleptic properties, but also increase the nutritional, biological value and benefits

of the product for the body. A promising direction for solving this problem is to improve the technology of mousse products from shrimp and raw materials of animal and vegetable origin.

Shrimp, like all seafood, is a source of complete protein. The concentration of useful micro- and macronutrients in shrimp is ten times higher than in meat. Thus, shrimp contain sodium, potassium, phosphorus, sulfur, calcium, magnesium, iron, zinc, copper, manganese, iodine, fluorine, chromium, cobalt, nickel, molybdenum and others. Shrimp meat is also rich in vitamins: E, C, PP, B1, B2, B3, B6, B9, B12, A, H. Eating shrimp helps to reduce sensitization of the body and prevent allergic reactions [2]. Shrimp meat should be used in aquatic mousses in combination with various plant and animal components to create balanced nutritionally and biologically valuable products.

The purpose of the work is to improve the technology of multicomponent mousses based on aquatic organisms.

II. LITERATURE ANALYSIS

A significant part of the range of fish paste products is pate and paste, due to their nutritional properties and unique sensory characteristics. The attention of many scientists is focused on expanding the raw material base for the manufacture of pasty products, improving organoleptic and rheological parameters and replacing traditional raw materials [3-5]. Scientists have developed a functional pate based on freshwater fish with the addition of squid [4]. Known technology of fish pate from pike, bream, which additionally contains pumpkin, vegetable oil and algae [5]. According to the patent of the Russian Federation № 2512341 "Method of production of vegetable-fish pastes and pates from carp", known technology for the production of vegetable-fish pastes and pates from carp with the addition of pumpkin, onion and CO_2 extract of black pepper, CO_2 extract of garlic. In the patent of the Russian Federation № 2166873 "Pate" shows a method of obtaining vegetable and fish pâtés using chitosan, as a structurant, and the addition of CO_2 extracts of spices.

Fish pastes are made from herring, mackerel, salmon, culled for mechanical damage, as well as small fish species. Raw materials are used mainly in salt form [6, 7]. The technology of making such a paste from salted herring and salmon is given in the patent of the Russian Federation № 2537502 "Method of preparation of fish paste", which includes the preparation of fish raw materials (salting fish, filleting, washing) and auxiliary materials (butter, cheese, broccoli, bell pepper) carrots and laconus), chopping, packing. Also common are pasty products made from minced meat of fresh sea or ocean fish or minced fish [6, 7].

The most common pasty products are fish oils, creams, mousses. The peculiarity of these products is the combination of high nutritional value with a light, pleasant texture. Therefore, the selection of fat base (butter, oil, mayonnaise), available fish raw materials, their ratio to ensure the appropriate rheological and organoleptic characteristics are the subject of research of domestic and foreign scientists [6−8].

For the preparation of fish oils use fish species such as herring, mackerel, sardines (ivasi, sardinela, sardinops), food waste from salmon disassembly [6, 7]. The technology of cooking " Delikatesne " and " Novynka " oils, which include boiled and

frozen krill meat and salted pollock caviar [6, 7], has been developed. Good taste and delicate texture are inherent in shrimp oil, which is prepared from protein paste "Ocean" or krill meat and butter. Shrimp oils have a pink-cream or pink color, pleasant taste and aroma, delicate texture [6, 7].

Due to their attractive appearance, light, airy consistency, high nutritional value and unique taste and aroma properties, creams and mousses from aquatic organisms deserve the attention of discerning consumers. There are recipes for Scottish fish cream, which, in addition to skimmed haddock fillet, includes milk, butter, eggs, fresh wheat bread, salt, pepper, flavoring (with the taste of shrimp or parsley) and some other components [6, 7].

N. M. Kupina and M. V. Kudriashova developed a technology for preparing low-salt creamy product from aquatic organisms (fish, squid, octopus, bivalves and gastropods), which is given in the patent of the Russian Federation № 2040189 "Method of preparation of low-salt creamy product from hydro". Known technologies of fresh salmon mousse with shrimp, fresh haddock meat with shrimp and smoked haddock meat. Which include at least 40.0% of fish meat with mayonnaise and bechamel sauce [6, 7].

Despite the wide world range and experience in the production of pasty products, their production in our country remains problematic. Modern technologies for the production of these products are based on the use of fish raw materials and a large number of synthetic flavoring and stabilizing additives. Therefore, an important task is to expand the range of pasty products based on crustaceans.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of research − indicators of quality of finished products.

The subject of research − technology of making shrimp mousse.

Determination of organoleptic parameters has been carried out by the profile method using a 5-point scale, according to the recommendations of T.M. Safronova.

The ultimate shear stress was determined using a penetrometer Ulab 3-31 M, in accordance with GOST 30469 – 95. Water activity index was measured using a highly sensitive device Hygro Palm HP23-AW (UK), according to DSTU ISO 21807.

Studies of the chemical composition have been performed according to the following methods: mass fraction of moisture – by drying the product sample to a constant weight in an oven SNOL (Labimpex LTD, Ukraine) at a temperature of 100-105ºC according to DSTU 8029:2015; mass fraction of ash – by a weightning method, after the mineralization of a portion of the product in a muffle furnace SNOL (Labimpex LTD, Ukraine) at a temperature of 500−600°C according to DSTU 8718:2017; mass fraction of lipids – by the Soxhlet extraction-weight method according to DSTU 8718:2017 on the SOX 406 Fat Analyzer (Hanon Instruments, China); mass fraction of protein – by Kjeldahl method of the determination of a total nitrogen, which is based on the ability of organic matter of the product sample to be oxidized with concentrated sulfuric acid in the presence of a catalyst according to DSTU 8030:2015, while samples ashing has been performed on a DK6 digester (Velp Scientifica, Italy), with a vacuum pump JP, distillation has been carried out on a steam distillation apparatus UDK 129 (Velp Scientifica, Italy).

The acid number of lipids was determined according to DSTU 4350: 2004 (ISO 660: 1996, NEQ), DSTU 4560: 2006. Peroxide number of lipids, according to DSTU 4570: 2006, DSTU 4560: 2006. The total volatile basic nitrogen according to GOST 7636– 85.

The number of mesophilic aerobic and facultative anaerobic microorganisms was determined in accordance with DSTU 8446: 2015; bacteria of the Escherichia coli group, according to DSTU GOST 30726: 2002; Staphylococcus aureus, according to GOST 10444.2-94; pathogenic microorganisms, including genus Salmonella, according to DSTU ISO 11290-1, DSTU ISO 11290-2.

Shelf life was determined by the dynamics of changes in the complex of organoleptic, physicochemical and microbiological indicators.

IV. RESULTS

The objects of the study were shrimp-based mousses with the addition of animal (milk cream, cream cheese) and vegetable raw materials (olive oil, apples, avocados). The control was selected mousse based on minced cod without the addition of plant ingredients. Recipes for mousses are given in table 1.

Table 1. Comparative characteristics of the prescription composition of control and experimental samples of mousses

Name of ingredients	**Ingredient content**, %			
		Experimental samples		
	Control	**№1**	**№2**	**№3**
Shrimp meat	35	47	52	62
Minced cod fish	40	-	-	-
Minced trout is slightly salty	-	42	-	-
Cream cheese	15	-	-	24
Cream	-	-	-	12
Avocado	-	-	22	-
Apple	-	-	15	-
Stone salt	0,8	1,2	1,2	1
Garlic	-	0,6	-	0,8
Olive oil	-	8	9	-
Egg yolk	3,6	-	-	-
Water	3	-	-	-
Xanthan gum	0,25	-	-	-
Carob gum	0,15	-	-	-
Aroma of shrimp	0,05	-	-	-
Paprika	0,15	0,6	0,4	0,1
Ground black pepper	0,2	0,6	0,4	0,1

The prescription composition of mousses determines the appropriate organoleptic characteristics. In particular, the color of mousses depends on the use of vegetable raw materials. Avocado gave a green tint in sample №2.

Flavor and aroma indicators are improved by spices and vegetable cheese, which was added by us according to recipes. Adding black pepper, paprika and garlic adds spiciness and originality to the taste.

Differentiated organoleptic analysis of mousses allows to establish the assessment of the intensity of individual quality indicators and to present the results in the form of a profilogram.

Comparison of the obtained samples of mousses with the help of a quality polygon is shown in fig. 1. Organoleptic evaluation of shrimp-based mousses was performed on the following indicators: external appearance, color, consistence, taste, aroma.

It is clear that the developed samples of mousses differ in organoleptic evaluation. According to the results of organoleptic evaluation, sample №3 is the best, because its area is the largest, and control - the smallest.

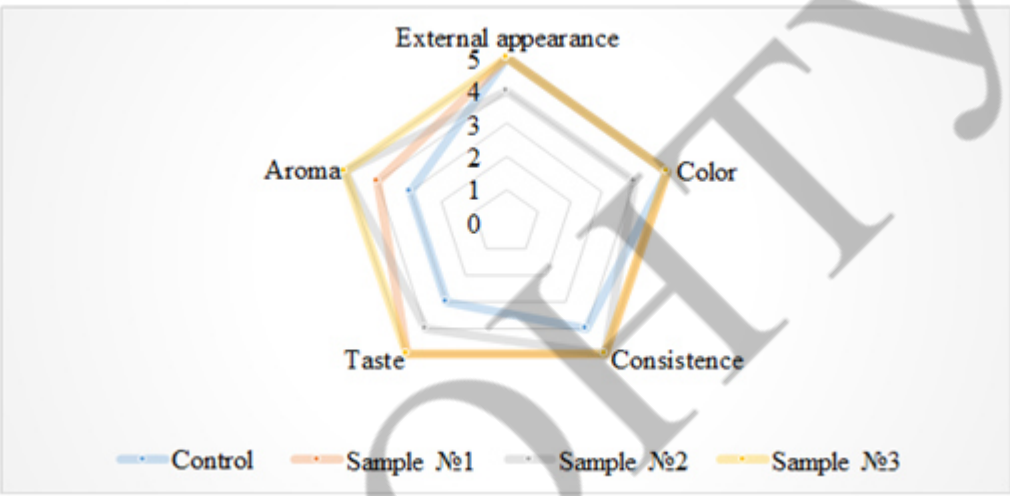

Fig. 1. Organoleptic evaluation of mousse samples

Relevant organoleptic characteristics were confirmed by the results of physicochemical parameters. Thus, the salt content in the control is 2.5%, and in test samples 1 and 2 is 2.3%, which corresponds to the norm of 1.5-2.5%, according to the requirements of the standard. To assess the consistency of the mousse, penetration measurements were performed and the shear stress was determined.

The measurement results are given in tabl. 2.

Table 2. Maximum shear stress of mousses (n = 3, p ≤0.05)

Name of samples	**Maximum shear stress, Pa**
Control sample	254,0
Sample №1	196,3
Sample №2	208,3
Sample №3	196,0

The results of the studies are shown in tabl. 2 show that the control sample is characterized by the highest value of the shear stress - 254 PA and, accordingly, has the densest structure compared to the developed samples. Sample №1 has a limit voltage of 196.3 Pa, sample №2 - 208.3 Pa, sample №3 - 196 Pa.

One of the important physical and chemical indicators is water activity. This indicator determines the resistance of the product to damage. The higher the activity of water, the more favorable conditions for the reproduction of microorganisms, the

higher the damage to the product by pathogenic microflora. According to this indicator, you can determine how perishable the product is, or vice versa. The activity of water in the finished product is shown in tabl. 3.

Table 3. Mousse water activity

Name of samples	Water activity	Microorganisms that can develop
Control sample	0,967	Bacteria, mold, yeast
Sample №1	0,989	
Sample №2	0,981	
Sample №3	0,979	

According to tabl. 3, we conclude that shrimp mousses are perishable products, as the rate of water activity in shrimp mousses is high. The range of such values suggests that the product is a favorable environment for the development of microorganisms (bacteria, mold, yeast).

The main indicator of nutritional value is the chemical composition. The results of studies of the general chemical composition of formulations are given in tabl. 4.

Table 4. General chemical composition of recipes

Name of samples	Chemical composition, %			
	moisture	fat	protein	carbohydrates
Control sample	50±2,0	44±0,2	5±0,7	0,5±0,1
Sample №1	64,5±1,5	7,5±0,2	18,7±0,7	0,4±0,1
Sample №2	67,25±2,25	9,95±0,2	15,7±0,7	3,63±0,1
Sample №3	66,89±2,1	12,3±0,2	16,6±0,7	1,48±0,1

From the tabl. 4 shows that the highest moisture content in the recipe of sample №2, and the lowest in the control sample, the highest fat content in the control sample, and the lowest in the recipe №1, the protein content is highest in sample №1, and the lowest in sample №2, the highest carbohydrates the content in the recipe №2, in the control and sample № 1 the carbohydrate content is minimal.

The chemical composition determines the caloric content of the product, which is presented in fig. 2.

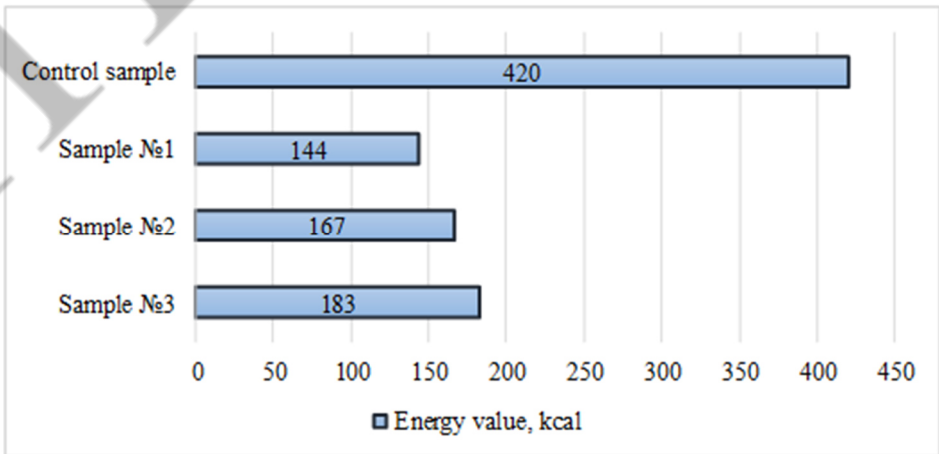

Fig. 2. Comparative characteristics of the energy value of mousse recipes

It is estimated that the energy value of the control sample exceeds the experimental ones, due to the fact that the bulk of the control formulation consists of butter and cream. Experimental samples have a much lower energy value, but the benefits are much greater, due to the high content of complete protein, the source of which is shrimp meat.

Based on the results of theoretical and experimental research, a technological scheme for the production of shrimp mousses has been developed, which is presented in fig. 3.

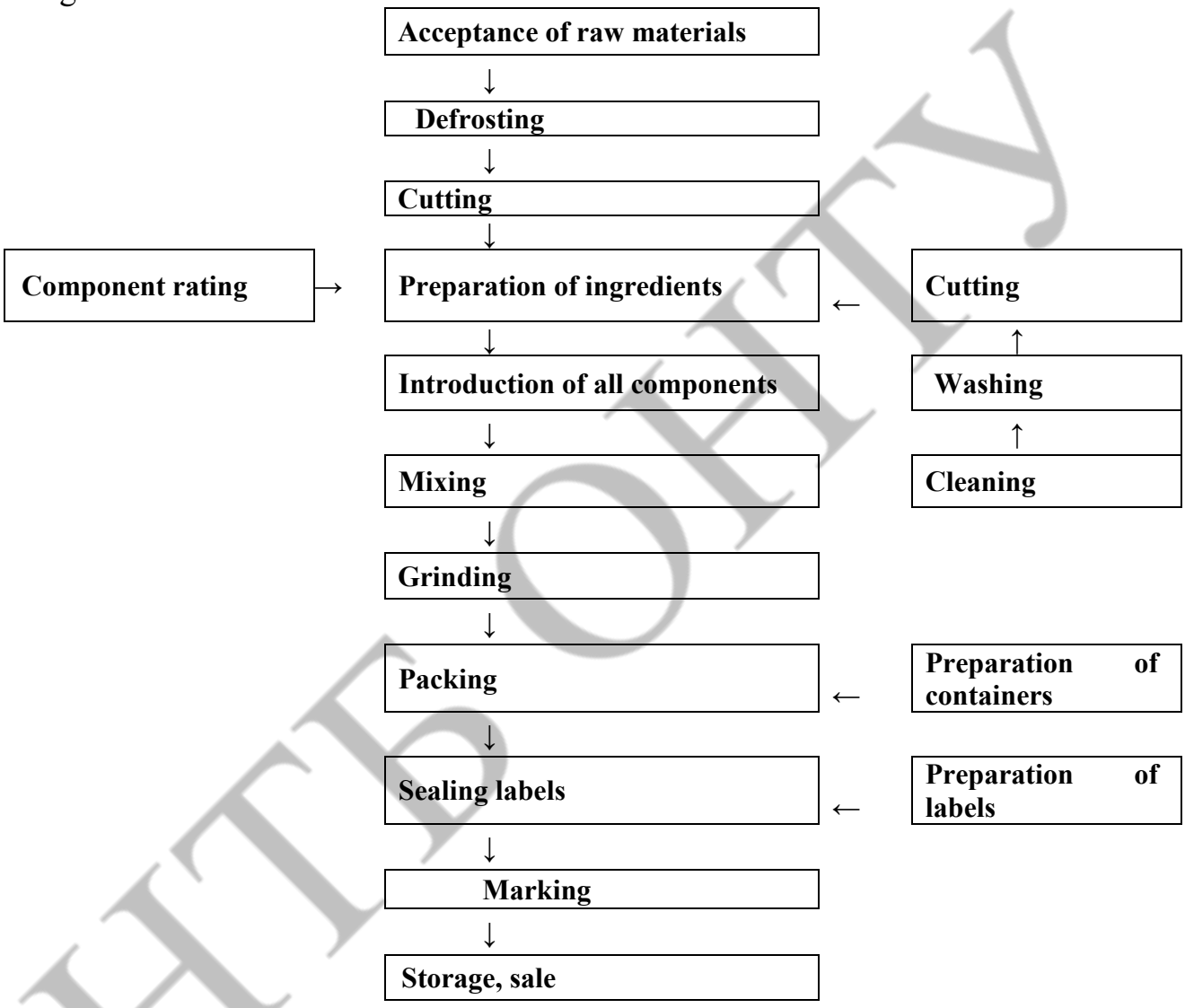

Fig. 3. Technological scheme of mousse production

The main technological operations are the preliminary preparation of fish and vegetable raw materials, which consists in washing, cleaning, grinding. The prepared ingredients are mixed in the appropriate recipe ratio, subjected to fine grinding and packing the mixture into molds. Store the finished product at temperatures from -2 to +2 ^{o}C for no more than 72 hours from the date of manufacture.

Food quality is a set of product properties that determine its suitability to meet certain needs in accordance with the purpose. The quality of any food product is determined by its characteristic properties, which are called quality indicators.

The results of studies of organoleptic characteristics of the product during storage for 72 hours are shown in fig. 4.

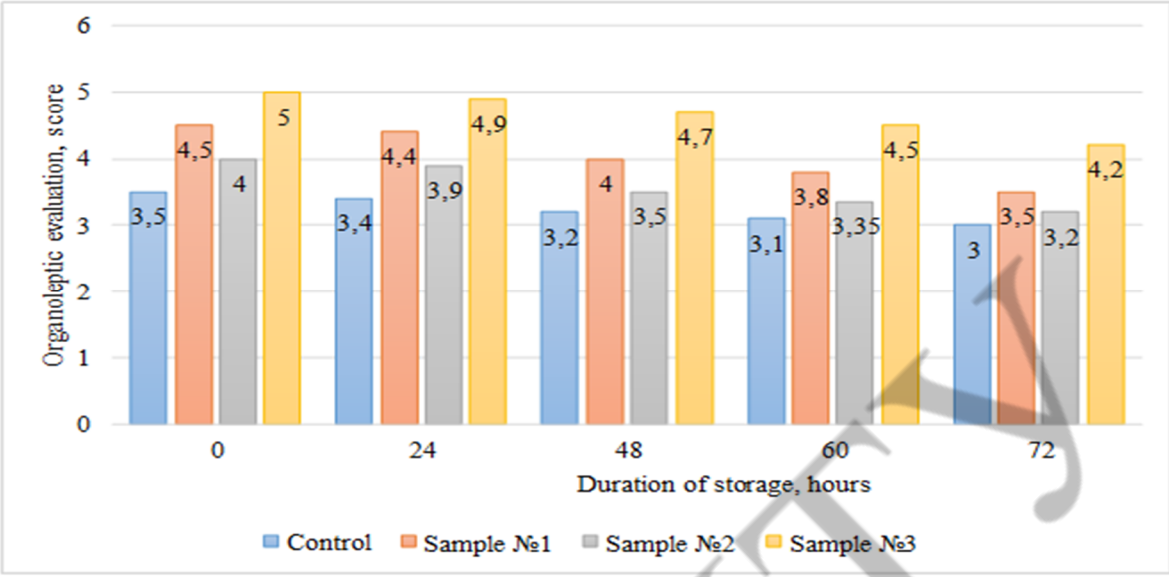

Fig. 4. Organoleptic evaluation of shrimp mousses during storage

Fig. 4 shows that gradually during storage mousse products reduce their organoleptic characteristics.

Acid and peroxide values are important indicators that must be determined during storage. Acid number is the amount of caustic potassium required in milligrams to neutralize free fatty acids. The acid number depends on the quality of raw materials used for production, methods and modes of its production, conditions and duration of storage of the product. The presence of lipid oxidation processes in the initial stages characterizes the peroxide value. Fig. 5 and 6 show the changes in peroxide and acid numbers during storage.

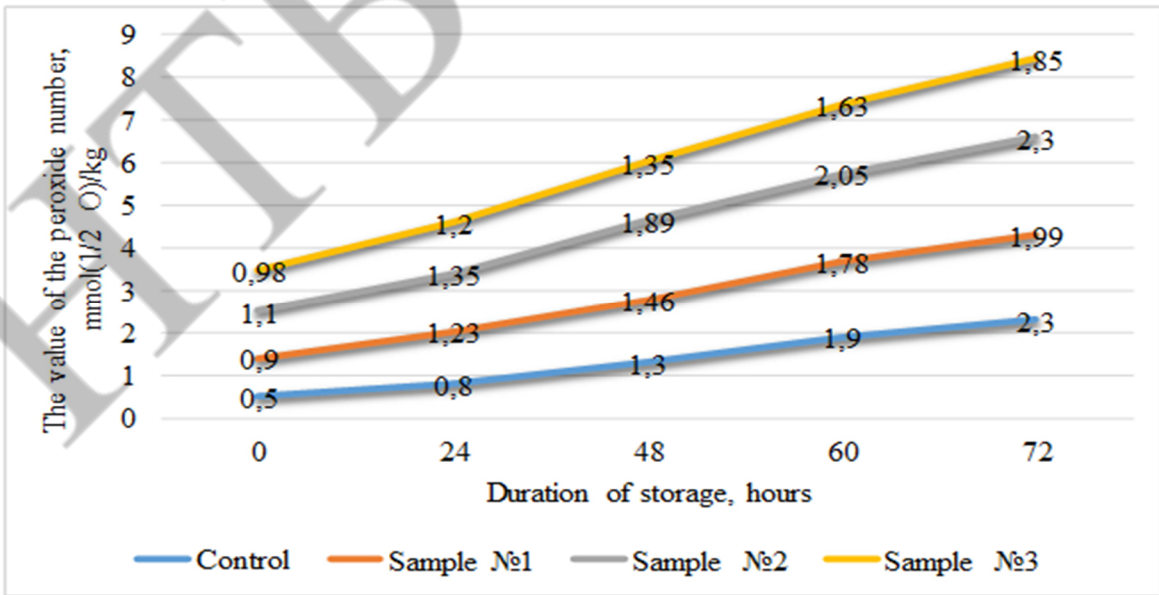

Fig. 5. Dynamics of lipid peroxide values in shrimp mousses

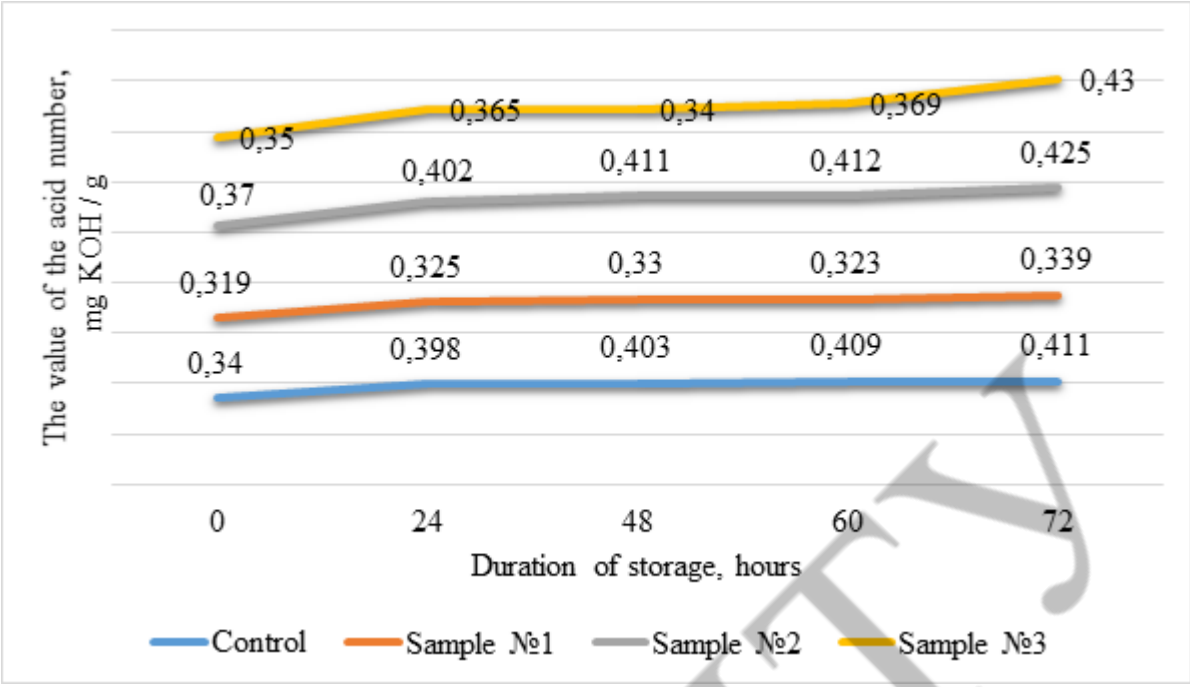

Fig. 6. Dynamics of lipid acid counts in shrimp mousses

In fig. 5 and 6 we can see that the indicators of acid and peroxide numbers during storage gradually increase, but these indicators, even at the end of the storage period are within acceptable limits.

The degree of microbiological processes and proteolysis was studied by changes in the total volatile basic nitrogen contents (TVBN). The total volatile basic nitrogen contents bases increases during storage under the action of enzymatic processes and the activity of microorganisms and is accompanied by the breakdown of amino acids to form ammonia, mono-, di- and trimethylamines.

The dynamics of TVBN content during storage is shown in fig. 7.

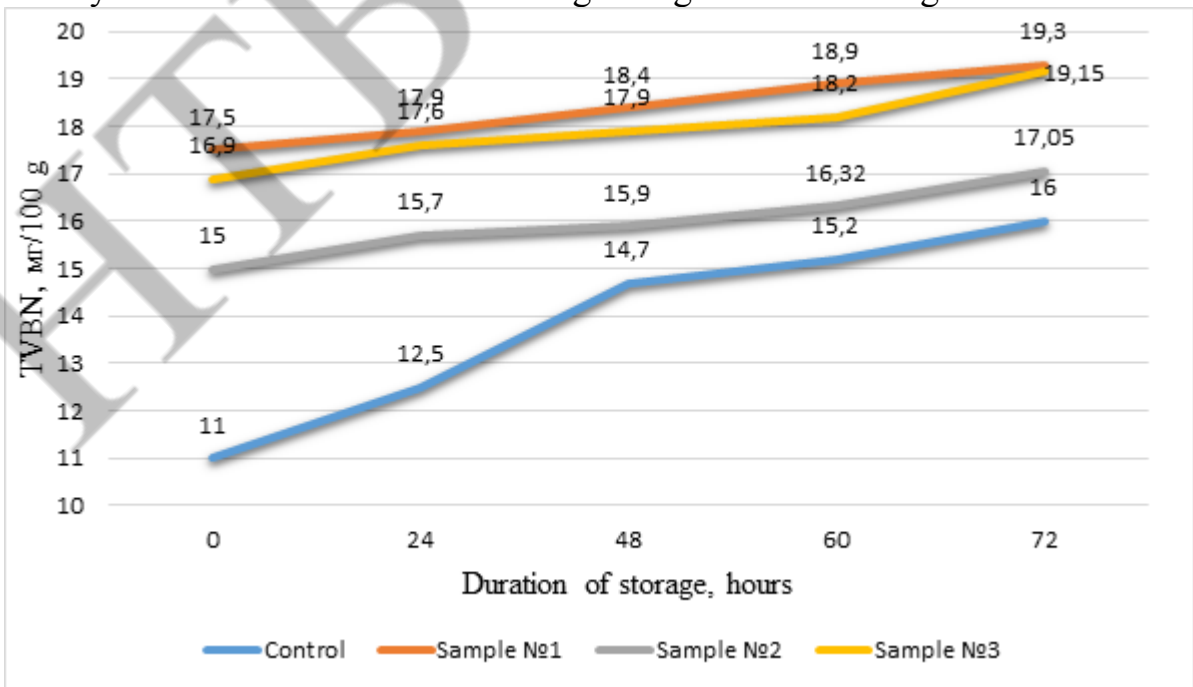

Fig. 7. Changes in TVBN indicators during mousse storage

Fig. 7 shows that at the expiration date of the product, ie after 72 hours, the content of TVBN in the control sample 16 mg %, in sample №1 − 19.3 mg %, in sample №2 − 17.05 mg %, in sample № 3 - 19.15 mg g % at the permissible level of 30 mg %.

The quality and safety of shrimp mousses were determined according to microbiological quality indicators. The state of the microbiological composition of shrimp mousses directly depends on the initial state of the microflora of raw materials, on the microbiological and sanitary condition of equipment and the enterprise as a whole, on compliance with sanitary norms of employees.

The results of research show that at the initial stage of storage, sample №2 is characterized by a higher degree of microbiological contamination compared to other samples, due to the addition of vegetable raw materials to the product. When storing mousses for 24 hours, the number of microorganisms increases in all samples. In sample №3 the amount of mesophilic aerobic and facultative anaerobic microorganisms (MAFAnM) is less than in other samples, due to the bactericidal properties of garlic. As of 72 hours of mousse storage, MAFAnM values are acceptable for product suitability, but close to the limit. Bacteria of the Escherichia coli group, Staphylococcus aureus and Proteus were not detected in 0.1 g of test samples. Pathogenic microorganisms, including Salmonella and L. monocytogenes, were absent in 25 g in all mousse samples.

Therefore, based on microbiological and organoleptic parameters, the allowable shelf life at a temperature of 0 to + 5◦C for mousses is not more than 72 hours.

V. CONCLUSIONS

Based on the results of theoretical and experimental research, the recipe and technology of shrimp-based mousses with the addition of animal (milk cream, cream cheese) and vegetable raw materials (olive oil, apples, avocados) have been improved.

A study of organoleptic, physicochemical, quality indicators and chemical composition of finished products. Based on the research results, the compliance of the indicators with the requirements of the standard has been established. According to organoleptic indicators, the highest score was obtained by sample №2. The salt content in the test samples and control corresponds to the norm - 1.5-2.5%. All samples have the appropriate mousse consistency, and the value of the shear limit stress of the control sample (254.0 Pa) exceeds this indicator of the experimental samples (196.0−206.3 Pa), which indicates a denser control structure compared to the developed samples. High values of water activity index (0.967-0.989) confirm that shrimp mousses are perishable products. Analysis of the results of research on the chemical composition shows that the experimental samples of mousse are characterized by high nutritional value due to the significant protein content.

The technological scheme of mousse production has been developed, which includes preliminary preparation of raw materials, fine grinding of the mixture and packing of the finished product.

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IMPROVEMENT OF RYE-WHEAT BREAD TECHNOLOGY BY APPLYING SUSPENSION NANO SUPPLEMENT

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Abstract. *Due to improving the rye-wheat bread technology with the functional and technological properties of suspension nanodrains supplements the samples of baked rye-wheat bread with a mass fraction of suspension nanodrains supplement 0.1%; 0.15% is used for the research; 0.2% by weight of raw materials, which is introduced in the form of a fatty suspension when kneading the dough in the technological process of rye-wheat bread. To determine the organoleptic (on a 5-point scale, taking into account the weighting coefficient of each indicator), technological, physico-chemical (titrated acidity, mass of moisture content, specific volume, porosity), microbiological (microbial contamination: mesophilic aerobic and optional anaerobic microorganisms (KMAFanM, CFU / g), the presence of bacteria of the Escherichia coli group (BGKP (coliforms), 0.001 g), detection of Staphylococcus aureus, Proteus and other pathogenic microorganisms (pathogenic microorganisms, including bacteria of the genus Salmonella 25 d), etc.), structural and mechanical (elasticity,%; modulus of elasticity E, Pa; shrinkage, %,) indicators are used generally accepted and standard methods.It is found that the introduction of suspension nanoadrains supplement in the amount of 0.1%; 0.15%; 0.2% by weight of raw materials helps to improve the organoleptic quality of rye-wheat bread, gas-holding capacity and loosening of the dough, reducing the duration of fermentation of dough masses by (10±4,0) minutes and aging of semi-finished dough products by (15±2,0) minutes (due to the ability of CNS nanoparticles to intensify biochemical processes).*

It is found that the highest rates were characterized by bread samples with a mass fraction of suspension nanodrains supplements of 0.1%.

Adding a suspension nanodrains supplements to the recipe of rye-wheat bread increases the specific volume by 1.18-1.22 times, the porosity of the crumb by 1.28-1.32 times, the yield of the finished product by 5-6%; reduces crumbs by 1.42 times. During the regulated shelf life, the process of reducing the porosity, shape stability and specific volume of bread slows down compared to the control.

The established microbiological parameters of rye-wheat bread using 0.15% suspension nanodrains supplements for 36 hours meet the requirements of regulatory documentation and indicate its high sanitary-microbiological characteristics.

The recipe was developed and the technological scheme of rye-wheat bread production was developed with the introduction of 0.15% suspension nanoadditive.

The recipe and the technological scheme of rye-wheat bread production is developed with the usage of 0.15% suspension nanoadrains supplements.

The scientific novelty is to study the effect of suspension nanodrains supplements on the organoleptic and microbiological properties of experimental samples of rye-wheat bread, including the storage term.

The practical significance is that its results can be used to develop technologies for the rye-wheat bread production with improved quality, safety and extended shelf life.

Key words: *formulation, suspension nanodrains supplements, functional-technological properties, quality.*

I. INTRODUCTION

One of the directions of development of innovative bakery products technologies is the usage of food additives-enrichers and improvers that allow to adjust the functional and technological properties of flour - the main raw material of flour products; to increase consumer properties and to prolong the preservation of freshness of finished products [1-5].

Bread makes up a significant share of the daily ration of Ukrainians [1-3], so its quality must meet all medical and biological requirements. These indicators depend on a number of factors, the main of which is the quality of the main and additional raw materials used in the production of bread [2-4]. The industry processes up to 50% of the total volume of flour with reduced properties [3], large bakeries use non-stop technology, which has a number of disadvantages, including those that affect the quality of bread [4].

In recent years, technologies with the use of various food supplements have been developed to form the necessary functional and technological properties of flour and dough masses. The need for these innovations is due to:

- the spread of single-phase accelerated methods of dough preparation;
- instability of the quality of flour and raw materials;
- expanding the range of flour products;
- improving the quality of finished products;
- increasing the nutritional value of flour products;
- increasing resistance to microbial and oxidative spoilage;
- extending the shelf life of flour products [6].

Improvers are natural or synthetic substances that are introduced into the recipe of bakery products and allow to regulate the functional and technological properties of raw ingredients (especially flour) and dough. They are used to intensify the technological process of bread production, enhance the aroma and color of the finished product, improve the structure and properties of the crumb. Today an important task in the bakery industry is the search for non-traditional raw materials, the structural components of which will not only intensify the biotechnological processes of flour production, but also improve the chemical composition and quality of finished products, have an economic effect. The intensity of biotechnological processes in bread production depends on the quality of rye and wheat flour, rye sourdough and yeast used. The quality of rye sourdough depends on many factors, but to a greater extent on the composition of the nutrient medium in which the cultivation of this semi-finished product. One of the ways to improve the composition of the nutrient medium for the cultivation of rye yeast is the introduction of biologically active supplements [2, 3, 5].

Therefore, to improve the technology of flour products, in particular, bakery, of practical interest is the use of supplement-improvers, supplement-concentrators, biologically active supplements, including nanometer size. This contributes to the improvement of biotechnological indicators of the quality of sourdough, rye-wheat dough, intensification of the technological process, improving the quality of flour products. The urgency and expediency of the paper is due to the lack of long-term bakery products on the Ukrainian market that do not contain chemical preservatives, insufficient satisfaction of the population's needs in bread products for therapeutic and prophylactic purposes [4, 5]. Therefore, in modern conditions, solving the problem of preserving the quality and consumer properties of rye-wheat bread in the process of sale and storage is relevant, and the search for areas that provide high quality organoleptic, technological, microbiological and physico-chemical indicators is an important task.

II. LITERATURE ANALYTICAL REVIEW

To improve the functional and technological properties in the bakery products production used food supplements of various origins: modified starches, enzymes, seeds, bran, whey and other improvers [14-17].

The authors [17, 18, 20-39] have made a significant contribution to the development of innovative technologies and the formation of the range of bakery products in the market.

Analytical review of literature sources [13-17] reveals a positive effect of dairy supplements on the properties of the dough and the quality of bread. Milk and dairy products contain complete proteins, milk fat and sugar. The most promising protein used in baking bakery products is skimmed milk powder and whey powder. But due to the high cost of these raw materials, their usage becomes economically impractical.

Valuable for bread products are products of soybean processing, sunflower seeds and cotton [39]. Soy flour contains up to 50% protein and 5-6% minerals. Soy protein has a valuable amino acid composition. Soybeans contain: 0.22% calcium, 0.69% phosphorus, 2.09% potassium and other minerals [15, 19, 29, 30, 33]. But 80% of soy is a genetically modified product. Therefore, the use of soy flour has some caveats.

Algae and chickpea technologies are known to improve the quality of bread [2, 3, 24, 25], but they have a negative effect on quality: dough elasticity, moisture and acidity of the crumb, shape stability, yield of the finished product.

The biological value of bread is small, but when consumed in the amount of 500 g of flour of the first or higher grades, the body receives from 21 to 64% of the daily requirement of vital amino acids. Baked bread without improvers does not contain such essential amino acids as lysine, methionine, leucine, isoleucine, phenylalanine, threonine, tryptophan and valine. Person almost completely covers the needs of iron through bread products (receives a significant proportion of manganese and phosphorus). A significant disadvantage of the mineral complex of bread is the low content of calcium and its unfavorable ratio with phosphorus and magnesium. Bread does not contain enough potassium, chromium, cobalt and some other elements. Therefore, increasing the mineral value is also an urgent problem [15, 16, 29, 30].

Analysis of recent research and publications [19, 20, 27-39] has shown that improving bread production technology is necessary to create an innovative product with specified functional and technological properties, because the consumption of such bakery products can increase the biological, physiological and nutritional value of various rations. Flour products are polyphase dispersed systems. Stabilizers are used to increase their stability (especially during technological processing and storage). A promising direction is the use of nanodrains supplementgs with stabilizing action [6, 39].

However, the use of bread improvers and food supplements in bread technology must meet sanitary, medical and biological requirements. In this regard, it is important to introduce into the recipe of the flour product (for example, rye-wheat bread) suspension nanoasupplements (SNS) - to form the necessary functional and technological properties of flour and dough and improve the consumer properties of the finished product. This is due to the ability of SNS nanoparticles to create sufficiently stable polyphase dispersed systems (including emulsions, suspensions) due to the "Pickering effect"; high ζ-potential 34… 44 mV; structural and mechanical stability factor associated with the complexing and electrostatic action of SNS nanoparticles, which leads to the spatial structuring and stabilization of polyphase dispersed systems of dough masses. In addition, the SNS is characterized by complex action: antioxidant, bacteriostatic, hydrating, thickening, water- and fat-retaining, fat- and water-binding properties [7-9, 11, 12, 38].

III. OBJECT, SUBJECT AND METHODS OF RESEARCH

In order to improve the technology of bakery products, participants of the educational-research-production cluster "Complete nutrition: energy-efficient production, storage and marketing" formulated a task - to work out a recipe for rye-wheat bread, which would contain ingredients to improve the quality of finished products.

Requirements for the product were: extended shelf life, esthetics, high biological, physiological and nutritional value.

Subject of research - suspension nanodrains supplements (in the form of fat suspension), samples of baked rye-wheat bread with a mass fraction of suspension nano supplements 0.1%; 0.15%; 0.2% by weight of the prescription mixture.

The object of research is the technology of rye-wheat bread.

Research methods: experimental research, organoleptic, microbiological and microscopic.

In the process of performing experimental work, standard and generally accepted research methods are used [7, 12].

The method of experimental research is used to confirm theoretical positions in practice.

Organoleptic research methods are used to confirm the expected results of organoleptic quality indicators of the finished product.

Microbiological and microscopic studies are performed to confirm the safety of the finished product during the guaranteed shelf life (36 hours).

The mass fraction of moisture is determined by thermogravimetric method of drying a portion of bread to constant weight at constant temperature. The yield of bread product - by weight. The study of the adhesive strength of the dough is based on the method of uniform separation from the steel surface. The acidity of the dough and bread is determined by titrimetric method. The structural and mechanical properties of the dough are investigated using a Brabender farinograph; the maximum shear stress is on the Labor penetrometer. IBE (microbiological indicators) were determined by: KMAFanM - according to GOST 10444.15, Escherichia coli bacteria - according to GOST 30518, Staphylococcus aureus - according to GOST 10444.2, pathogenic microorganisms, including bacteria of the genus Salmonella - according to DSTU according to DSTU ISO 6579: 2006 GOST 10444.12. The presence of bacteria was determined according to GOST 10444.15-94, GOST 10444.8-88, GOST 29185-91.

To assess the organoleptic characteristics of bread, a scale is compiled taking into account the weights and scores of the products. The analysis of bread samples is carried out by the Tasting Commission of the Department of Food Technology, Light Industry and Design of the Ukrainian Academy of Engineering and Pedagogy and the Tasting Commission of the Department of Technical and Logistics of the National Academy of the National Guard of Ukraine.

The use of such a wide range of methods determines, firstly, a fairly high validity and reliability of the results, and secondly, forms a rich array of primary scientific material, so the conclusions and results are objective.

IV. RESULTS

Scientists of leading universities of Ukraine within the cooperation of the educational-research-production cluster "Nutrition: energy efficient production, storage and marketing", which includes the Ukrainian Engineering and Pedagogical Academy and the National Academy of the National Guard of Ukraine, developed an innovative product - bread rye-wheat, which contains a functional ingredient - a suspension nano supplements. It is an supplement-improver based on double iron oxide (FeO Fe2O3), which has great potential and carries a wide range of new functional and technological properties and promising technological applications. It should be noted that most nanomaterials used in food products occupy an intermediate position between nano- and microstructures. Thus, the diameter of DNA is 12 nm, liposomes 30 ... 10000 nm, amylopectin 44 ... 200 nm, cubosomes 500 nm, nanosensors <1000 nm. Nanobiotechnology is one of the most actively developing areas of modern nanoscience and in recent years has attracted more and more attention from researchers in various fields of chemistry, physics, biology, biochemistry, medicine and engineering. Nanobiotechnology can potentially affect many aspects of food technology. Food safety and quality, means of delivery of biologically active components, new materials for pathogen detection and environmental protection are the main areas of application of nanomaterials in food products [7-9, 11, 12, 38].

Nanoparticles of suspension nano supplements have a complex action and high bioavailability to biopolymers, in particular, proteins, carbohydrates. Therefore, they have new functional and technological properties and promising technological applications. Noncovalent adsorption of polymer molecules and H2O dipoles occurs

on the surface of magnetic nanoparticles of suspension nano supplements. The process of adsorption of biopolymer food ingredients and water is determined mainly by ionic, vanderwaals, hydrogen and hydrophobic interactions. These interactions occur between the surface of nanoparticles and adsorbent molecules and entail a change in the free Gibbs energy. The result is the formation of supramolecular ensembles that significantly affect the functional and technological properties of raw materials (eg, flour) and semi-finished products (eg, dough), as well as the quality of finished products [7-9, 11, 12, 38].

In previous studies [7-9, 11, 12, 38] it is found that suspension nanosupplements in the formulation of food products leads to a comprehensive improvement of their consumer and functional-technological properties. Thus, SNS nanoparticles have bacteriostatic and antioxidant properties, promote better digestion of protein components of food, have moisture-, fat-retaining and fat-emulsifying effect, are a source of easily digestible iron, promote metabolic processes.

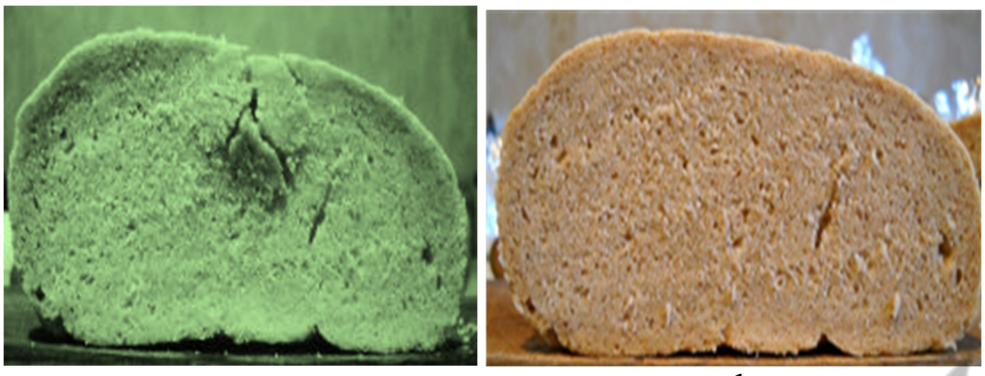
Table 1 shows the recipes of rye-wheat bread with the introduction of 0.1%; 0.15%; 0.2% of suspension nanosupplements- SNS (in the form of fat suspension) to the weight of raw materials (experiment) and control (bread "Darnytsky").

Table 1 - Recipes for rye-wheat bread "Darnytsky" (control) and rye-wheat bread with the adding of the SNS (experiment)

Title of raw materials	Consumption of raw materials, kg			
	Prototypes (samples) of rye-wheat bread			
	Sample 1 – control	Sample 2 – with 0,1% SNS	Sample 3 – with 0,15% SNS	Sample 4 – with 0,2% SNS
Wheat flour	40,0	40,0	40,0	40,0
Peeled rye flour	60,0	60,0	60,0	60,0
Pressed baker's yeast	0,5	0,5	0,5	0,5
Solt	1,4	1,4	1,4	1,4
SNS fat suspension	–	0,2	0,3	0,4
Total	101,9	102,1	102,2	102,3
The output of bread, %	138,4	143,0	144,1	144,3

For distribution and functioning of nanoparticles of suspension nanosupplements (SNS) by volume of dough mass SNS is introduced in the form of a fat suspension when kneading dough in the technological process of rye-wheat bread in the amount of 0.2 kg; 0.3 kg; 0.4 kg per 100 kg of raw material, equal to 0.1%; 0.15%; 0.2% SNS by weight of raw materials, respectively (see table. 1).

The mass fraction of suspension nanosupplement (SNS in bread is limited by its effect on quality and safety indicators (including organoleptic and microbiological indicators) of the finished product: providing unwanted foreign taste and darkening of bread crumbs with increasing mass fraction of nanosupplements. Previous research has established a massive share of SNS in food systems, which improves the quality of finished products. It is: 0.10%; 0.15%; 0.20% by weight of raw materials [7, 11, 12]. In fig. 1 and 2 is shown prototypes of rye-wheat bread and their organoleptic analysis, respectively.



a b

Fig. 1. Prototypes of rye-wheat bread: a - sample 1 - control, b - sample 3 - with 0.15% SNS

Fig. 1 shows that the prototype of rye-wheat bread with 0.15% SNS has better organoleptic characteristics compared to the control: the correct, oval shape; light brown color of the crumb, which is tender, finely porous, elastic; the surface of the crust - smooth, without swelling, cracks, explosions. This positive effect of the introduction of 0.15% SNS is confirmed by the data of Fig. 2.

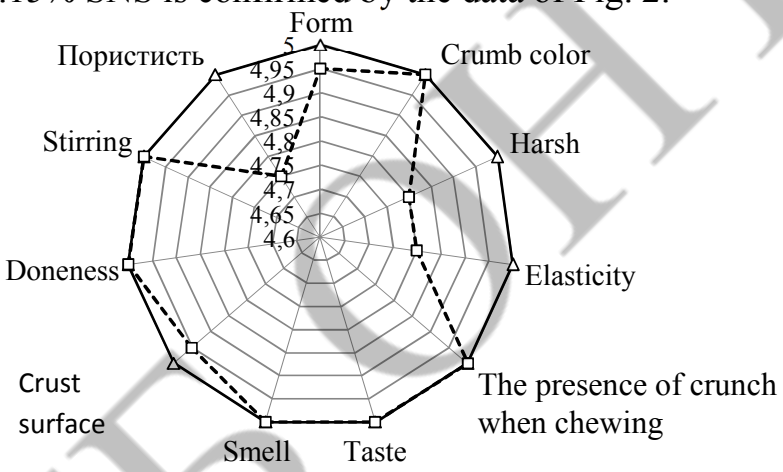


Fig. 2. Organoleptic parameters of samples of bread "Darnytsky" (control) and rye-wheat bread with 0.15% SNS

As can be seen from Pic. 2, the introduction of 0.15% SNS helps to improve the organoleptic quality of rye-wheat bread compared to the control - bread "Darnytsky".

Table 2 shows the results of organoleptic analysis of experimental samples of rye-wheat bread.

Table 2 - Organoleptic parameters (in points) of experimental samples of rye-wheat bread

Characteristics	Prototypes of rye-wheat bread			
	Sample 1 – control	Sample 2 – with 0,1 % SNS	Sample 3 – with 0,15 % SNS	Sample 4 – with 0,2 % SNS
From	4,8±0,1	4,9±0,1	5,0±0,1	5,0±0,1
Crust surface	4,9±0,1	5,0±0,1	5,0±0,1	5,0±0,1
Taste	5,0±0,1	5,0±0,1	5,0±0,1	5,0±0,1
Smell	5,0±0,1	5,0±0,1	5,0±0,1	5,0±0,1
Crumb color	4,6±0,1	5,0±0,1	5,0±0,1	4,9±0,1
Crumb porosity	4,7±0,1	5,0±0,1	5,0±0,1	5,0±0,1
Crumb elasticity	4,7±0,1	4,9±0,1	5,0±0,1	5,0±0,1
Crumb harsh	4,7±0,1	5,0±0,1	5,0±0,1	5,0±0,1

From the data of organoleptic analysis, the rational amount of suspension nanosupplements (SNS) - 0.15% by weight of raw materials.

Fig. 3 presents the technological indicators of experimental samples of rye-wheat dough, which shows that the humidity and acidity of the dough with the introduction of 0.15% suspension nanosupplements (SNS) meet the requirements of regulatory documentation. Improves gas holding capacity and loosening of the dough.

Table 3 - Technological indicators of the experimental sample of rye-wheat dough

Rye-wheat dough index	Prototypes of rye-wheat dough	
	Sample 1 – control	Sample 3 – with 0,15 % SNS
Moisture of the dough%	47,0±2,4	48,4±2,4
The acidity of the dough beg.,°	6,9±0,3	6,1±0,3
The acidity of the dough end.,°	7,8±0,4	7,1±0,3
Duration of dough fermentation, τ·60 s	55±5,0	45±5,0
Duration of dough aging, τ·60 s	60±3,0	45±2,0
Shear stress limit, Pa	445,0±22,0	494,0±23,7
Adhesion strength (steel), kPa	2,5±0,2	1,9±0,1
Plastic viscosity, kPa ·s (while γ=0,02 s^{-1})	7,0±0,3	9,2±0,4

This reduces the duration of fermentation of dough masses by (10±4,0) minutes and aging of dough semi-finished products by (15±2,0) minutes compared to the control due to the ability of nanoparticles of suspension nanosupplements (SNS) to intensify biochemical processes.

Also compared to the control increases: the maximum shear stress in 1.12 times; plastic viscosity 1.3 times (due to the ability of the SNS to form solvate and lipid complexes and stronger moisture and fat content in the structure of the product); decreases the adhesive strength (to steel) by 1.3 times (due to the reduction of free moisture in the dough by increasing the water holding capacity of the dough under the action of suspension nanosupplements).

In addition, the evaluation of the quality of experimental samples of rye-wheat bread was performed on physico-chemical parameters (Table 4).

Table 4 - Physico-chemical and technological parameters of experimental samples of rye-wheat bread

Rye-wheat bread index	Prototypes of rye-wheat bread	
	Sample 1 – control	Sample 3 – with 0,15 % SNS
Moisture of bread, %	47,5±2,4	48,0±2,4
Acidity of bread,°	7,5±0,4	7,2±0,3
Specific volume of bread, sm^3/g	1,8 ±0,1	2,2 ±0,1
Porosity of bread, %	58,0±2,9	75,4±4,0
Losses during heat treatment,%	9,8±0,4	3,7 ±0,1
Bread output, %	138,4±2,1	144,1±2,5

As can be seen from table. 4, moisture and acidity of bread using 0.15% suspension nanosupplements (SNS) meet the requirements of regulatory documentation. At the same time in rye-wheat bread from the SNS increases: the

specific volume of 1.18-1.22 times, the porosity of the crumb 1.28-1.32 times (due to the intensification of biochemical processes), the yield of 5-6 %; losses during heat treatment are reduced by 5-6% compared to the control (due to the stabilizing and water-holding capacity of the suspension nanosupplement).

According to the results of research, a technological scheme for the production of rye-wheat bread with the introduction of a suspension nanosupplement - SNS (Fig. 3). A distinctive feature of the new technology is the introduction of SNS in the form of a fatty suspension when kneading the dough.

The following rational technological parameters are determined: when kneading the dough, a portion of sourdough is mixed with yeast suspension, sugar-salt solution and water. Then add wheat flour and SNS fat suspension.

Mixing is carried out within (12-15) minutes. The dough matures (40-50) minutes at a temperature of (25-28) ° C. The acidity of the ripe dough is (7-8) Neumann's hail.

At the next stage, the dough is divided into pieces of a certain mass, rounded, placed in oiled forms and sent to the oven to stand for 45-50 minutes at a temperature of (30-32) ° C and relative humidity (75-80)%.

Baking of dough blanks is carried out in the oven at 4 temperature zones for 34 minutes: (230–240) oC - 7 minutes, (220–230) oC - 7 minutes, (210–220) oC - 13 minutes, (200–210) oC - 9 minutes.

Cooling and storage of bread after baking is carried out in a granary at a relative humidity of (70-75)% [7,11,12].

The quality of bread is assessed by microbiological safety indicators immediately after production and during the regulated shelf life; as well as the physical and chemical parameters and structural and mechanical properties of bread during storage.

In fig. 4. the technological scheme of rye-wheat bread production with the addition of suspension nanosupplement is presented.

In fig. 5 shows studies of shrinkage and elasticity of experimental samples of rye-wheat bread during the storage.

To determine the quality of rye-wheat bread with the introduction of suspension nanosupplements, the following indicators are studied: the ability of products to harden in terms of stability, specific volume, compressibility, shrinkage, elasticity, porosity, swelling, crumb crumbs.

As can be seen from Fig. 5, on the first day after baking the bread is almost stale; after 24 hours the shrinkage is: for control (3.3 ± 0.1)%, for bread with 0.15% CIS (1.2 ± 0.05)%, in addition, the shrinkage is practically preserved for the first 36 hours, on in contrast to the control, where it increases (2.2 ± 0.1) times. With increasing shelf life, the elasticity of bread samples decreases: after 36 hours for control by (4.5 ± 0.2)%, for bread with 0.15% SNS S only by (1.2 ± 0.05)%, ie much slower . This is due to the water and fat retention capacity of suspension nanosupplements (SNS)

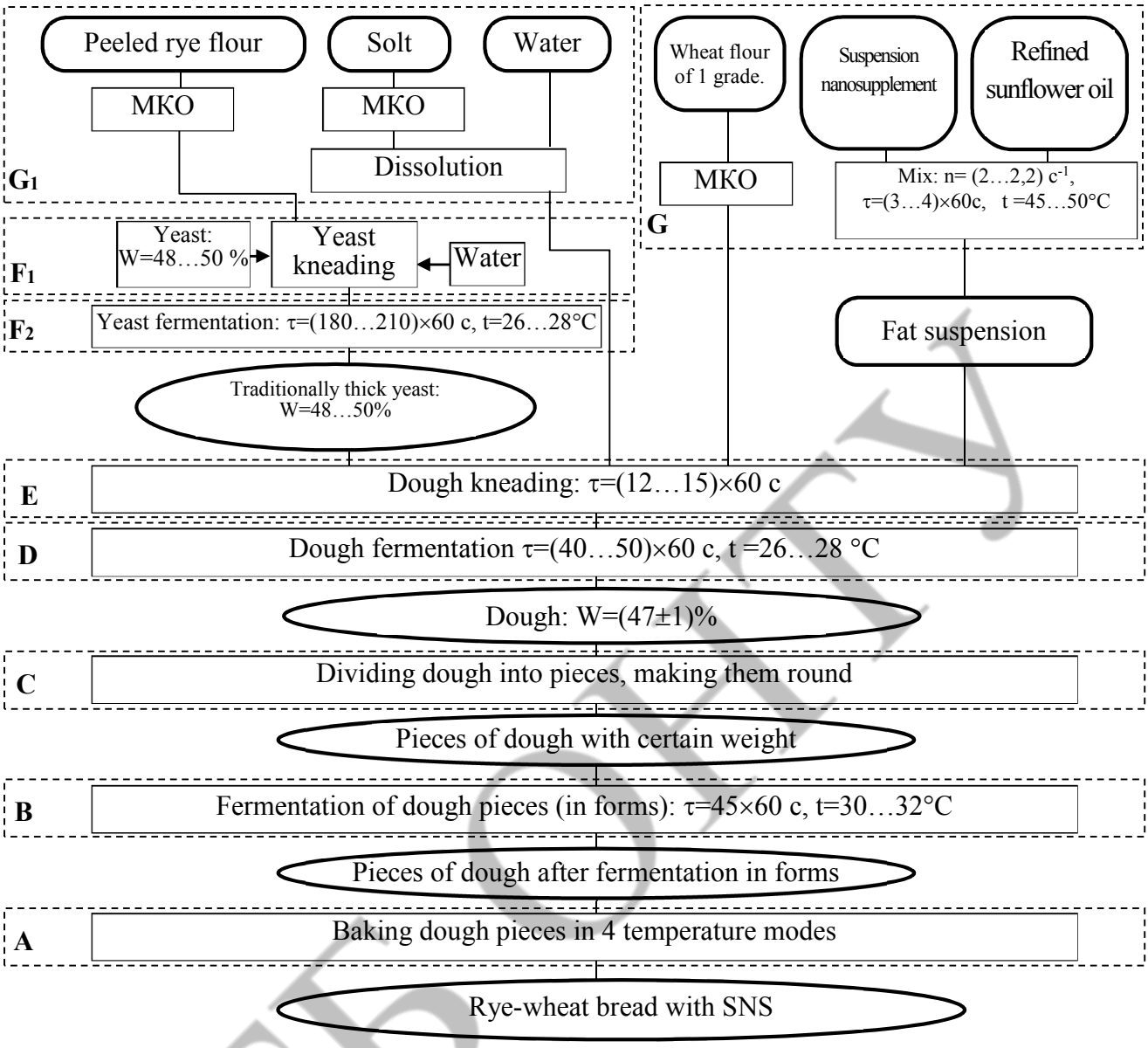


Fig. 4. Rye-wheat bread with SNS production technological scheme: D, E, F_1, F_2, G_1, G_2 – subsystems of the bread production technological scheme

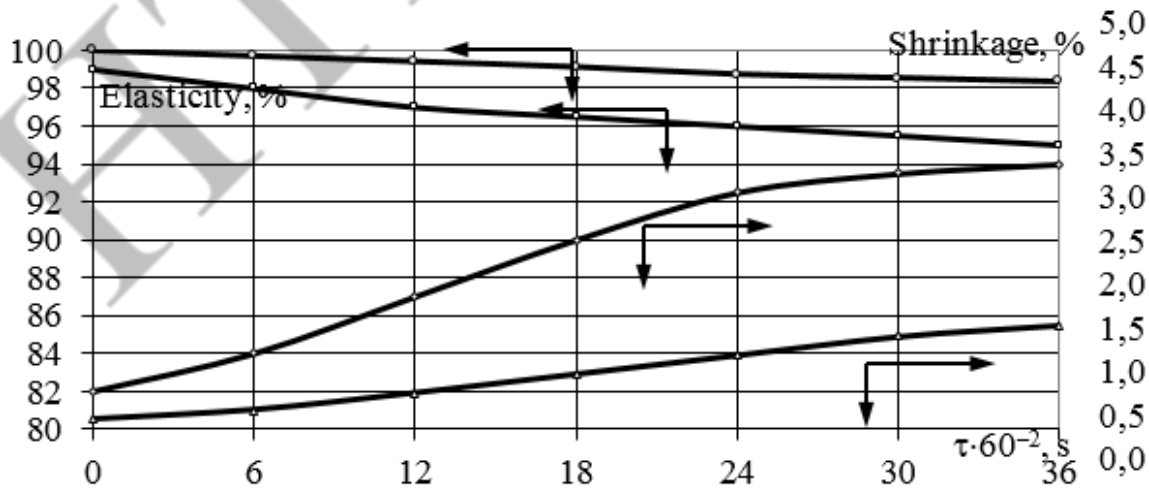


Fig. 5. Elasticity and shrinkage of experimental samples of rye-wheat bread: sample 3 - with 0.15% SNS, - sample 1 - control, - sample 3 - with 0.15% SNS, - sample 1 - control

In fig. 6 shows studies of shape stability, porosity and specific volume of experimental samples of rye-wheat bread during storage.

From the data of fig. 6 it is showed that changes in the porosity of rye-wheat bread with 0.15% SNS correspond to trends in specific volume and stability. The introduction of suspension nanosupplements (SNS) slows down the reduction of these indicators during the regulated shelf life: porosity, stability and specific volume of bread from 0.15% SNS compared to control increases by 4.3-4.7%, 1.6-1, 7 times and 1.8–2.4 times, respectively (due to the ability of the SNS to clusterize and steric stabilization of the food system).

For a more in-depth study of the process of hardening of rye-wheat bread, the indicators of swelling and crumbliness of the crumb are determined (Table 5), which shows that the ability to harden bread with 0.15% SNS is much lower than in the control sample, traditionally produced enterprises of the industry.

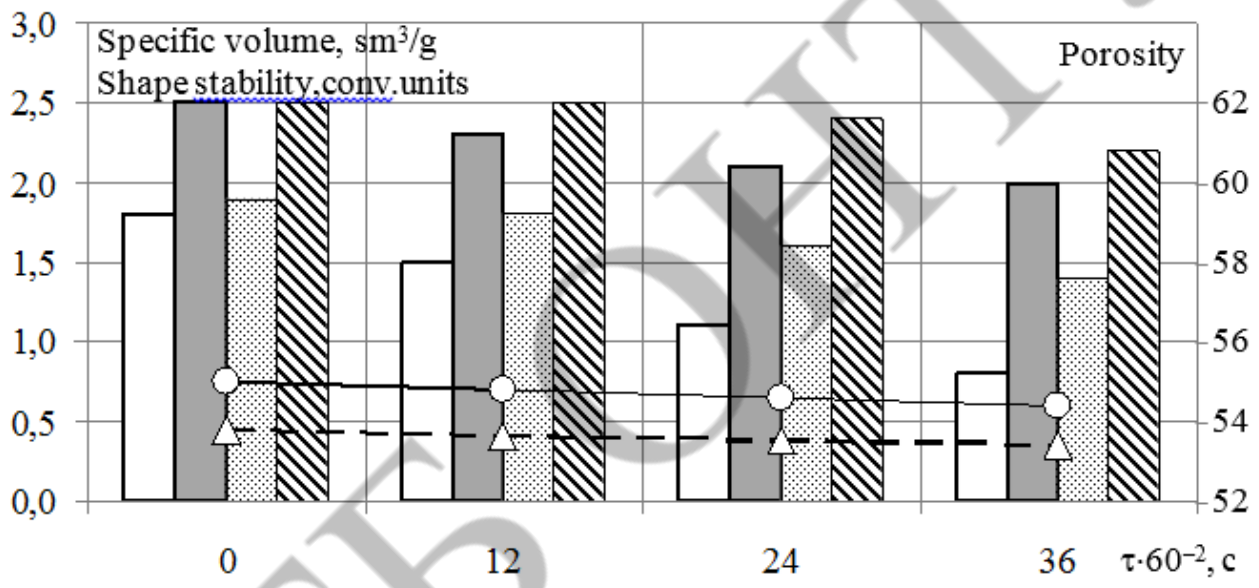


Fig. 6. Specific volume, form stability and porosity of the rye-wheat bread samples while storing: ▭ – specific volume.

Sample 1–control, - specific volume of sample 3 - with 0.15% SNS, - porosity of sample 1-control, - porosity of sample 3 - with 0.15% CIS, - shape stability of sample 1-control, - shape stability of sample 3 - with 0.15 % SNS

Table 5 - Quality indicators of experimental samples of rye-wheat bread (36 hours of storage)

Index	Prototypes of rye-wheat bread	
	Sample 1 – control	Sample 3 – with 0,15 % SNS
Compressibility, penetrometer units	29,0 ± 1,4	36,0 ± 1,8
Swelling of the crumb, %	249,0 ± 12,0	305,0 ± 12,0
Crumb harsh, %	16,9 ± 0,8	11,9 ± 0,6

The safety of bread using suspension nanosupplement (SNS) is evaluated by microbiological indicators. The research results are given in table. 6.

As can be seen from table. 6, microbiological indicators of rye-wheat bread using 0.15% suspension nanosupplement during the regulated shelf life (36 hours) comply with regulatory documentation and indicate its high sanitary-microbiological characteristics.

Table 6 - Microbiological indicators of rye-wheat bread with 0.15% SNS (after 36 hours of storage)

Characteristics	Standart	Bread with 0,15 % SNS
KMAFAnM, KUO / g	No more $1,0\times10^3$	$0,9\times10^2$
Yeast CFU / g	No more 1,0×10	4,0
BGKP (coliforms)	Not allowed in 0.1 g	Not found
Pathogenic m / o, including bacteria of the genus Salmonella	Not allowed in 25,0 g	Not found
CFU molds / g	No more 5,0×10	10

V. CONCLUSIONS

1. The technology of rye-wheat bread production with the introduction of suspension nanosupplements has been improved. A distinctive feature of the new technology is the adding of SNS to the form of a fat suspension when kneading the dough.

2. It is found that the introduction of suspension nanosupplements in the amount of 0.15%; from the mass of raw materials contributes (compared to control) to improve: organoleptic quality of rye-wheat bread; gas holding capacity and dough loosening; reduction of the duration of fermentation of dough masses by (10±4,0) minutes and aging of dough semi-finished products by (15±2,0) minutes (due to the ability of SNS nanoparticles to intensify biochemical processes); increase the ultimate shear stress by 1.12 times and plastic viscosity by 1.3 times and reduce the adhesive strength (to steel) by 1.3 times (due to the structure-forming ability of the nanoparticles of the supplements and the water-holding capacity of the dough under the action of SNS).

3. It is determined that in rye-wheat bread from the SNS (compared to the control) increases: the specific volume of 1.18-1.22 times, the porosity of the crumb 1.28-1.32 times (due to the intensification of biochemical processes) , yield by 5-6%; losses during heat treatment are reduced by 5-6% (due to the stabilizing and water-holding capacity of the suspension nanosupplements).

4. It is proved that the introduction of SNS slows down the process of hardening of rye-wheat bread in the process of regulated shelf life - 36 hours (compared to control): inhibits the reduction of elasticity and shrinkage of bread; increases: porosity, shape stability and specific volume of bread from 0.15% SNS by 4.3-4.7%, 1.6-1.7 times and 1.8-2.4 times, respectively; compressibility and swelling of bread crumbs in 1.22-1.24 times; reduces crumb crumbs by 1.42 times (due to the SNS 's ability to cluster and sterically stabilize the food system).

5. It is established that according to organoleptic indicators, safety indicators, conditions and terms of storage the new product meets the requirements of regulatory documentation.

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2. ECONOMICS AND ADMINISTRATION

PROSPECTS OF TECHNOLOGY INTRODUCTION OF CORPORATE BLOCKCHAIN IN THE CONDITIONS OF DIGITALISATION OF ECONOMY

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Abstract. *The article is sanctified to the research of modern trends of digitalisation of economic activity. Examinations of the main components of Blockchain technology as one of the instruments of digital transformation of the state's economy is executed. The analysis of functioning of Blockchain network, principles of data transmitting in this network, processing and storage of data; the features of Blockchain using in business is described; analysis of basic trends of digital infrastructure development; determination of the basic directions of the use of Blockchain technology for the organization of business processes in different branches of economy; comparative analysis of Blockchain's corporate decisions's application from IBM and AWS; describing for the Ukrainian enterprises of Blockchain's corporate of expediency application is conducted. On the basis of methods of expert evaluation the estimation of perspective diversification activity of international IT-company in the direction of business consulting from the grant of services of Blockchain corporate is carried out.*

Keywords: *technology, business consulting, Blockchain, corporate Blockchain, data, information, network, analysis, experts.*

I. INTRODUCTION

Actuality. The acceleration of public progress stipulates permanent transformations and structural transformations of the economic systems under the act of the newest technologies. Digital technologies become a leading resource next to the traditional factors of production. These technologies assist the increase of enterprises' competitiveness, thus an assistance to provide the transparency of doing business becomes their important aspect. One of the most perspective technologies of this direction is Blockchain technology. Digital transformatisation for Ukraine in the conditions of eurointegration is very actual. Digitalisation of domestic enterprises due to the introduction of Blockchain must give the possibility to become us the valuable participants of outer informative space and to assist the forming of effective and transparent business processes. The marked arguments actualise the use of this technology in Ukraine.

The aim of the research. Systematization of theoretical and methodological bases of the use of Blockchain technology analysis and the development of research and practice recommendations in relation to the economic value for the Ukrainian enterprises of corporate Blockchain is described.

Theoretical, methodical and practical meaningfulness of the given results. The key aspects of Blockchain use in business, grouped directions of the use of this technology for organization the business processes in different bracnhes of economy

are considered. On the basis of methods of expert evaluation the gr efficiency of diversification activity of international IT-company in the direction of business consulting with the grant of services of corporate Blockchain is carried out.

Informative sources of the research. Legislative and normative acts of Ukraine, official publications of international organizations, monographic literature, materials of scientific conferences, electronic resources from the Internet, results of questioning are used.

II. LITERATURE ANALYSIS

The researchers of many domestic scientists are sanctified to the problems of digitalization of economy scientific developments, such as: D. Hladkyh, O. Humeniuk, I. Davydova, H. Karcheva, D. Kasianenko, L. Kurhusenkova, O. Lapko, T. Vine, P. Putsenteilo, Z. Tymoshenko. Thus, part of questions remains debatable enough, in particular the use of digital technologies on a base pf Blockchain. This situation can be explained by that traditionally Blockchain technology is used at the market of cryptocurrency and possibility of its use for other spheres is remaining unnoticed.

Scientists try to define the trends of development and influence of modern digital technologies on different spheres of business. Thus, in scientific works of V.M. Zhukovskyi the modern tendencies of digital technologies application in personnel management is investigated [1]. O. I. Kravchuk, I. O. Varis investigate the digital technologies of personnel management in the conditions of quarantine limitations [2]. The Boston Consulting Group undertook the research in relation to the necessity of digital culture forming for the achievement of digital transformation purposes [3].

Domestic and foreign scientists investigate the trends of cryptocurrency: N. Hryschuk, B. Ihnatova, O. Demydov, A. Zheleznov, M. Kravets, V. Kornieiev, V. Mischenko, I. Sytnyk, O. Cheberiako, V. Lukianov and A. Burkovska. These scientists studied the nature and features of cryptocurrency. T. Zheliut and O. Brechko set the features of transactions realization from cryptocurrency, differences from operations with traditional currency. A. Tsyhanova investigates cryptocurrency's emission. V. Kornieiev and O. Cheberiako [4] described advantages and ldisadvanatges of cryptocurrency from the different countries' experience, offering, that corresponding financial services must be licensed by the state as the type of professional activity on the stages of mining and trading and financial consulting.

Also, the question of digital transformation of economy, certain possibilities of the use of Blockchain technology as innovative technology of business processes in different branches of state's economy is investigated by the scientists. Thus, the researches of Blockchain questions as the direction of accounting development the following sicentifc researches are devoted, such as M. V. Dubinina, S. V. Syrtseva, O. V. Byhanov, N. O. Tusova, O. V. Melnychenko, V. V. Kornieieva, H. M. Tarasiuk [5]. Also, perspective direction of the use of Blockchain technologies is insurance due to the conclusion of smart contracts [6].

In recent year the use of this concept became popular in society. Such popularity allows us to attribute it to neologisms that are constantly in mass consciousness. This category also often meets in the separate legal documents of our state. Thus, in the decision of № 13-rd Rada of the National Bank of Ukraine from 26.05.2020 «About

the activity of mangement of the National Bank of Ukraine in relation to perfection of the payment system and problem of digital currencies of central banks and payment systems on Blockchains» it is suggested to take into account information of Rada of the National Bank of Ukraine on perfection of the payment system and problem of digital currencies of central banks and payment systems on Blockchains and information about the problems and prospects of of digital currencies development of central banks and analysis of results of pilot scheme «e–hryvnia (e-UAH)». In Resolution of Cabinet of Ministers of Ukraine from 25.03.2020 №274 (questions to the competense of vice-prime ministers of Ukraine), the necessity of development of virtual assets providing is marked, Blockchain, artificial intelligence, of digital innovations development [7]. Thus, this resolution is doubled from Resolution of Cabinet of ministers of Ukraine from 18.09.2019 №856, that sets the circle of competenses of Ministry of digital transformation [8].

Domestic legislation in this sphere is remaining unsettled. It is confirmed by Conclusion in relation to the project of Law on virtual assets. In particular, it is marked in this document, that by its aim the project does not contain contradictions and, mainly, corresponds to the international and law obligations of Ukraine, that is formed on the base of eurointegration directions. However, it is marked that this document needs substantial perfection, especially, it concerns the providing with correspondence to Recommendations of Group of the financial events development of fight against money structuring (FATF) and corresponding Directive 2015/849 [9].

The legislatively connected questions are features of legal regulation of technologies application of the distributed information processing on the whole (technology of the distributed register as DL-technology, and «Blockchain» technology as its variety), taking into account decentralizing character of storage and processing of information. The separate legal aspects of application of the marked technology in scientific literature of the last time are investigated [10, 11].

Thus, deiscussed terminology in the sphere of Blockchain technology, an ambiguousness of perception in society was brought to the necessity of study of the state of the legislative regulation of this sphere. Research of the contest of legislative suggestions, that is accepted and registered in Verkhovna Rada of Ukraine, resolutions of Cabinet of Ministers of Ukraine and documents of the National Bank of Ukraine allowed to define the general features:

- the authors of projects and other normative acts give determination in the text of legislative act to the certain terms of technical character, id est the aim of the legislative regulation is not regulated by certain relations, but creation of legislative definitions;
- most actively “Blockchain” technology is developing in the field of state registers;
- in the field of the personal authentication, introduction of the personal electronic keys for the personal activity of the state is not set;
- strengthening of the state’s responsibility for functioning of the system;
- stimuli are supported that influence on providing the functioning of the system by users;
- events in relation to security of information (from loss and distortion) [12-17].

It is concerned that Blockchain shows the chain of blocks of transactions. Thus, it is the distributed database that has the opportunity to support the list of records (they are named blocks), that increases constantly. The marked base has safety devices from modifications. All blocks of this base contain the mark of time and necessary references to the previous blocks of hash-trees [18].

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of the research is the use of Blockchain technology.

The subject of the research is theoretical and methodological principles, organizational mechanisms of analysis of the directions of Blockchain technology use.

Methods of the research. The achievement of the declared aim of the research is carried out by the means of scientific and special methods. The methods of induction and deduction, methods of the scientific abstracting, classification, theoretical generalization and comparison, are used for exposure, selection, theoretical analysis, actualization, classification, generalization of the printed sources from the range of problems of Blockchain technology use; methods of statistical analysis of dynamics rows - for the study of of digital infrastructure trends progress; methods of expert estimations - for description of efficiency of diversification activity of international IT company in direction of business consulting with the grant of services of corporate Blockchain; statistical methods for the evaluation of homogeneity of expert group are given.

IV. RESULTS

4.1. The main components of Blockchain technology

Blockchain shows a digital cluster, that is impossible to “break” and that can be programed not only for the record of financial transactions but also for other existent data and absolutely any information [19]. We interpret Blockchain as the technology that facilitates work in the process of transactions registration and watching of assets in business. An asset can be material or non-material. Practically everything, that has a value, can be found in the network of Blockchains, decreasing the risk and cutting down expenses for all attracted.

Information that is stored in the Blockchain network circulates by the principles of the general and regular updating of database. This principle became the new basis of the use of networks that has corresponding advantages and disadvantages. The database for Blockchain network is impossible to keep on on transmitter, and it results in the volume, that all records are subject to general availability and verification. Existence of the centralized copy that would be stolen, break or change, because information simultaneously spreads through the networks of thousands of computers and becomes accessible to all subjects of the internet becomes impossible. Blockchain technology contains the “built-in” mechanisms of defence. Due to storage of identical blocks of information for the Blockchain networks, it is impossible to control by one organization; there is not “vulnerable” center for hacker attacks.

The volumes of operations in the whole world is growing in geometrical progression and it will increase complication, vulnerability, unefficiency, and charges on the current transaction systems. The increase of electronic commerce, Internet

banking and purchases, together with growing mobility of people in the whole world, entailed the increase of transactions volumes. For solving such problems, rapid pay networks, that provide the mechanisms of establishment of trust, does not require the specialized equipment, does not have duplication of payments, provide transparency and trust to business are needed. Thus, the study of basic features of Blockchain technology allowed them to define in detail and put in order:

1. Features of the normatively-legal regulations at national and international level.
2. Interpretation of category of «Blockchain» on the basis of existent determinations and approaches as technology that facilitates work in the process of transactions registration and looking through the assets in business.
3. Most popular directions of Blockchain use, the sphere is taken to the state registers as confessed by leading experts in the sphere of the state strategic planning of the most progressive with considerable prospects.
4. Existed limitations in effective realization of many economic operations that can be decreased due to Blockchain use.

The dynamics of the amount of scientific reseachers for the last few years and the problems of Blockchain technology is given in Fig. 1.

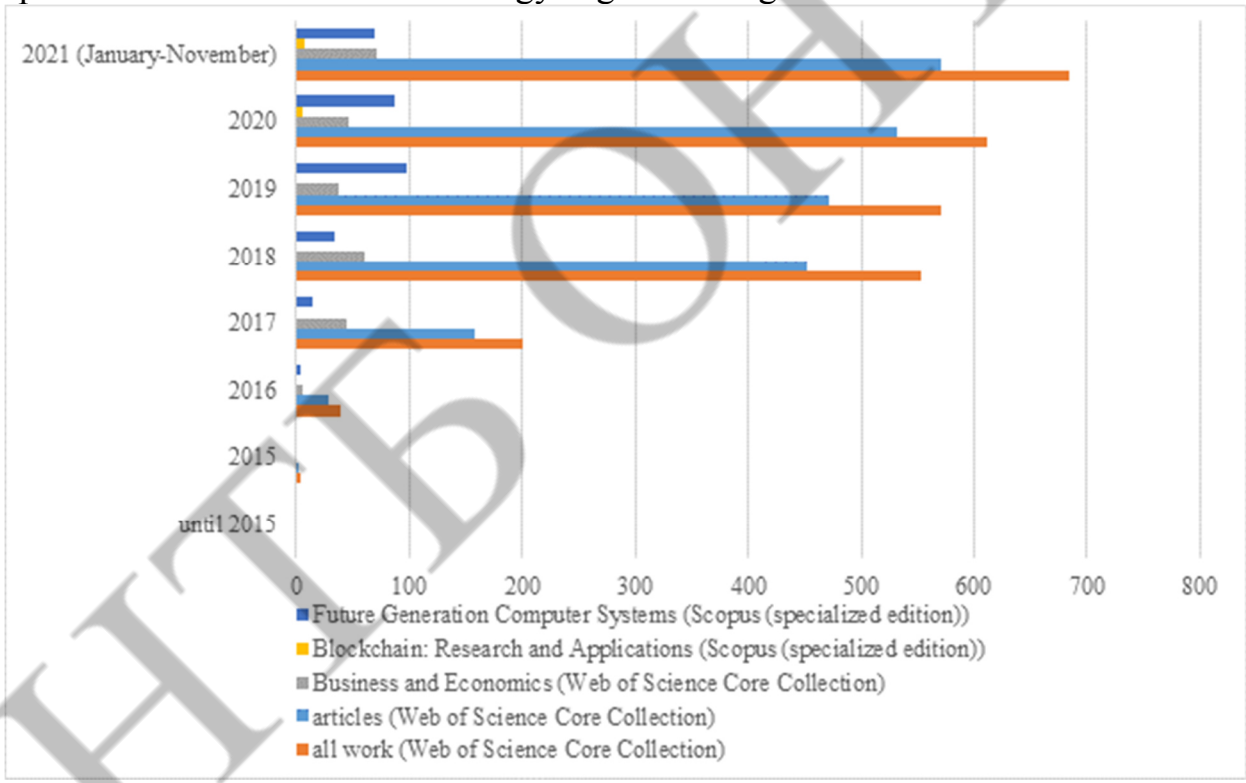

Fig. 1. Dynamics of the number of scientific papers on the blockchain in scientometric databases until November 2021 [calculated for 20-22]

The amount of all publications in relation to Blockchain technology in Web of Science Core Collection (WOS) and specialized editions of Scopus, the amount of articles by all directions and amount of the articles by direction of "business and economy" were analysed by us. The amount of articles continues to increase, that certifies growing actuality of the investigated technology in 2021.

4.2. Analysis of Blockchain network, principles of transmission, processing and storage of data. Key concepts of Blockchain for business

Basis of Blockchain technology is made by application of the following technological receptions and methodologies of work in industry of data enciphering: asymmetric cryptosystem (asymmetric algorithms of enciphering); receptions of data randomising (hash-functions: MD and SHA); for the recording of randomising results the table of hashcoding is used; Smart Contracts are the method of data communication (values in digital image) from one participant to other; realization of POC mechanism (Proof of concept) and talkens are the claim of agreement in the system (it is proof of conception as the method of event verification).

Blockchain functioning is related to implementation of enormous amount of calculations, for realization of which corresponding calculable powers that is given by the providers of cloudy services for considerable monetary resources are needed. But it is necessary to mark the warning for the proprietors of cloudy services accounts, that unconscientious miners, that get a commission for activity from defence of Blockchain constancy, can use their accounts. Thus, "newbie" that use cloudy services without the proper level of awareness in the sphere of cyber safety can get from AWS, Azure, Google Cloud, Gigacloud [23] or other providers of cloudy services the accounts on large sums, that can be ten and thousand USA dollars.

Information about this type of swindle is got as warning for the users of cloudy services as the result of conducted interview with an expert in the sphere of Cyber Security (DevSecOps at Jacobian Engineering) that has AWS Certified Security (Specialty Issued by Amazon Web Services Training and Certification) [24], and also AWS Certified Solutions Architect (Professional Issued by Amazon Web Services Training and Certification) [25]. Undertaken research of basic elements of Blockchain technology allowed to set and describe in detail basic advantages and disadvantages of this technology (Table 1).

Table 1. Grouping the advantages and disadvantages of blockchain technology

№	advantages	disadvantages
1.	Decentralization - all members of the blockchain network have equal rights.	Scalability - the size of the blockchain will increase with the number of transactions.
2.	Network transparency - data is publicly available, and deleting or modifying it is excluded.	The likelihood of a new type of fraud.
3.	Versatility - the possibility of application in completely different areas of business and public administration.	Probable breach of integrity if more than 50% of the computing power is on a single device.
4.	Reliability - transaction verification is available to all participants in the system and allows only legitimate transactions.	-

Blockchain for business is private, settled network with well-known personalities and without the necessity of the cryptocurrency use. To understand how Blockchain works for business, it can do revolution in business networks, it is necessary to set clearly four main key conceptions of Blockchain for business (Table 2).

Table 2. Contents of key blockchain concepts for business

№	Blockchain concept	Content concept
1.	Shared ledger	Only a distributed system of records shared in the business network is added
2.	Permissions	ensuring proper visibility. transactions are secure, authenticated and verified
3.	Smart contract	business conditions built into the transaction database and executed with transactions
4.	Consensus	All parties agree to verified online transactions

In business network transaction can be tested and passed in Shared ledger through the consensus. Blockchain for business requires consensus as the method of application of that mechanism that is considered the best in any branch segment. Smart-contract is a set of rules that regulate business, it is kept on Blockchain and executed automatically as the part of transaction. Realization of conceptions is impossible without establishment of basic participants of blockchain network (to take into account legislation of their actions) (Table 3).

Table 3. Blockchain network members and the content of their activities

№	Members	Content of activity
1	business blockchain user (Member)	business user with permissions to join the blockchain network and conduct transactions with other network members.
2	Regulator	blockchain users with special permissions to control transactions occurring in the network may be prohibited from conducting transactions
3	Blockchain developer	Programmers who create applications and smart contracts that allow blockchain users to make transactions in a blockchain network.
4	Blockchain network operator	Individuals with special authority and permissions to create, define, manage, and track a blockchain network.
5	Traditional processing platforms	Existing computer systems that blockchain can use to increase processing. This system may also need to initiate blockchain requests
6	Traditional data sources	Data systems that can provide data to influence the implementation of smart contracts and help determine how to communicate and transfer data between traditional applications and the blockchain through API calls using MQ-style cloud messaging (managed message broker service)
7	Certification Authority (Licensing)	Issues and manages the various types of certificates required to authorize the launch of a blockchain.

4.3. Trends of digital infrastructure development

Information technologies that provide the construction of digital infrastructure can be divided into 4 basic groups [26, p. 140]: internet of things, cloud computing, robotic technologies, artificial intelligence; Big Data and additive technologies 3D; technologies of connection, quantum and supercomputer technologies; Blockchain technologies, cyberphysics systems, digital planning and design. On the whole, the development of informatively-communication technologies in the world can be estimated by the amount of their users (Fig. 2).

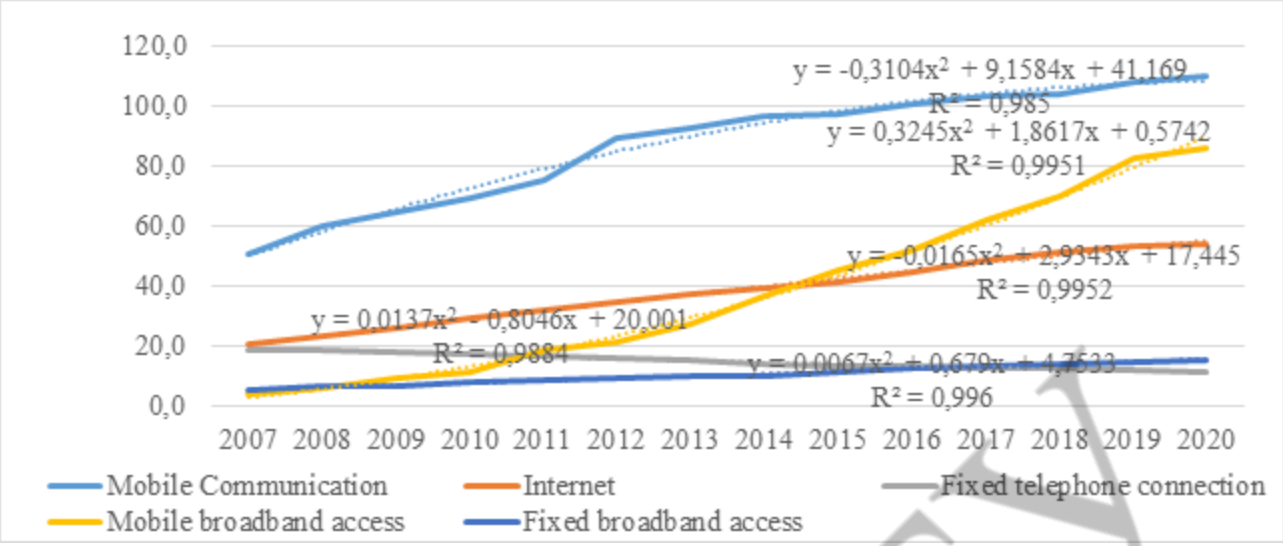

Fig 2. Number of subscribers in the world by types of information and communication technologies in 2007-2020, (% of the total population)

Dynamics during the investigated period is qualitatively designed after polynomical dependences and that is why they can be used for prognostication. Thus, at the end of 2020 there is 53,8% population of the world, used the Internet, comparatively with 20,6% in 2007. During 2007–2020 the amount of subscribers of mobile broadband access grew quicker from 4% in 2007 to 85.9% in 2020 [27].

The important factor to increase the access to the Internet are the appearance of new technologies of mobile communication and passing to the next generations, dissolution in years between such technological gaps each time diminishes: between 2G and 3G is 10 years, between 3G and 4G is 5 years. In 2018 the newest was the fourth generation, and already now there is preparation to the introduction of 5G. It needs considerable investments, but will allow to operating the considerable volumes of data much better, to process their greater volumes and link with the greater amount of devices [28, p. 7]. It is forecasted, that 2025 more than half of population will have the access to 5G (Table 4) [29, p. 8].

Table 4. Use of mobile technologies by regions and generations in 2018 and 2025 (forecast), %

Regions	2018			Forecast until 2025			
	2G	3G	4G	2G	3G	4G	5G
Asia and Oceania	34,12	2,34	45,28	5,00	13,00	67	15,00
Latin America	26,26	39,89	35,12	5,00	21,00	65,00	8,00
Middle East and North Africa	37,06	40,08	23,32	10,00	32,00	52,00	6,00
Central and South Africa	59,29	3,65	6,21	14,00	59,00	24,00	3,00
Countries of the former CIS	36,15	4,36	19,33	2,00	18,00	68,00	12,00
Europe	18,15	36,23	46,67	1,00	7,00	63,00	29,00
North America	9,12	21,01	69,38	2,00	7,00	44,00	4,00
The world together	29,55	28,34	43,32	5,00	20,00	59,00	15,00

There is a tendency to the increase of part of IT sector in GDP of countries during the last years, besides ityields to the design of polynomials with the proper level of reliability (Fig. 3) [29].

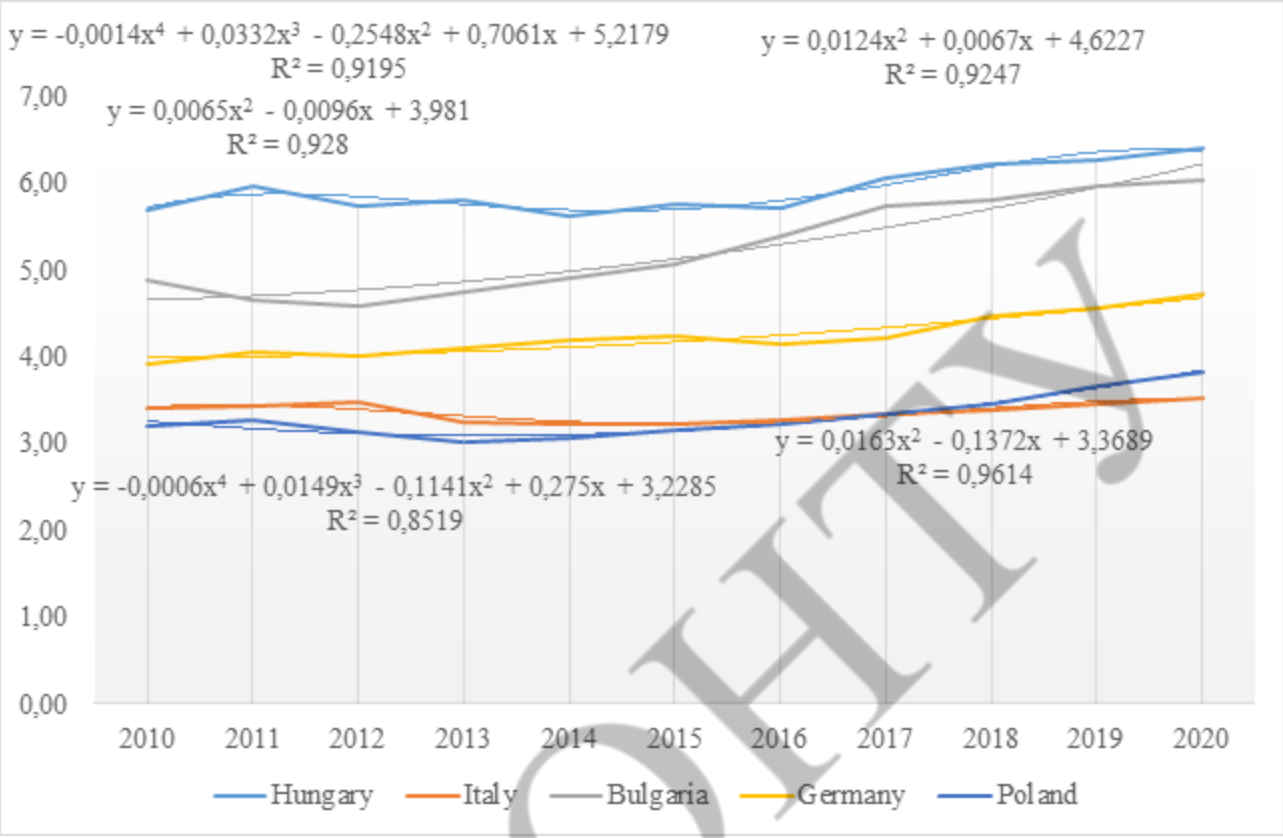

Fig. 3. Share in the GDP of the IT sector in some European countries, %

In most European countries this is 3-5%, but in some it is about 6-8%. In Ukraine this index in 2020 on different estimations was from 4% to 5,5%, however, one of goals of Ministry of Digital Transformation of Ukraine is its increase to 10% in 2024. Digital transformation must certainly take place in parallel with introduction of technologies that guarantee data protection and prevent cybercrime. In Ukraine it can be realized on the base of Blockchain.

4.4. Use of Blockchain technology as innovative technology of organization of business processes in different branches of state's economy

Blockchain technologies are perspective for development of electronic registers of right of ownership on earth and other objects of the real estate, digital platforms for storage, transferrableness and administration of these citizens, organization of purchases, electronic budgets, providing of electronic referendums, e-petitions, e-voting, electronic management, creation of single electronic state demographic register as the digital identifier of citizens of Ukraine, development of modern systems of integrated deliveries chains [30, p. 81].

Blockchain technologies can give the opportunity to pass and keep information safely, barriering its from interferences, consequently, they will be especially actual in domestic conditions. Introduction of Blockchain technologies and other digital technologies will allow to promote comfort and functionality of many systems and

processes, provide financial cost and charges reduction on personnel, and also substantial increase of safety of information and its transparency.

Forecast, that the amount of projects with the successful use of Blockchain considerably will grow during 2022-2026, and 2030 to the general effect from its use due to the reduction of charges and creation of new income will attain 3 trl. USA $ [31, p. 35].

The example of the use of Blockhain technology of divided data storage with the aim of information defence in Ukraine by Ministry of Digital Transformation the digital platform of e-state «Action» is realized. Portal "Action" allows to get access to the state on-line services, and also to information from national electronic informative resources. It is also possible to use mobile application "Action" with the similar functional.

One of the best methods to understand Blockhain is to estimate its permanent potential and define, can it improve the method of doing business by the organization, and also to consider the cases of its use. Thus, it follows to define those industries that can use this technology potentially. Perspective to learn experience of IBM Blockchain (business consulting or management by its network). Blockchain technology of IBM or actual Blockchain networks of IBM helped many businesses. IBM Blockchain has its own experience solving business problems by means of Blockchain technology and due to large branch experience and Blockchain technological examination. IBM unites all unique systems which are necessary for success achievement.

4.5. Prospects of Blockchain application in accounting, audit and insurance

Technology of Blockchain shows the set of tools that can become the catalyst of development not only for the developed countries. Due to this technology financial mediators must lose their meaningfulness, and the population of country will be in more equal terms with comparison to more provided layers of popualtion.

For today the American institute of the certificated public accountants (American Institute of Certified Public Accountants, AICPA) works on the development of regulations, corresponding algorithms, instructions, educational materials, to help the certificated accountants and public accountants better understand and apply Blockchain technology in practice in bookkeeping and audit. Basic idea: relative simplicity of accounting (cryptocurrency show non-material assets with the undefined term of the useful use, their sale is subject to taxation, capital augmentation is taken into account [32]).

Another perspective direction of the use of Blockchain technology is insurance, at the construction of different decisions this technology provides reliability and transparency for clients, to modernize this industry:

- smart-contracts help to provide automatic insurance payments, bring down risks and on the whole to improve quality of customers' service;
- efficiency of Blockchain system makes markets decentralize, fully digital and more safe, reduces time of the inquiry processing and cost of transactions;

abandonment from mediators and transparency of public Blockchain platforms, promotes trust to the system, substantially increases speed of work and reduces its cost;

- the high-rate of transaction processing allows easier to pick up the individual cost of services and makes market more flexible;
- new types of insurance and general economy are appeared and developed: P2P of insurance, microinsurance, point (self-reactance) insurance;
- availability of insurance services and more and more users get the access to the market.

4.6. Analysis of Blockchain's corporate decisions application (IBM, AWS)

The modern world requires innovative decisions that is why many world companies are developing exactly by means of this technology. Leaders that make decision often look closely to Blockchain technology with the aim of increasing the work efficiency, cost reduction and risks. Blockhain gives a sinergistical effect at creation of new business models to organizations.

AWS gives the specialized instruments for satisfaction of certain necessities, if it is necessity for the centralized database of register that supports unchanging and transactions records by cryptographic methods, or multilateral, is fully managed by Blockchain networks that helps to work without mediators are checked up. Clients with the workloads constrained with the use of Blockchain technology and registers choose AWS more often than any other supplier of cloudy decisions. 25% of all workloads of Ethereum in the world work on AWS.

Amazon Managed Blockchain simplifies the difficult work related to application of Blockchain networks, increasing time of placing of Hyperledger Fabric platforms on 60%. Managed Blockchain Service simplifies management networks, as it supports the interface of command line of AWS, services of AWS CloudFormation and Amazon Cloudwatch Logs. Amazon QLDB works in 2-3 times quicker of traditional platforms, giving the transaction processing to the operators, analogical SQL, and debenture model of data.

AWS has more than 70 tested partners of Blockchain decision that provide support of all basic protocols of Blockchain technology, including Hyperledger Sawtooth, Corda, DAML, Ethereum, Quorum, Blockstack, Blockapps Strato, RSK, Kadena ScalableBFT and many others. AWS offers resources for on-line training and certifications that will help to work on the achievement of set goals in any place and in comfortable time. The company offers flexible possibilities from AWS Training and Certification – from the format of Digital training and online-lectures with a teacher in comfortable rate to the remote examinations [33].

The last version of IBM Blockchain platform is based on feedback from more than 500 clients. These systems work in different environments - both local and in cloudy. Protocol with an open code, for work in any calculable infrastructure is created. Nestlé Company inculcated the closed blockchain system for supplying control of foodstuffs. OpenSC Company, created by Boston Consulting Group and World fund of wild nature, became the partner of Swiss giant in this project. OpenSC develops Blockchain platform that helps the enterprises of food industry to remove illegal, harmful for environment products from the deliveries chain. Nestlé is inalienable part of IBM FoodTrust, and asserts that due to creation of this ecosystem of closed Blockchain in the company, they are able maximally to realize an intrinsic value and

increase this technology. The example of such world giant, as Nestlé, proves that introduction of Blockchain system destroys the enterprise on a new level [34].

Software and interface of IBM Blockchain Platform provide flexibility, productivity and powerful possibilities necessary for opening of Blockchain technologies potential. Advantages of IBM Blockchain Platform are following:

- the tested Blockchain system that is already successfully used in different industries, with the numerous examples of introduction. IDC, Everest Group, Juniper Research, HFS Research, BRG and other companies name this platform as the branch leader. Also round-the-clock support service passed the verification in practice;
- to begin quickly work, it is possible to join to already operating client networks. But at presence the special necessities of IBM Blockchain Platform will help the enterprise to create new network that answers such necessities;
- the advanced instruments of management will allow to invite in the range of network development and plug into the network other organizations from other local IT infrastructure. Support of multicloudy environments functions means the possibility to invite addition users that work for other strangers cloudy environments;
- the IBM Blockchain Platform is created on the basis of Hyperledger Fabric platform from Linux Foundation. The open source code, support of local infrastructure and possibility to work with the cloudy environments of extraneous suppliers allow to avoid attachment to the certain suppliers.

Thus, the choice for collaboration with Blockchain services providers are difficult enough, that is why it follows to be oriented on the specific of company activity and its clients.

4.7. The explanation of economic value for Ukrainian enterprises of the technology of corporate Blockchain

Practical part of the research is realized on the base of LTD «First Bit» that works in Ukraine from 2005 and it has offices in Kyiv and Odesa. LTD works on IT market during 20 years in 5 countries of the world. More than 14 years in Ukraine company offers complex solutions of of different tasks complication, IT services for effective business management are also offered. Also «First BIT» is «Center of the real automatization», «Center of Certificated Training», «Center of production and trade competense», «Center of accompaniment» and it is the member of «Union of business automatization». The clients of the company get necessary services for successful management: mobile additions, web decisions, cloudy services, own developments are offered.

Thus, this company is powerful enough with stable position at the market of IT services, but it can become the prospect of Blockchain technology introduction. Organization can quickly join to already existed network created on the basis of IBM Blockchain Platform. In addition, consulting corporation can work out its own network with exact accordance with its necessities. Thus, activity diversification due to partnership of consulting from the introduction of tBlockchain systems will result to company's withdrawal to a new level among competitors, expanding new markets, will provide the proper level of stakeholders' loyalty, will assist to personnel development.

It is also necessary to mark, as LTD “First BIT” develops not only at the internal market but also on external, this enterprise topically will be necessary to inculcate Blockchain systems for the clients.

For introduction of events from organization of consulting partnership in relation to Blockchain systems, it is necessary to conduct the estimation analysis of workers’ relation to the quality of personnel training on the enterprise. And also to conduct the expert questioning of results estimation at the terms of traditional directions storage and with the use of Blockchain technology [35]. For this purpose the enterprise can conduct questioning with the use of ***Google Forms***. Corresponding questionnaires, questioning and given results (annex A) is conducted were designed by us.

Questioning was done among the staff. 12 persons took part in questioning. The answer of every respondent for a question is analysed as diagrams (Fig. 4-10).

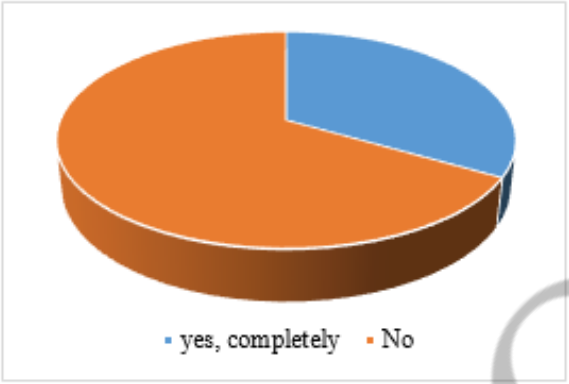

Fig. 4. Distribution of answers to the question: "Are you satisfied with your own level of qualification?"

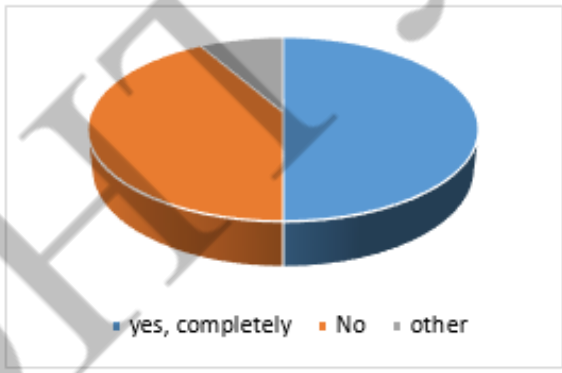

Fig. 5. Distribution of answers to the question: "Do you like the methods of training employees in the company?"

Fig. 6. Distribution of answers to the question: "Is it necessary to conduct training only on professional qualities, or also on personal?"

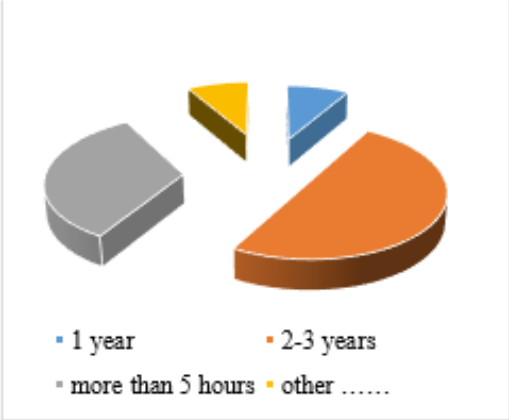

Fig. 7. Distribution of answers to the question: "How many hours a week are you ready to devote to training?"

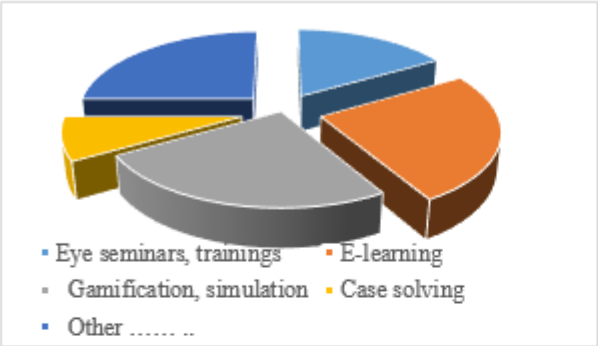

Fig. 8. Distribution of answers to the question: "Which option to get information do you like best?"

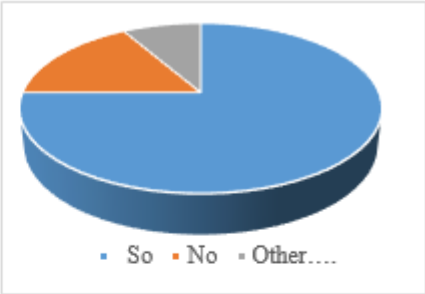

Fig. 9. Distribution of answers to the question: "Do we need to evaluate the effectiveness of training?"

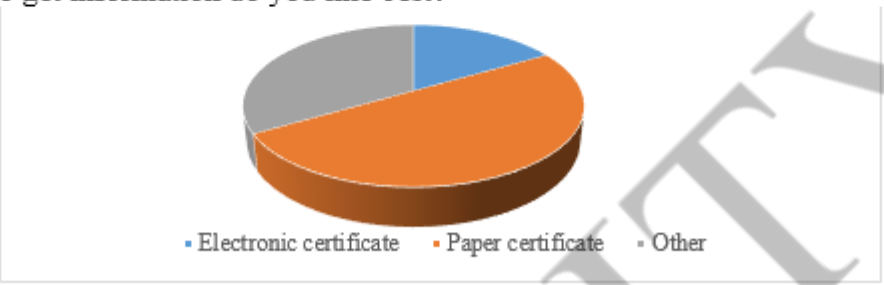

Fig. 10. Distribution of answers to the question: "In what form do you want to receive certificates based on learning outcomes?"

All data from the above-mentioned diagrams are taken from answers, grouped of Google Forms. Thus, analysing results, it is possible to say, most workers are not satisfied with their qualification (66,67%) that certificates about their aspiration to the development. Respondents' opinions in relation to the degree of satisfaction of existent teaching system is practically distributed almost in half. In relation to the problem of training on professional and personality qualities, then anymore 90% respondents consider that it is necessary to conduct training on both. 50% polled workers are ready to spend time for training of 2-3 hours a week, but anymore 33% of workers can have training more than 5 hours for a week. 25% of workers were chosen method of e-learning training, other 25% of workers like gamification, and only 16,67% liked face-to-face seminars, that is fully expectant for IT company. Such distribution of answers means that workers are ready for the introduction of innovative information technologies. Fully was unexpected that 50% respondents wish to get paper certificate on the results of training. 75% of polled workers consider that efficiency of training needs to be estimated.

Next step in the estimation of personnel readiness to the introduction of innovative technologies in company's activity of realization of evaluation expert's results of LTD «FIRST BIT» diversification activity due to the introduction of consulting partnership direction in relation to Blockchain technology is offered. 13 employees of financial subdivisions (annex B) took part in questioning (Fig. 11).

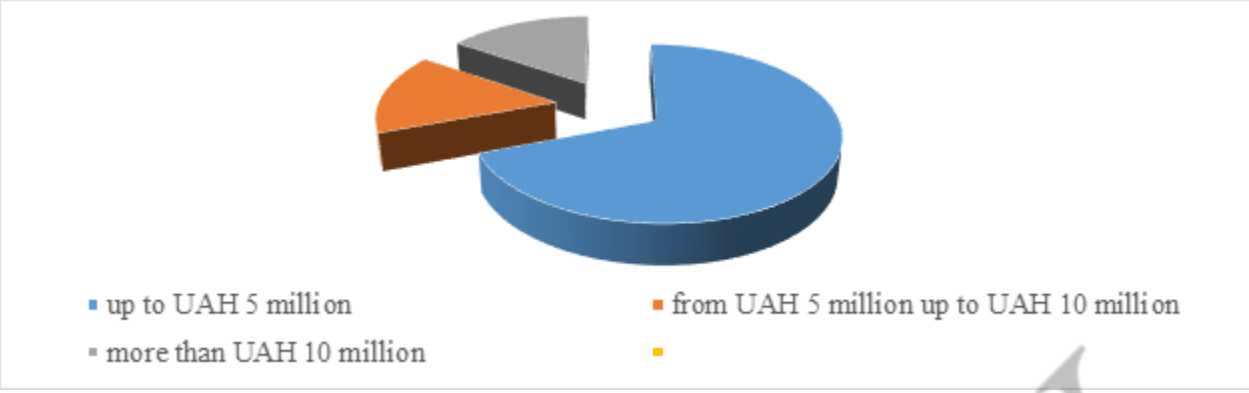

Fig. 11. Distribution of responses according to the most probable indicator of the company's revenue growth from the proposed range, provided that the existing traditional areas of activity are maintained

Thus, almost 70% experts think that at the terms of starahe of existent traditional activity directions, annual increase of income will be less than 5 мmln.hrn. (Fig. 12).

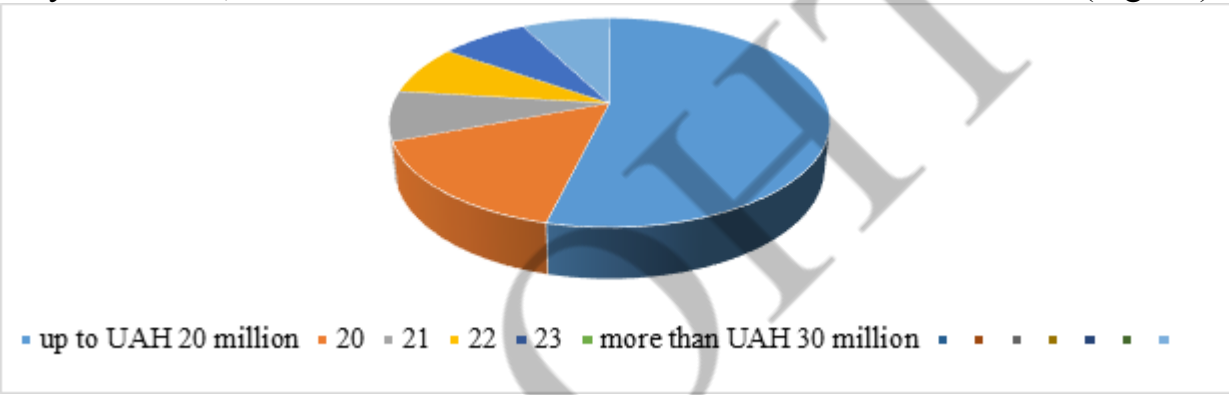

Fig. 12. Distribution of answers according to the most probable indicator of the company's revenue growth from the proposed range, provided that the company's activities are diversified in the direction of implementing a consulting partnership for the development of blockchain technology

Almost 54% (7 persons) of experts think that annual company's income will grow less than on 20 mln.hrn. annually on condition of activity diversification in direction of consulting partnership from introduction of Blockchain technology, only one person (7,7% polled) considers that it will exceed 30 mln.hrn. Other four experts (38,46%) consider income will grow in the range from 20 million hrn. to 23 mln.hrn. Let us conduct the estimation of expert group's opinions homogeneity (Table 5).

Table 5. Grouping of experts according to the growth of the company's revenues from the proposed range, provided that the company's activities are diversified in the direction of implementing a consulting partnership for the development of blockchain

Income increase, UAH million	**Up to 20**	**20-23**	**More than 30**	**Total**
Number of experts, persons	7	5	1	13
Specific weight, %	53,85	38,46	7,69	100
X_{av}	20,65			
Deviation $\Delta X = (X_i - X_{av})$	-2,15	0,85	10,85	…
ΔX^2	4,64	0,72	117,64	122.99

The size of this forecast must be checked for reliability and typicalness. Determine the standard deviation that characterizes dispersion of separate experts' opinions in relation to mean value.

$$\sigma = \sqrt{\frac{\sum(X_i - X_{av})^2}{n}} \quad (1)$$

X_i – i expert's opinion, the forecast of the enterprise's income is increasing

X_{av} – average arithmetic selections of experts' forecast values

$$\sigma = \sqrt{\frac{122.99}{13}} = 3.076 \text{ UAH million}$$

Determine the variation coefficient that characterizes homogeneity of expert group's totality:

$$CV_{\sigma} = \frac{\sigma}{X_{cep}} \times 100\% \quad (2)$$

$$\frac{3{,}076}{20{,}65} \times 100\% = 14{,}89\%$$

As the calculation value of variation coefficient $CV_{\sigma} < 33\%$, then the expert group can be considered homogeneous, that specifies the possibility to use expert estimations for further calculations.

The next stage of Blockchain system introduction on the enterprise will be to choose the consulting corporation that is the provider of global informative networks. LTD «First Bit» can quickly join to already existent network bwhoch was created on the basis of IBM Blockchain Platform. In addition, consulting corporation can work out its own network with exact accordance with the company's necessities. As clients of LTD «First Bit» are companies in the field of distribution, import, export, logistic, rent of apartments and row of concomitant services, then it will be expediently to inculcate exactly IBM Blockchain Transparent Supply. It will help to provide transparency at the level of all partners on the deliveries chain. The common use of data is the key to success in business. Blockchain platform allows promoting efficiency of data exchange as the enterprise only determines who can look over data. Decision for providing of deliveries chain transparency allows creating unchanging, divided register for the general use with partners on the deliveries chain, to promote the degree of trust and transactions efficiency. Blockchain plays an important role in the world, where speed, exactness and cooperation determine the optimal deliveries chain [36].

IBM Blockchain Transparent Supply gives Blockchain platform by means of what company can create the own ecosystem of data exchange with partners within the framework of reliable deliveries chain [37].

For the clients of LTD «First Bit» the introduction of this system will bring advantages:

- possibility to confirm the commodities origin and show to the consumers advantage of brand among the competitors, namely: complete information about the products origin on the basis of Blockchain data with limitation of rights for access;
- to look through the information about supplies in all deliveries chain practically in real-time, to optimize supplies by means of function of automatic addition, in order to

avoid goods scarcity or surplus supplies, to improve the indexes of realization and inculcate the dynamic pricing;

- to provide complete transparency and decreasing of administrative charges, related to the settlement of discussed situations, products recalling, demonstration of normative requirements observance and documentation exchange with business partners.

In difficult times, so as the world pandemic, this question has a greater value. Companies and consumers expect the guarantee of commodity authenticity from the brands, in that time as participants of deliveries chain require the responsible choice of suppliers and transparency increase with the aim of minimization of discussed situations. Also, it is needed to mark that the main advantage of introduction of this system will be fully training of company's guidance and employees of using the platform, technical support 24/7 and absolute accompaniment.

Thus, introduction of consulting partnership from Blockchain system development from IBM Blockchain. It will result to the increase of clients' loyalty and partners due to providing of of their activity transparency was offered by us. It is no less important that after introduction of IBM Blockchain Transparent Supply the envisaged of workers' training and certification is needed. Thus, the input of consulting partnership with possibility of Blockhain systems development under the needs of our customers will result to the company's withdrawal on the new level among competitors, expanding new markets.

V. CONCLUSIONS

The actuality of undertaken research in relation to the analysis of Blockchain technology use is confirmed by the certain tendencies of digital transformation in the conditions of eurointegration processes. The special accent is done to the prospects of introduction of Blockchain technologies that will give possibility for our state to become the valuable participant of outer space informative and will assist the forming of effective and transparent business processes.

Systematization of theoretical and methodological bases of Blockhain technology allowed to set the features of the normatively-legal regulations of this phenomenon at the national and international level. Duscussion of terminologies in the sphere of Blockchain technology, ambiguousness of perception in society, lacks of the state of the legislative regulation of this sphere are marked. The offered interpretation of "Blockchain" category on the basis of existent determinations and approaches as technology that facilitates the work in the process of transactions registration and looking through the assets in business-network are given. The most popular directions of Blockchain use, existent limitations are considered in effective realization of many economic operations that can be dicreased due to Blockchain use and were determined by us.

The swiftly growing dynamics of the amount of publications in relation to Blockchain technology in the scientometrical bases of Web of Science Core Collection and Scopus, that is sharp evidence of growing actuality of Blockchain technologies is marked. The important element of the research is the study of Blockchain network work, principles of transmission, processing and storage of data, that allowed to set

bases of this technology, that are based on technologies and methods of work from data enciphering, their essence, content, advantages and disadvantages. An interview is conducted with an expert in the sphere of cybersecurity, as the result of given information on the new type of swindle with the use of cloudy services for Blockchain system unconscientious miners.

We consider the key conceptions of Blockchain for business, that is taken Shared of ledger, Permissions, Smart of contract, Consensus, their specifications, and also clearly participants of Blockchain network and the content of their activity, is described in details. Investigating the basic progress of digital infrastructure trends, we make the approach to the determination of digital economy as economic system, that characterizes the new technological mode of economy and has the characteristic deployment of digital technologies on the basis of innovations and their implementation in all types of economic activity and sphere of vital functions of the society.

Also we grouped and detailed information technologies that provide in-process the construction of digital infrastructure and place in this infrastructure of Blockchain technology. We formed the hypothesis, that the use of Blockchain technology allow to bring down the level of bureaucratization, will promote business transparency, will assist the general increase of IT industry income, and it will allow to attract domestic and foreign investors due to the simplification of business registration procedures.

On the results of analysis, grouping of directions of Blockchain technologies application is executed in business. The training of corporate decisions directions of Blockchain application is undertaken from IBM and AWS, experience of international companies that apply these decisions in practice is studied, and also the description of corporate decisions from IBM for international IT company, worked out events from organization of partnership of consulting with IBM company in relation to the development of blockchain systems as direction of activity diversification of the company is carried out.

For the considering of introduction of the given events, the conducted estimation of workers' relation to the quality of personnel training on the enterprise and expert evaluation of the results of activity diversification due to the introduction of partnership consulting direction in relation to Blockchain technology is described. Distribution of answers marked that the workers of company are ready for the introduction of innovative information technologies.

In relation to the prospect of diversification of enterprise's activity experts marked that this direction is perspective. Thus, the introduction of consulting partnership from the development of IBM Blockchain system will result the increase of clients' loyalty and partners due to providing of their activity transparency is offered.

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ANNEX A

Monitoring of the state of personnel training activities in LLC "FIRST BIT"

Objective: to assess the attitude of employees to the quality of staff training activities at the enterprise.

Provide one answer to each of the following questions, please.

1) Are you satisfied with your level of qualification?

- yes, completely
- no
- other …

2) Do you like the methods of training employees at the company?

- So
- No.
- Other ….

3) Is it necessary to conduct training only on professional qualities, or also on personal?

• Yes, need both
• No, only for professionals
• No, personal only
• Other…

4) How many hours a week are you ready to spend studying?

- 1 hour
- 2-3 hours
- More than 5 hours
- Other……

5) Which information option do you prefer?

• Face-to-face seminars, trainings
• E-learning
• Gamification, simulation
• Solving cases
• Other …… ..

6) Do we need to evaluate the effectiveness of training?

- So

- No.
- Other ….

7) In what form do you want to receive certificates based on learning outcomes?

• Electronic certificate
• Paper certificate
• Other

ANNEX B

Expert evaluation of the results of diversification of the activities of the company "FIRST BIT" through the introduction of consulting-partnership on blockchain technology

Objective: comparative evaluation of the company's performance while maintaining traditional trends and using blockchain technology

1. Choose the most probable indicator of the company's revenue growth from the proposed range, provided that the existing traditional areas of activity are maintained

- Up to UAH 5 million.
- From UAH 5 million to UAH 10 million
- More than UAH 10 million

2. From your point of view, what increase in income is possible due to the diversification of your company's activities in the direction of implementing a consulting partnership for the development of blockchain technology.

- Up to 20 UAH million
- 21 UAH million
- 22 UAH million
- 23 UAH million
- 24 UAH million
- 25 UAH million
- 26 UAH million
- 27 UAH million
- 28 UAH million
- 29 UAH million
- 30 UAH million
- More than 30 UAH million

BUSINESS PROJECT TO START AND DEVELOP THE BUSINESS OF DODON&CO DESIGN AND CONSTRUCTION AGENCY

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Advisor: Denysenko Nataliia
Kyiv National University of Construction and Architecture (Ukraine)

Summary of the Project. *The purpose of this work is to create a business plan based on market research of the construction industry and services in Ukraine, for establish and develop a design and construction agency «Dodon & Co». To do this, the target audience was identified, the strategy of market conquest, marketing research was performed, SWOT - analysis of the agency's activities was formed. The Ukrainian construction market, the market of design and construction services in Vinnytsia and the main competitors of the Design and Construction Agency are analyzed «Dodon & Co». The organizational scheme of personnel management of the agency is formed. The financial and investment plan on the basis of which economic efficiency and expediency of realization of business idea, payback of the project is defined is made. A pilot project of the restaurant complex "Kalyna", p. Chernyatyn, Zhmerynskyi district, Vinnytsia region.*

Keywords: *business project, market, competitors, construction industry, design and construction services, design, monolithic services, strategy, perspectives, results.*

I. INTRODUCTION

Most people think of working in the construction industry, they think about the actual construction - building structures such as houses, commercial buildings or other structures. The beginning of real estate construction involves the creation of a project and the use of a number of construction services that allow you to create a real construction project. No large investment is required to start such a business. The team of specialists, experience and modern design technologies are important. The business plan for the creation and development of a design and construction agency is a roadmap for a successful partnership with the best professionals and meet customer needs.

Like the five blind men encountering different parts of an elephant, each of the numerous participants in the process of planning, designing, financing, constructing and operating physical facilities has a different perspective on project management for construction. Specialized knowledge can be very beneficial, particularly in large and complicated projects, since experts in various specialties can provide valuable services.

Market analysis based on the results of the monthly analytical study "Review of the development of the construction industry of Ukraine" from PAU, for 6 months. In 2021, the Ukrainian construction market grew by + 0.2% compared to the same period in 2020. The general market trend is the growth phase of the Ukrainian construction industry market and the acceleration of growth trends [2].

The volume of the construction works performed from January to June 2021 made 77 billion hryvnias (+0.2)% in comparison with 2020, owing to the following: (+16.4)% in residential construction; (-4,9)% in commercial construction; (-2,8)% in

infrastructure construction (hereinafter without the statistics for Crimea and the ATO area). It should be noted that the construction market started growing two months earlier in comparison with the last year (it started to grow in September 2020). The volume of the construction works performed in 2020 made 202 billion hryvnias (+4.0)% in comparison with 2019, owing to the following: (-18.5)% in residential construction; (-2,7)% in commercial construction; (+14,8)% in infrastructure construction. The indices are specified in the comparative prices.

Dodon&Co Design and Construction Agency will be established a private agency to provide the package of design and construction services, which will include conceptual and brief design, development of the design project, construction documentation and monolithic services at 19Sh Nahirna Str., Vinnytsia.

The main type of economic activity of Dodon&Co Design and Construction Agency according to the Classifier of the Types of Economic activity is: 41.20 — construction of residential and non-residential buildings, 42.99 - construction of other facilities, 71.1 — activities in architecture and engineering, provision of technical consulting services, 71.11 — architecture activities, 74.10 — specialised design activities.

The purpose of the project is to establish the design and construction agency to develop the business of provision of high-quality monolithic services and a number of services of design, modelling and interior design in construction projects. It is a family business done by the coordinated team of the experts who implement construction projects in different areas. The agency will be focused on needs of customers with the different paying capacity. The design and construction agency will organise the continuous flow of orders to provide high-quality monolithic services.

The principal task of Dodon&Co Design and Construction Agencyis to provide full-scale design and construction services.

The project will be implemented in stages within a year, in accordance with the schedule that is made of the pre-investment, investment and operational stages (Table 1).

Table 1. Implementation Schedule of Dodon&Co Design and Construction Agency

Stage	Actions	Deadline
Pre-investment stage	– fund-raising	January 2022
	– development of the business plan	
	– receipt of technical documentation	
	– funding	
Investment stage	– lease (purchase) of the premises	February 2022 - March 2022
	– purchase of the equipment	
	– purchase of the starting materials	
	– development and launch of the agency's website	
Operational stage	– achievement of the operating profit	By December 2022
	– achievement of the design capacity by the agency	

In order to optimise its project costs and income, Dodon&Co needs to develop the data base for the market entry strategy. It takes analysis of the market environment, assessment of the competition level, determination of the market capacity and prospects of its development in Vinnytsia.

II. LITERATURE ANALYSIS

The construction industry in our country has become one of the indicators showing that the Ukrainian economy is overcoming the crisis. The construction product index, which was less than 100% from 2012 to 2015, has been confidently demonstrating annual growth of construction product volumes since 2016. Thus, according to the State Statistics Service of Ukraine, the index in 2016 made 117.4%, in 2017 — 126.4%, in 2018 — 108.6%, in 2019 — 123.6%, in 2020 — 105.6% (Fig. 1).

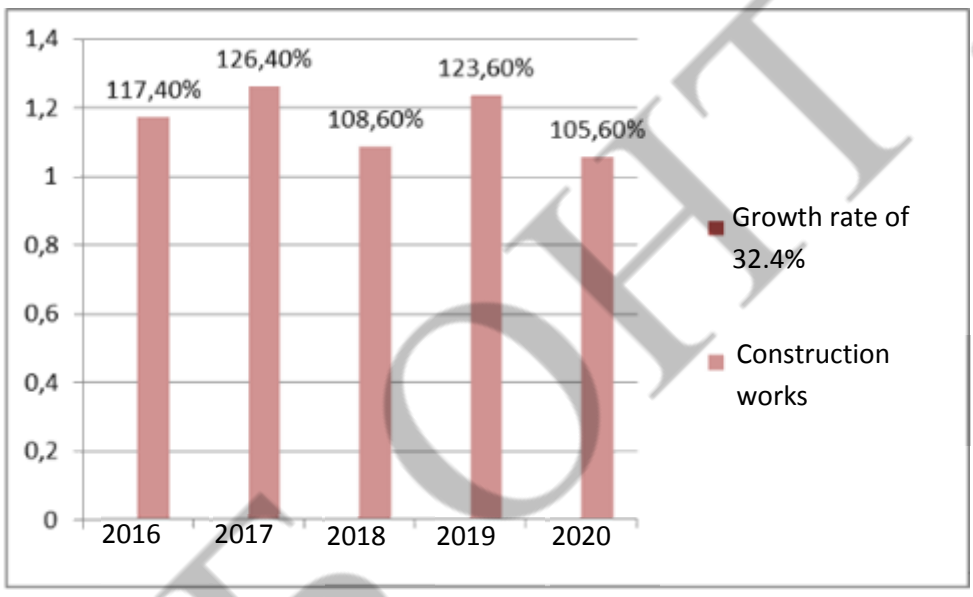

Figure 1. Dynamics of performance of the construction works in Ukraine in 2016-2020, in %

Source: data of the State Statistics Service of Ukraine

In 2020, the construction market demonstrated the negative dynamics in comparison with the previous years. The main negative factors of 2020 were the coronacrisis deteriorated with the reform of the state architectural and construction control and supervision introduced almost concurrently with the strict quarantine in March. As a result of the decrease in the household income and more complicated authorisation procedures in the construction industry, the volume of residential construction went down by almost 20%. For reference, in 2019, there was an increase by 4.2%. Instead, the engineering structures gave plus 3.9% (in 2019 — plus 26.6%). The outcome was reached owing to the Big Construction Programme.

The drivers of growth at the Ukrainian construction market are the sectors of construction of non-residential premises and engineering structures. The construction product indices by the types for January to August 2021 in the given sectors made 101.8%. The residential construction volume grew by 2% only in comparison with the equivalent period of the previous year.

The Ukrainian construction market kept developing in 2021, the demand levelled off, and the market is stable now. In general, the consumer demand has the good level although it is lower than it used to be in 2019.

Therefore, the construction industry facilitates development of small and medium-sized businesses more than any other industry. Development of the construction industry entails imminent economic growth in the country and resolution of numerous social issues.

According to the Main Statistics Directorate in Vinnytsia Region, the volume of the construction products made in the region in January 2020 made 196.1 million hryvnias.

The volumes of the construction products by the types made:

- for construction of buildings — 101.8 million hryvnias or 51.9% of the total volume;
- for engineering structures — 94.3 million hryvnias or 48.1%.

According to the Main Statistics Directorate in Vinnytsia Region, the construction product index in January 2020 made 131.7%.

In 2019, the regional enterprises and organisations utilised 15,524.2 million hryvnias of capital investment at the expense of all the funding sources, which was 1.6% less than the volume of the capital investment for 2018 in the comparative prices.

The most specific share of the capital investment (98.7% of the total volume) was utilised to create tangible assets, including:

- buildings and structures — 44.1% of all the investment;
- machines, equipment and tools, vehicles — 51.9%.

The main investment source still was own funds of enterprises and organisations, which resulted in utilisation of 68.9% of the total capital investment.

The share of the borrowed funds, bank and other loans made 3.7%.

The household funds for construction of the housing made 7.8% of the capital investment.

The state and local budget funds were 17.9%, and the other funding sources were 1.7%.

The volume of the housing commissioned in 2019 was 287.4 thousand square meters of the general area.

The general area of the housing commissioned in 2019 in comparison with the respective period of 2018 went up by 28.3%.

As for the region, most housing was constructed in Vinnytsia and Vinnytsia District (68.3% of the total volume of the housing).

The founders of the agency are experienced in provision of the monolithic construction services, so the market analysis should focus on the existing and potential competitors at the market.

Monolithic construction is a popular technology, both in construction of high-rise buildings, residential estates, office centres and low-rise industrial facilities or cottages. It is a complex unique technology of reinforced concrete construction, which enables constructing buildings and facilities of any shape and height in really unique projects in the short time frames.

The main principle of monolithic construction is that concrete is poured into the form work, which determines its future form. When the concrete sets, further actions are taken with or without the form work subject to characteristics of the building.

The benefits of monolithic construction include speed of construction, long period of operation of more than 110 in the moderate climate, high strength, even allocation of load upon the foundation and small weight, especially in comparison with the panel and brick structures.

Customised design projects should be developed with account of the terms of reference so that the monolithic building will have all the maximum benefits of the structure, and its defects will be mitigated. The monolithic construction market is developing actively now, which allows designers to use their imagination to the full. It means that the sector will have endless innovation.

Dodon&Co Design and Construction Agency is going to perform the entire working process: design to construction, engineering works, so the full package of the services will be provided.

The model of the product/market matrix is used to determine the market sweeping strategy (Fig. 2).

		MARKET	
		Old	*New*
PRODUCT	*Old*	Market entry *if the market is growing* √	Market development *if new niches appear*
	New	Development of the product *if the company is well known*	Diversification *if there is a small range*

Figure 2. Product/market matrix for Dodon&Co Design and Construction Agency

Thus, in order to enter the growing market and to offer the existing service in the best manner, Dodon&Co Design and Construction Agency must use the strategy for entering the market niche of the package design and construction services. The low-cost strategy should be used to win over consumers and develop the corporate policy, and development of the project needs the vertical integration strategy. Combination of certain aspects of these strategies will allow performing the project tasks and achieving the purpose.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of the competition is indicators of revenue and expenditure of the project, as well as indicators of the effectiveness of its implementation.

Subject - the project of creating a design and construction agency.

The purpose of the work is to determine the feasibility and effectiveness of the project to provide comprehensive construction services.

Research methods. The competition used general scientific and special methods that allow to systematically solve problems in the chosen direction of research. The most important theoretical and applied developments are based on the provisions of

general management theory, financial and economic management, strategic management and the use of such methods as: *systematic approach* - in the general study of the problems of implementation and implementation of the idea in a certain business atmosphere; *analysis and synthesis* with the use of abstraction, as well as modeling and formalization - in the development of the project of the Design and Construction Agency "Dodon & Co" to provide comprehensive construction services; *interpolation* - in determining the indicators of economic efficiency of the project; *discounting method* - when determining the future value of cash flow; *observation, comparison and measurement* - during the assessment of the market situation and the project implementation potential of the Dodon & Co Design and Construction Agency; *graphical method* - to illustrate the results of the analysis.

IV. RESULTS

In the competitive scientific work it is defined full-scale design and construction services, which will include conceptual and brief design, development of the design and construction documentation. Development of the unique, highly-functional and efficient design of the house for each customer. Qualified consulting at all the stages, from design to final implementation and start of work at the facility. Full-scale design that is consistent with the customer's lifestyle, needs and taste. Provision of monolithic services by the agency. Cooperation with the best experts and specialised suppliers. The services to be provided by Dodon&Co Design and Construction Agency are presented in Table 2.

Table 2. Services of Dodon&Co Design and Construction Agency

No.	Work types	Unit of measure (UAH)	Cost (UAH)
1	Cost estimate works	pcs	7,000
2	Design of residential houses	sq. m	50
3	Design of townhouses, cottages	sq. m	65
4	Design of low-rise houses	sq. m	70
5	Design of garages	pcs	5,000
6	Design of industrial buildings	sq. m	70
7	Replanning of premises	pcs	4,000
8	Monolithic services	with customised calculations	
9	Designer supervision	0.1% to 0.4% of the cost of the construction works	
10	Construction consulting	cons.	700
11	Interior design	sq. m	700
12	Obtaining authorisation documents	doc.	8,000

The benefits of Dodon&Co Design and Construction Agency will be provision of both individual services and a package of design and construction services. Customers will be offered a package of high-quality design and construction services provided by the highly-qualified experts at one place.

Analysis of Competitors

There are the following main competitors at the market of design and construction services in Vinnytsia.

Architectural Bureau "Korovai architects", Vinnytsia provides full-scale architectural services, including conceptual and brief design, development of the design and construction documentation.

TradeWade LLC, the construction and installation enterprise. TradeWade LLC offers the following services: monolithic construction, construction of residential and non-residential premises, major and minor repairs at buildings and structures, practical assistance and support during production of design documents.

Ukrbudproektrestavratsiia, Vinnytsia designs and constructs industrial and residential buildings. Services provided by Ukrbudproektrestavratsiia: construction consulting, drafts of construction intentions; examination of buildings and structures.

Architecture and Design Workshop PLIASOVYTSI LLC, Vinnytsia. Company's services: development of architectural projects of any complexity (from low-rise buildings to full-scale design of neighbourhoods, industrial enterprises, malls, cultural facilities and other residential and public buildings), development of building drafts, design documentation on construction and reconstruction, designer supervision over construction.

Plans, building design, Vinnytsia. The company's principal activity is selling standard designs of residential detached houses, customised design as well as provision of additional services that help construct the building promptly.

Orange Studio, the design studio in Vinnytsia, is a team of creative and experienced designers.

The analysis of competitors has shown that the full-scale construction services offered by Dodon&Co Design and Construction Agency are mostly provided by the Architecture Bureau "Korovai architects" and TradeWade LLC. Comparison of the competitive ability level by the types of works is shown in Figure 3.

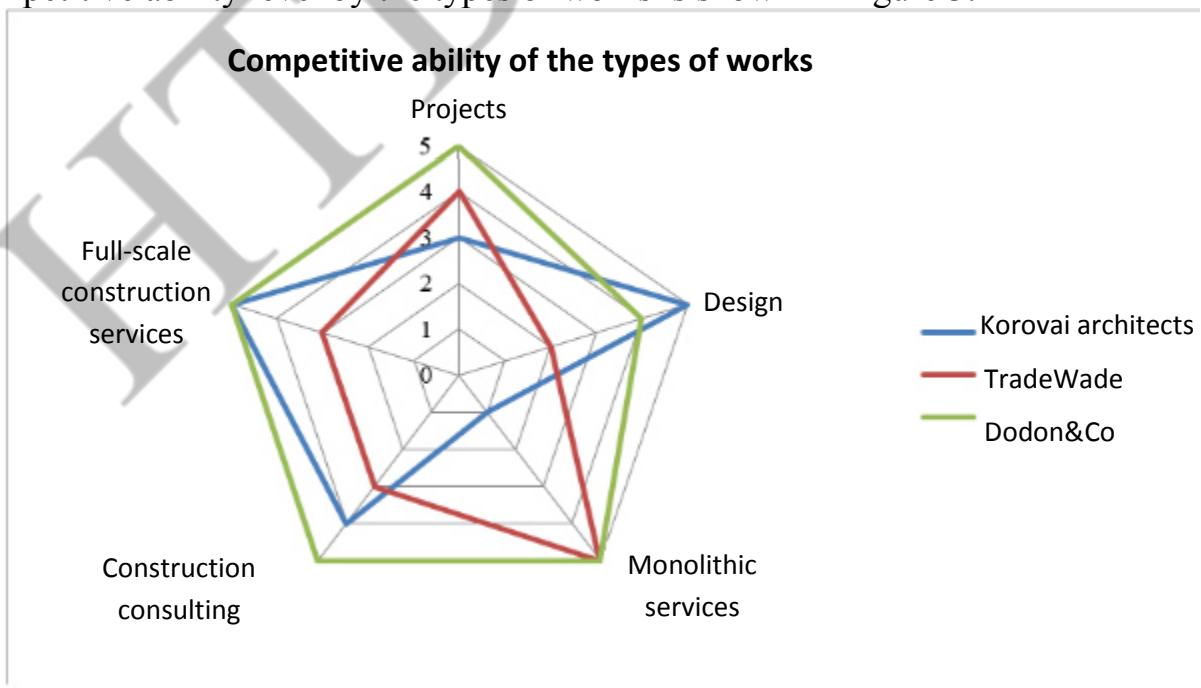

Figure 3. Competitive ability of the types of works

The benefits of Dodon&Co Design and Construction Agency will be full-scale design and construction services. Customers will be offered a package of high-quality design and construction services provided by the highly-qualified experts at one place.

Sales and Marketing Plan

The marketing strategy of Dodon&Co Design and Construction Agency will be developed within the market penetration strategy, the idea of which is to get new customers (without having to solicit the competitors' customers) owing to the growth of the market and target niche.

The annual sales volume plan for the Project will depend on growth of the segment in physical terms. Coverage of 70% of the new niche is planned by the end of the first year of the agency's operations (2022). When the services are provided during the year, the sales volume will be as follows (Table 3).

Table 3. Sales plan (provision of services) of Dodon&Co Design and Construction Agency

Period (months)	Estimated volume of the full-scale services (psc)	Estimated cost of the full-scale service (UAH)	Total (UAH)
1	1	28,500	28,500
2	2	28,500	57,000
3	3	28,500	85,500
4	3	28,500	85,500
5	4	28,500	114,000
6	4	28,500	114,000
7	5	28,500	142,500
8	5	28,500	142,500
9	6	28,500	171,000
10	6	28,500	171,000
11	7	28,500	199,500
12	8	28,500	228,000

The pricing strategy is developed within the framework of the low-cost strategy, so it will be the lowest in the niche.

For Dodon&Co Design and Construction Agency to enter the market and maintain its competitive ability, special marketing actions are necessary (Table 4).

Table 4. Marketing Plan of Dodon&Co Design and Construction Agency

Purpose	Establishment of the design and construction agency, market entry with building and interior designs by April 2022		
Analysis	stages	period	cost, UAH
	Analysis and assessment of the macro and micro environment of the project	November to December 2021	
	SWOT analysis	January 2022	
	Analysis of the target audience	February 2022	
Achievement tools	stages	period	cost, UAH
	Development and implementation of the advertising strategy	January-February 2022	

	Selection of advertising channels	February 2022	
	Development of the website	February 2022	5,000
	Contact collection system	on a permanent basis	
	Use of personal contacts for notification	on a permanent basis	
	Survey	February-March 2022	
	Survey	February-March 2022	
	Determination of marketing communication	on a permanent basis	
	Development of the SMM marketing strategy	on a permanent basis	
	Creation of a Facebook business page	April 2022	
	Development of advertising messages	on a permanent basis	2,000
	Search engine advertising	on a permanent basis	3,000
	Social media campaigns	on a permanent basis	
Budget:			**10,000**

The potential customers of Design and Construction Agency will be owners of private buildings, land plots, commercial and technical buildings. (Table 5.)

Table 5. Target audience of the business

Business model	Work types	Monolithic services
B2B Construction organisations, production, trade and state-owned, municipal and private enterprises	Cost estimate works, design of residential houses, townhouses, cottages, low-rise buildings, garages, industrial buildings, replanning of commercial and technical premises	Monolithic services for construction business customers, owners of commercial and technical premises
B2C Married couples and families with children who improve their living conditions or make their dream of living in a detached house come true	Cost estimate works, design of the residential house, garage, technical premises, replanning of premises, interior design, construction consulting, designer supervision, execution of authorisation documents	Monolithic services by customised orders

At present, the most efficient methods for an advertising campaign are Internet and social media advertising. The active advertising campaign will be run only in 2022.

Dodon&Co Design and Construction Agency is planning the following types of advertising:

- Own small promo-website that describes its services, prices and works performed
- Social media page

- Advertising at online bulletin boards
- Placement of advertising materials in construction stores
- Partnership with construction companies and construction stores
- Placement of information materials into mail boxes
- Recommendations by existing customers

Both the advertising campaign and website development costs must be optimum within the low-cost strategy. As of March 2022, development of the company's website costs at least UAH 5,000, and expenses for maintenance and promotion thereof depend on the package of services. The average price of the optimum business package is at least UAH 1,000.

Also, it is planned to make the service more accessible for consumers by developing Dodon&Co mobile application, which plays an image role (care about consumers, exclusivity of the service, innovation by the agency), makes the service closer to immediate consumers, improves the service and generally enhances the quality.

Organisational structure of Dodon&Co Design and Construction Agency

By its legal form, Dodon&Co Design and Construction Agency is a small enterprise whose activity does not require many employees, and the low-cost policy does not provide for high salaries. In the beginning, no employees are going to be hired, and the agency is going to cooperate with the outsourcing companies.

The senior executive of the agency is the Director, who is also the owner. His principal functional duties are to resolve current and legal issues of the company, to enter into contracts with suppliers and contractors, to regulate the level of salaries, to select the agency development strategy, to implement the pricing policy etc. The Director carries out overall management of Dodon&Co Design and Construction Agency and controls implementation of strategic tasks by the staff.

The organisational staff management structure is based on linear connections (Fig. 4).

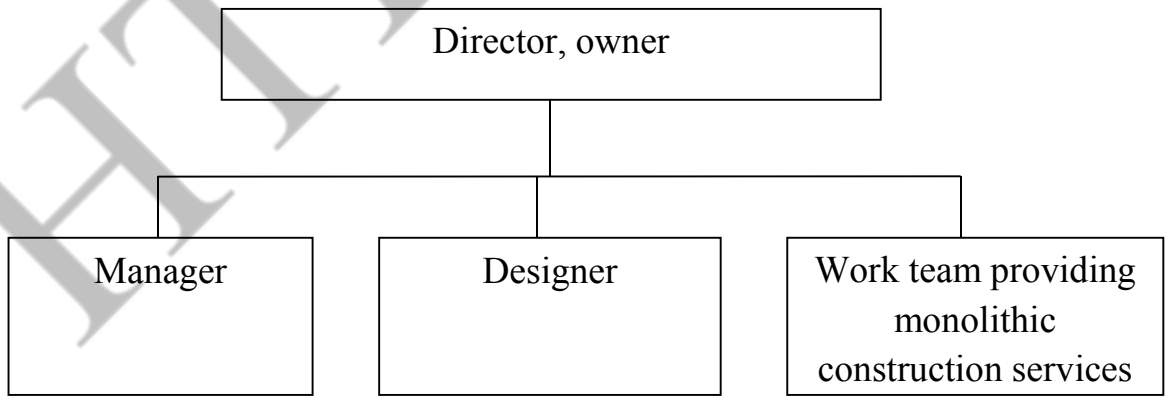

Figure 4. Organisational staff management structure of Dodon&Co Design and Construction Agency

The Director is in charge of the manager, who is responsible for: receiving orders on the website and by telephone, forming orders and organising project implementation, maintaining the customer base, and advertising.

The designer's main duties include: collecting design input data, resolving technical issues in connection with the designated objects during the entire construction design period, designer supervision over construction of the objects being designed, consulting on the issues within the competence, participating in analysis and consolidation of practical experience in development of projects and implementation thereof in construction, and proposing feasible adjustments to the general and principal design solutions.

SWOT analysis of operations

The low-cost strategy is based on the SWOT analysis of operations, which is presented in Table 6.

Table 6. SWOT analysis of operations

	S, Strengths	**W, Weaknesses**
	1. Wide range of types of activities 2. Work team providing monolithic services and tools 3. Established connections with construction organisations 4. Contacts with highly-qualified experts who are ready for partnership 5. Qualified management staff 6. Experience in design software 7. Experience in modern technologies for monolithic services 8. Social project sponsorship	1. Insufficient experience in provision of full-scale design and construction services 2. Insufficient experience in partnership with highly-qualified experts 3. Need to study new versions of software products for design
O, Opportunities	**SO, Strategic solutions**	**WO, Strategic solutions**
1. Consumers' interest in high-quality full-scale design and construction services 2. Use of the potential of the family business team in construction services, design and organisation of options of full-scale design and construction services	General strategy for developing full-scale design and construction services by the types of activities, more active communication with construction organisations, development of partnership with highly-qualified experts	1. Strategic options of packages of design and construction services 2. Strategy for partnership with highly-qualified experts 3. IT strategy for updating software versions and training
T, Threats	**(ST), Strategic solutions**	**(WT), Strategic solutions**
1. Insufficient funding to implement the general development strategy 2. Decrease in the real household income as a result of the economic crisis 3. Decrease in orders as a result of Covid-19 quarantine 4. Appearance of new competitors 5. Weather conditions	1. Engagement of investors into new projects by developing a business plan (S-5, T-5) 2. Use of efficient marketing communication channels (S-4,6, T-2, 4) 3. Analysis of strategic solutions and practical implementation of equivalent services of competitors (S-1, T-4)	1. Discounts on the package of design and construction services (W-1, T-2) with different options 2. Discount to regular customers (W-1, T-2) 3. Optimisation of costs with alternative packages (W-1, T-2) 4. Optimisation of marketing communication costs (W-1, T-2)

According to the SWOT analysis, the strategic solutions that will be gradually implemented within the business plan have been established.

Financial and Investment Plan

The financial plan of Dodon&Co Design and Construction Agency provides for grouping of income and costs of the pre-investment, investment and operational stages by elements and items, on the basis of which economic performance and feasibility of the business idea are determined.

The estimated costs of the first year of the Project are UAH 200,670; UAH 252,246 are costs of the investment stage that form initial investment. The estimated income of the Project is UAH 677,828, plus depreciation of the fixed assets during the first year: UAH 1,539,000.

The detailed expenses for market entry to be incurred by Dodon&Co Design and Construction Agency are presented in Table 7.

Table 7. Detailed expenses

Description	**Amount (UAH)**
Expenses for fixed assets (non-recurring ones)	
PC	53,448
Laptop	62,472
Total	**115,920**
Expenses for intangible assets (non-recurring ones)	
Website development	5,000
AutoCAD software	57,278
3-D MAX software	54,898
АВК-5	9,150
Total	**126,326**
Sales expenses (monthly ones)	
All types of advertising	5,000
Website maintenance and update	2,000
Personal vehicle expenses	4,000
Total	**11,000**
Administrative expenses (monthly ones)	
Communication	300
Internet	200
Office supplies	200
Coffee, tea, water for customers	500
Lease of premises	3,000
Total	**3,900**
Business expenses (monthly ones)	
Utilities	300
Total	**300**
Financial expenses (monthly ones)	
Cash withdrawal %	
Payment system service %	
Taxes	5% of profit
Unified social tax	1,320
Total	**1,320+ 5% of profit**
Organisational expenses (non-recurring ones)	
Licensing of activities	10,000
Total	**10,000**

High-quality services of Dodon&Co Design and Construction Agency require the computer equipment of the higher level to work with the special software and to develop the website for dynamic communication with customers. Moreover, there are planned monthly expenses for advertising, website maintenance and transport.

The aggregate income is planned to equal the aggregate expenses (to reach the break-even point) at the fifth month.

Starting from the fifth month of project implementation, Dodon&Co Design and Construction Agency will obtain the additional result, profit.

The design process will involve such software as AutoCAD, 3D MAX, ABK-5. This software requires modern hardware, namely a PC, a laptop.

Figure 6 shows the share of the founders' own contribution and the investment necessary.

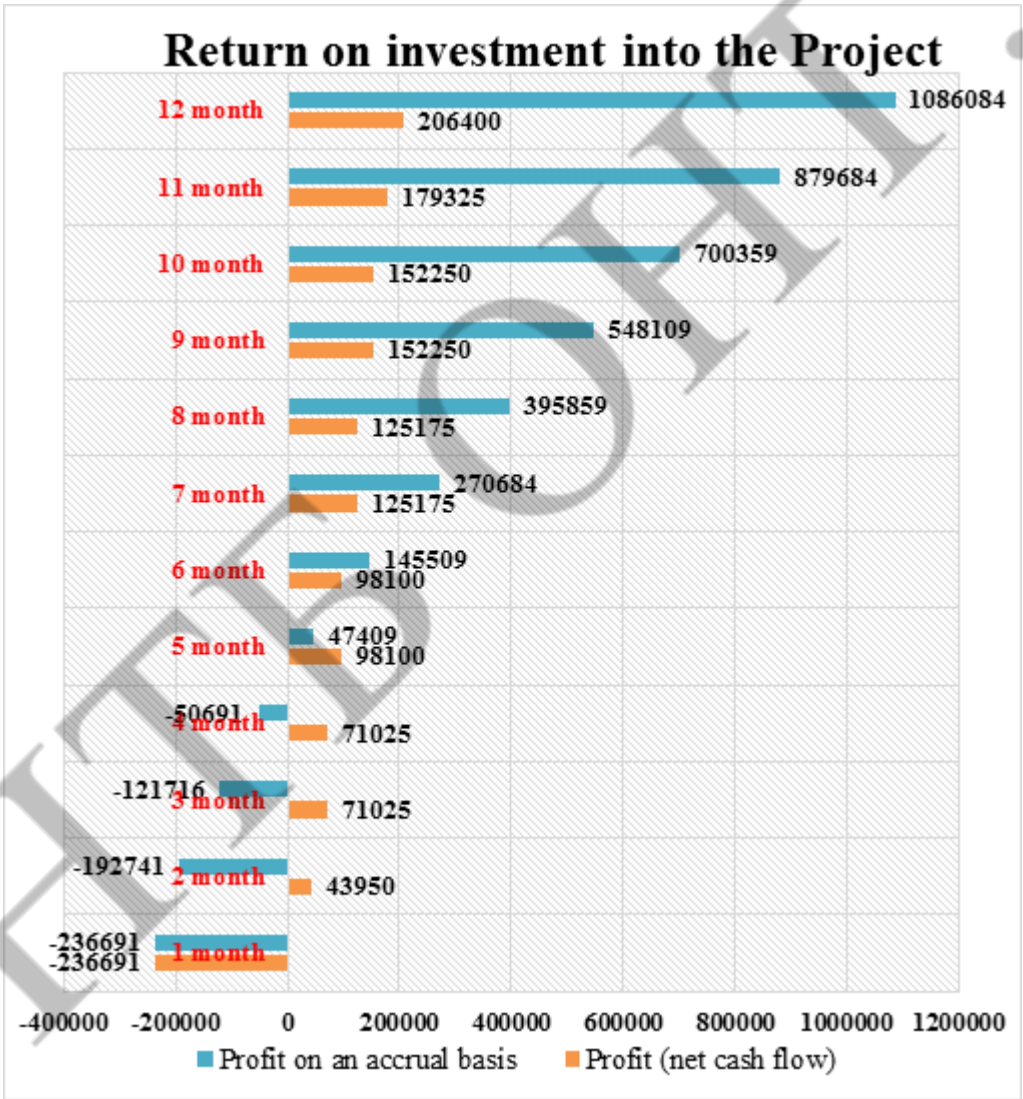

Figure 5. Business profitability (break-even point)

UAH 256,446 is the amount necessary to start the business, which is 100%. Own contribution: UAH 28,200, which is 11%.

Licensing — UAH 10,000.

Lease of premises — UAH 3,000.

Website development — UAH 5,000.
Advertising — UAH 5,000.
Transportation expenses — UAH 4,000.
Communication — UAH 300.
Internet — UAH 200.
Office supplies — UAH 200.
Coffee, tea, water for customers — UAH 500.

Modern specialised equipment for monolithic services (approximate value of UAH 100,000, purchased in 2019-2021, period of provision of monolithic services). Open-source software.

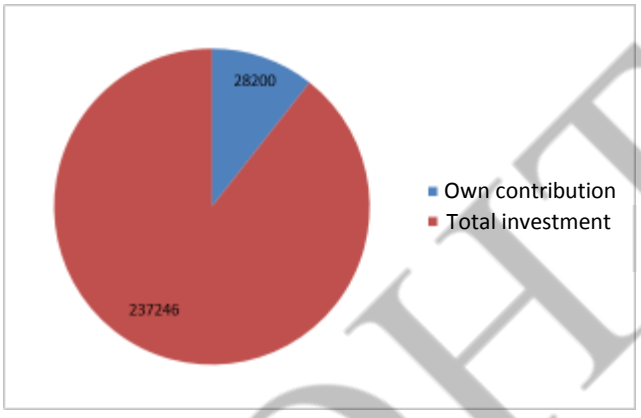

Figure 6. Shares of own contribution and investment

The investment is going to be raised as grants, loans and partnership.

The necessary investment will be used to purchase the specialised software and hardware, to provide design services

V. CONCLUSIONS

Studies of the construction services market have shown that the construction industry facilitates development of small and medium-sized businesses more than any other industry. Development of the construction industry entails imminent economic growth in the country and resolution of numerous social issues.

Monolithic construction is a popular technology, both in construction of high-rise buildings, residential estates, office centres and low-rise industrial facilities or cottages. It is a complex unique technology of reinforced concrete construction, which enables constructing buildings and facilities of any shape and height in really unique projects in the short time frames.

The benefits of Dodon&Co Design and Construction Agency will be full-scale design and construction services. Customers will be offered a package of high-quality design and construction services provided by the highly-qualified experts at one place.

The results of research and approbation can be used for similar business projects.

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FEATURES OF ACCOUNTING OF EXPENDITURES OF BUDGET ORGANIZATIONS WITHIN THE FRAMEWORK OF CROSS-BORDER COOPERATION PROJECTS

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Cross-border cooperation programs are one of the key tools for the European Union to support its neighbors. This assistance is provided within the framework of two large-scale initiatives of the European Union: the European Neighborhood Instrument and the Territorial Cooperation Program of the Eastern Partnership countries. The money comes in the form of grants. These funds should help address common challenges related to the rapid movement of people and goods, humanitarian and environmental issues. For accounting purposes, grants are financial resources that the donor provides to the recipient on a non-repayable basis and which are aimed at achieving certain objectives set by the grantor. From the standpoint of accounting, grants are included in income from non-exchange transactions. Grants are own revenues of budgetary institutions and bodies of government and local self-government. In this case, grants have a specific purpose and should be spent on goals defined by the person providing the grant. Upon receipt of grant funds, the grantee is provided with the Instruction within which the grantee must act. This document states that accounting is conducted in accordance with national law. The main problem of grant accounting is the lack of common approaches to developing effective mechanisms for improving the accounting system taking into account the requirements of international standards, lack of elaboration of the transition to common methodological principles, as well as creating unified organizational and information support The paper considers in more detail the accounting in the budgetary institution of the projects of the Joint Operational Program of Border Cooperation "Black Sea Basin 2014 - 2020" Black Sea Basin. The main problems that arise in accounting under national law and the discrepancy with accounting in other EU countries are studied.

Keywords: *accounting, cross-border cooperation, grants, international standards, revenues, expenditures, budget organization, audit, higher education institutions.*

I. INTRODUCTION

Today, cross-border cooperation is carried out both at the interstate level and at the level of territorial communities, their representative bodies, local executive bodies. Such cooperation contributes to the social and economic convergence of border regions and the creation of new opportunities for their development, including the development of economic, social, scientific and technical, environmental, cultural and other relations, exchange of experiences.

Ukraine has borders with seven states, 19 of the 27 administrative-territorial

units are border. On the territory of such border regions as Vinnytsia, Volyn, Zakarpattia, Ivano-Frankivsk, Lviv, Luhansk, Odessa, Sumy, Kharkiv, Chernivtsi, Chernihiv, Donetsk, nine Euroregions were created - Bug, Upper Prut, Dniester, Dnieper, Carpathian Lower Danube, Slobozhanshchyna, Donbass and Yaroslavna, five Euroregions created with EU member states (Poland, Slovakia, Romania, Hungary). Cross-border cooperation has been carried out within Euroregions since 1993.

The Government of Ukraine adopted a resolution "On approval of the State Program for the Development of Cross-Border Cooperation for 2021-2027" [1.1], which was developed by the Ministry of Regional Policy pursuant to the Law of Ukraine "On Cross-Border Cooperation" [1.2].

The program outlines the goals and priorities, contains specific ways and means of solving problems, action plan, sources of funding, identifies the responsible executors of these activities.

Its implementation should continue to form a positive international image of our country, solve the problem of disparities in socio-economic development of Ukraine, increase employment in the regions of Ukraine, promote exports and imports of goods and services, improve the environment, attract funding for cross-border projects and create new bodies for cross-border cooperation.

Ukraine is currently a participant in four joint operational programs (either cross-border or cross-border cooperation programs). These are: "Ukraine - Poland - Belarus", "Ukraine - Hungary - Slovakia - Romania", "Black Sea Basin", "Ukraine - Romania". In December 2016, the Government of Ukraine and the EU concluded four relevant agreements on the financing of joint operational programs for cross-border cooperation.

These programs are funded by the European Union under the European Neighborhood Policy (ENP). The EU thus supports reforms in the political, economic and social spheres in certain countries that are members of the EU or have borders with it.

Quite often the European Regional Development Fund and the Instrument for Pre-Accession participate in the financing of programs. However, the main donor of all projects is the European Union.

The European Neighborhood Instrument (ENI) is the financial instrument of the European Neighborhood Policy, through which these programs are financed and within which they operate.

Analysis of international experience shows that in many developed countries one of the important tasks is to focus on finding alternative sources of funding.

Given the limited budget, an important area of business should be to find sources of funding from non-governmental and international funds, programs and grants. For many organizations, a grant is an opportunity to move to a qualitatively different level of work. That is why it is important to be able to take advantage of this opportunity and look at potential donors from a long-term partnership.

The purpose of the work is to conduct a comprehensive study of the features of the reflection in the accounting of the costs of grants received by budgetary organizations.

II. LITERATURE ANALYSIS

Despite the urgency of this issue, we see the lack of scientifically sound developments in the methodology of accounting for grants in domestic science and legislation. The issue of accounting for the financing of non-profit projects is the development of National Accounting Regulations (Standards) (NP) and National Standards for Public Sector Accounting (NSDS). Research in this area has been covered in the works of many scientists, such as A. Rybalchenko, S. Londara, V. Nikitenko, N. Vnukova, P.I. Gaidutsky, VP Galushko, S.I. Zorya, B.I. Paschaver, D.W. Polozenko, VV Yurchyshyn et al., But the issues of accounting methodology in modern conditions of decentralization are open and insufficiently studied. In addition, these issues are practically not considered outside the public sector.

Problems of methodology and organization of accounting and reporting of various non-profit organizations are considered in the works of many domestic scientists: PY Atamasa, MT Belukhy, F.F. Butynets, RT Jogi, S.O. Levitskaya, LG Lovinska, S.V. Svirko, VV Sopka and others

The lack of accounting regulations that take into account the peculiarities of accounting for state grants necessitates the improvement of methodological, methodological and organizational support for accounting for state grants.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of the study was cross-border cooperation in the form of participation in grants provided by the European Union and the cost of items under the budget of these projects.

The subject of the study is the method of accounting for the costs of budgetary organizations in cross-border cooperation projects.

The methodological basis is scientific methods based on the requirements of objective and comprehensive analysis of cost accounting of budgetary organizations.

In solving the tasks were used general scientific methods and techniques of research: monographic, economic - statistical, graphic, balance, tabular and empirical research methods: observation, comparison, description, generalization, analogy.

IV. RESULTS

4.1. The economic essence of grants

Grant (English "grant" - a gift, grant, scholarship) is a targeted financial grant provided to scientists for research [2.1].

A grant is a free targeted grant provided on a competitive basis to an organization, initiative group or individual for the implementation of the declared project in a particular field of activity [2.1].

Grant - a charitable contribution or targeted donation provided by individuals and legal entities in cash and in kind [2.1].

Grant - funds transferred free of charge by the donor (fund, corporation, government agency or individual) to a non-profit organization or individual to perform

a specific job [2.2].

Grant - funds, equipment or other resources that are irrevocably transferred by the donor (foundation, corporation, government agency or individual) to a non-profit organization or individual to perform a specific job. Unlike a loan, the grant does not have to be repaid [2.3].

Grants are the most common tool for financing projects through donor organizations, and receiving grant assistance allows you to concentrate in the process of project implementation a large enough amount of funds for its implementation. However, the funds received in the form of a grant must be used to meet the intended objectives of the proposed project.

The most common source of additional resources for enterprises are funds that provide assistance in the form of grants. In domestic law, there are several definitions of the term "grant" presented in table. 1.

Table 1. Definition of "Grant" in accordance with national law

Source: Developed by the author, using the legislation of Ukraine

Legislation	The essence of the concept
1	2
Law of Ukraine "On Scientific and Scientific-Technical Activity" [1.3]	Grant - financial or other resources provided on a gratuitous and non-refundable basis by the state, legal entities, individuals, including foreign and (or) international organizations for the development of material and technical base for scientific and scientific-technical activities, specific fundamental and (or) applied scientific research, scientific and technical (experimental) developments, in particular the remuneration of scientific (scientific and pedagogical) workers in the framework of their implementation, in the areas and under the conditions specified by the grantors.
Law of Ukraine "On Culture" [1.4]	Grant - financial resources provided on a non-refundable basis to the entity conducting activities in the field of culture, for the implementation of cultural and artistic project
Law of Ukraine "On the Ukrainian Cultural Foundation" [1.5]	Grant - financial resources provided on a gratuitous and non-refundable basis by the Ukrainian Cultural Fund to an entity operating in the field of culture for the implementation of a project, the decision to finance which was made in the manner prescribed by this Law
Law of Ukraine "On Implementation of the Global Fund to Fight AIDS, Tuberculosis and Malaria in Ukraine" [1.6]	Grant - Global Fund funds provided to the principal recipient (s) on a gratuitous and non-repayable basis (non-repayable financial assistance) for the implementation of targeted measures in the field of prevention and combating HIV / AIDS, tuberculosis in Ukraine and is charitable

Order "On approval of the Procedure for registration of international scientific and technical programs and projects implemented in the framework of international scientific and technical cooperation by Ukrainian scientists" [1.7]	Grant - financial or other resources provided free of charge and non-refundable basis by foreign states and (or) international organizations for the development of material and technical base for scientific and technical activities, conducting specific basic and (or) applied research, scientific and technical experimental) developments, in particular for the remuneration of scientific (scientific and pedagogical) workers in the framework of their implementation, in the areas and under the conditions determined by the grantors

The concept of grants for accounting purposes is provided in International Accounting Standard 20 "Accounting for Government Grants and Disclosure of State Aid". In accordance with paragraph 3 of IAS 20, government grants are government assistance in the form of transfers of resources to an entity in exchange for past or future compliance with certain conditions associated with the entity's principal activities. They do not apply to such forms of state aid, which cannot have a reliably determined value, as well as to transactions with the state, which do not differ from the usual commercial operations of the entity "[1.8].

Thus, grants are targeted funds provided free of charge and on a non-refundable basis to non-profit organizations or individuals for the implementation of social projects, charitable programs, research, training, and other socially useful purposes, followed by a report on their use. grantor.

Grants are awarded based on the results of grant programs-competitions, which are announced for non-profit organizations.

Grant programs can be open (when all organizations that meet certain requirements of the donor organization are eligible) or closed (when only organizations that meet the specific conditions of the grant program are allowed, for example, only regional partners of the donor organization or organization that previously received did not receive) grants from this (or other) fund, organization of a certain administrative region, etc.).

It is generally accepted that a grant is a certain amount of money. But analyzing the concepts presented in table. 1. It can be concluded that in fact not only financial but also other grants can be provided as grants, such as material and technical resources received by enterprises, citizens, public organizations and legal entities to perform certain tasks or achieve the goals specified in the terms of this grant, formulated in the whole project and described in the project application. It is important to understand that a grant is a resource that should be focused solely on implementing the project's stated intentions.

4.2. Accounting for the cost of grant funds

The methodology of accounting for grant costs in Ukraine is based on generally accepted in international practice accounting principles, which include the principles

of: continuity of activities; autonomy; accrual; double entry; monetary meter; cost; implementation; materiality; prudence; continuity; compliance; periodicity.

Both large infrastructure projects (Large Infrastructure Projects, LIP), as well as conventional and micro projects are financed. The budget of large projects can reach 7 million euros, ordinary (regular) - 2.5 million euros, micro - 60 thousand euros.

If we talk about cross-border cooperation programs, it is worth mentioning the TESIM project (Technical Support to the Implementation and Management of ENI CBC programs). This is a technical assistance project of the Directorate General for Enlargement and Neighborhood of the European Commission. The project provides support in the implementation and management of programs as a kind of main consultant during the implementation of cross-border cooperation programs.

One of the projects in which the Odessa National Academy of Food Technologies participates is the Black Sea Basin.

The program covers Armenia, Bulgaria, Georgia, Greece, Moldova, Romania, Turkey and Ukraine. During 2014-2020, 54 million euros were allocated for the program. Thematic areas of projects are the development of tourism and private entrepreneurship, modernization of the agricultural sector and increasing its competitiveness, protection of the environment, including the Black Sea and its basin.

It should be noted that all projects under international cooperation programs are similar, although not without some technical differences. Accordingly, the algorithm for cost accounting for them is also similar.

When concluding a grant agreement for a specific project, the main beneficiary and beneficiaries participating in the project are selected.

The main beneficiary is the organization specified in the Project Description, which has signed the Grant Agreement and which is responsible for the financial and substantive implementation of the Project.

Beneficiary - the organization specified in the Project Description, participating in the Project under the conditions specified in this Agreement, associated with the Principal Beneficiary under the Partnership Agreement for the implementation of the Project.

The Lead Beneficiary and Beneficiaries must ensure that expenditure for the project is easily identified and traced to and within their accounting and bookkeeping systems.

The accounts:

a) may be an integrated part or an adjunct to the Lead Beneficiary and the Beneficiaries' regular system;

b) have to comply with the accounting and bookkeeping policies and rules that apply in the country concerned;

c) enable to easily trace, identify and verify all revenue and expenditure related to the project.

The common provisions on accounting included in the EC Financial Regulation no 966/2012 on the financial rules applicable to the general budget of the Union.

The project accounts are the main source of information for:

• Following up the project budget

• The preparation of the financial reporting

• The expenditure verification accompanying the payment requests
• Any financial control by MA/JTS, EC or other authorised bodies

The Project Implementation Manual (PIM) states the need for:

✓ Always use the accounting methods established by the national legislation of the respective country!

✓ Use analytical (cost) accounting codes if project accounts are maintained as part of your organization's regular accounting system.

✓ Be sure to organize accounts (computerized or manual), bearing in mind all supporting documents required by applicable national law.

Eligible Costs are the actual costs incurred by the Lead Beneficiary and/or beneficiaries that meet all of the following criteria:

a) they are incurred during the project implementation period; An exception to this rule concerns the costs associated with the final reports, only for the verification of costs and, if necessary, the final appraisal of the project. These costs may be incurred after the project implementation period.

b) they are indicated in the estimated total budget of the project;

c) they are necessary for the implementation of the project;

d) they are identifiable and verifiable, in particular recorded in the books of the Lead Beneficiary and/or beneficiaries;

e) they comply with the requirements of the current tax and social legislation;

f) they are reasonable, justified and comply with the requirements of sound financial management, in particular with regard to economy and efficiency, as well as the requirements of visibility;

g) they are supported by invoices, proof of payment and/or documents of equivalent probative value;

h) notwithstanding subparagraph (a), the costs associated with studies and documentation for projects, including the infrastructure component, are eligible even if incurred during the project preparation period, which begins after the date of approval of the Project Program.

The grant cannot be profitable for the lead beneficiary or any of the beneficiaries of the project. Profit is the excess of receipts over eligible costs approved by the MA at the time the balance request was submitted.

Keeping clear and up-to-date documentation is vital for the Lead Beneficiary and beneficiaries. Without them, it is not possible to prove that the declared costs are in accordance with the terms of the Grant Contract.

Eligible costs must be identifiable and verifiable, and in particular must be recorded in the books of the Lead Beneficiary. The Lead Beneficiary and beneficiaries must allow access to agents of the Audit Authority, the European Commission, the European Anti-Fraud Office and the European Court of Auditors, the relevant authorities in the countries participating in the Programme, the MA and any bodies/organizations authorized by the MA to carry out inspections, inspections and audits, as well as to examine supporting documents, accounting documents and any other documents related to project financing. Supporting documents and records must be available for verification within five years of the payment of the Program balance.

Supporting documents and records should be easily accessible and kept in such a way as to facilitate verification.

The cost of each project must be provided for under one of the budget items and a group of activities.

For costs to be eligible, beneficiaries must demonstrate that they have the appropriate supporting documentation for each type of cost, as described below for each budget line.

For example, personnel costs, including internal management or internal expertise, are eligible provided they are paid to employees who are directly employed by the relevant beneficiary and who perform tasks related to the project. Personnel may either be already hired or hired by the Beneficiary specifically for the project after the conclusion of the Grant Contract.

Personnel costs should only be declared on the basis of actual costs!

With regard to civil servants involved in the implementation of the project, their salary is entitled to the condition:

a) civil servants directly employed by the Lead Beneficiary and/or beneficiaries

b) wages are paid in accordance with the relevant national legislation of the relevant Lead Beneficiary/beneficiaries in relation to the employment of civil servants. In such a case, these salaries can be considered as co-financing.

Expenditure on staff costs shall be limited to the following:

a) salary payments related to activities which the entity would not carry out if the project concerned was not undertaken, fixed in an employment/work contract, an appointment decision (both hereinafter referred to as "employment document"), or by law;

b) any other costs directly linked to salary payments incurred and paid by the employer, such as employment taxes and social security payments provided that they are:

- fixed in an employment document or by law;
- in accordance with the legislation referred to in the employment document and with standard practices in the country and/or organization where the individual staff member is actually working; and
- not recoverable by the employer.

In brief, the calculation of the cost of an employee includes the following:

- Gross salaries;
- Social security costs;
- Other remuneration-related costs , according to the national legislation provisions in force.

Up to 7% of eligible direct costs of the project, excluding costs incurred in relation to the provision of infrastructure, can be applied for indirect costs incurred by the Lead Beneficiary/Beneficiaries and necessary for the implementation of the project.

The following costs shall not be considered eligible:

a) debts and debt service charges (interest);

b) provisions for losses or liabilities;

c) costs declared by the Lead Beneficiary and/or the Beneficiaries and financed by another project or programme from any other sources;

d) purchases of land or buildings;

e) exchange-rate losses;

f) duties, taxes and charges, including VAT, except where non-recoverable under national legislation, unless otherwise provided in appropriate provisions negotiated with CBC partner countries and as identified in the related Financing Agreement;

g) loans to third parties;

h) fines, financial penalties and expenses of litigation;

i) contributions in kind;

j) costs exceeding the threshold of 15% of the EU contribution established for activities outside the Programme eligible area;

k) used purchased equipment.

The savings identified in the project's budget during its implementation can be used to broaden the scope of planned activities and/or undertake additional complementary activities.

All the additional activities, financed from the saved funds, should have a complementary character to the implemented project, ensure a stronger contribution to the project's results and objectives and guarantee greater benefits to the identified target groups.

4.3. Verification of costs in the framework of cross-border cooperation projects

European institutions, which allocate funds and want to be sure of their legal and correct use, are the customers of project cost audits. That is why the opinion of an independent auditor, who provides objective and unbiased information, is extremely important, and therefore such work will be in demand. In addition, the number of cross-border cooperation programs will grow.

Table 2. National system of management and control over the implementation of cross-border cooperation programs

Source: Developed by the author, using the legislation of Ukraine

National Authority for Joint Operational Programs	National Checkpoint	Representative of Ukraine in the group of auditors	National contact point
Ministry of Economic Development and Trade	Ministry of Finance of Ukraine together with the State Audit Service and the Audit Chamber of Ukraine	Accounts Chamber	Ministry of Internal Affairs of Ukraine
Effective functioning of the national system of management and control over the implementation of cross-border cooperation programs	Formation of an open list of independent auditors for auditing expenditures on projects within the framework of cross-border cooperation programs, their training	Cooperation with the audit team, participation in the development of procedures for the audit team and audit strategy	Cooperation with the European Office for the Prevention of Abuse and Fraud

Moreover, the inspection is quite formalized, and its features are clearly prescribed by the customer. All the auditor needs is to strictly adhere to these requirements and understand their essence. Any deviation from the templates, rules, requirements is highly undesirable, because in this case the work of the auditor may not be accepted.

When starting work on a project, the auditor should read the Project Implementation Manual very carefully. In essence, this is a technical task that is an appendix to the grant agreement. It determines the front of the auditor's work, provides guidance on the procedures to be followed, and describes the customer's expectations from the audit.

It is also necessary to read the Guidelines for reporting in eMS (Guide on reporting in eMS).

Electronic Monitoring System (eMS) is a special electronic monitoring system, which contains all the necessary information on projects and documents for the work of the auditor. It also shows the stages of project implementation, the results of cost audits, etc. The appointed auditor receives individual access to the project and works in this system.

To date, projects of three cross-border cooperation programs have been included in eMS: "Ukraine - Hungary - Slovakia - Romania", "Black Sea Basin", "Ukraine - Romania". Implementation of the projects of the program "Ukraine-Poland-Belarus" is still carried out outside of this system.

The system is maintained by the Joint Technical Secretary (JTS). It is created by the governing body (global and national) for the purpose of practical implementation of programs and projects.

The main purpose of the auditor - to verify the reality, correct reflection in the accounting and legality of income and expenses on the project.

During the cost audit, the auditor performs general procedures, budget cost compliance procedures, analytical review, and some selected costs in accordance with the terms of the grant contract.

The auditor uses the rules and regulations applicable to the selection of the relevant cost sections, as well as the principles and criteria for verifying the cost recovery specified in the cost verification engagement.

The auditor examines all costs incurred: staff, travel, external examinations, equipment, administrative and entertainment costs, etc., depending on the specifics of a project.

The auditor's report is prepared according to a form that can also be found in eMS. As a rule, the report should be prepared in English, as it is working in cross-border cooperation programs.

Thus, the audit of project costs under cross-border cooperation programs is, in essence, a set of arithmetic operations that confirm or refute the proper use of funds by the recipient, audit compliance with the beneficiary of all documents accompanied by grants, and collection of evidence of productive work. over the project. At the same time, the auditor must take very seriously all the formal requirements of the clients of such an audit.

V. CONCLUSIONS

The legislation allows higher education institutions to attract additional grant funding to develop their core business. However, as our study shows, raising such funds is associated with significant difficulties due to legislation. These difficulties are due to the fact that higher education institutions, which are financed from the state budget, have the status of budgetary institutions. This imposes significant procedural restrictions on them, both in terms of accounting and in terms of the use of funds - even those they receive from donor organizations in the form of grants or charitable contributions. In particular, the legislation clearly regulates the procedure for accounting for such funds, possible areas of their use, the procedure for purchasing works and services, the level of remuneration of employees involved in the implementation of projects, and so on.

The analysis of the legal framework showed the unregulated accounting and analytical support of grants as alternative sources of enterprise financing. Based on a thorough analysis of existing regulations, the essence of the concept of "grants" is determined. It is determined that one of the main directions of improving the regulation of accounting for grant expenditures in cross-border cooperation is the development of a separate regulatory document that would regulate the methodological principles of accounting, receipt and use of funds and its reflection in financial statements.

The practice of accounting for the costs of budgetary organizations in the framework of cross-border cooperation projects shows the inconsistency of Ukrainian legislation with accepted European standards. Thus, the adaptation of accounting of the received guarantors to the requirements of international standards will help increase the informativeness of the reporting of budgetary organizations and increase the provision of assistance and implementation of programs of socio-economic development of Ukraine.

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RESEARCH OF STRATEGIC GUIDELINES FOR THE DEVELOPMENT OF HOTEL ENTERPRISES

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Abstract.*With the deepening of globalization and global integration processes, the modern hotel business, under the influence of external and internal changes, is forced to seek new tools and management methods. Successful operation and continuity of hotel business is paramount in a market economy, dynamically uncertain and unstable environment.*

Today, domestic and foreign economists have created a methodology for choosing strategies for enterprise development. Theoretical bases and practical recommendations on hotel business strategic development, hotel economy strategic management problems are investigated in scientific works. However, despite the scientific research depth, the hotel business development strategies issues have not been fully covered in scientific papers. Each hotel is unique, so the developing process a strategy for each hotel business is unique, it depends on the company's market position, dynamics of its development and potential, behavior of competitors, characteristics of goods or services, economy, cultural environment and many other factors. Thus, there is a difficult task - to develop theoretical and methodological aspects and to form practical tools for the hotel business development strategies.

During the study of the strategic management system were used: a systematic approach; method of comparison; systematization and generalization; system-search and problem-search; theoretical analysis, synthesis and generalization.

Keywords:*hotel business enterprises, strategies, development, tourism, investment costs.*

I. INTRODUCTION

Relevance of the research'schosen topic. With the deepening of globalization and global integration processes, the modern hotel business, under the influence of external and internal changes, is forced to seek new tools and management methods. Successful operation and continuity of hotel business is paramount in a market economy, dynamically uncertain and unstable environment.

Today, domestic and foreign economists have created a methodology for choosing strategies for enterprise development. Theoretical bases and practical recommendations on strategic development of hotel business, problems of hotel economy strategic management are investigated in scientific works of I. Ansoff, I. Ageeva, R. Braimer, Yu. Dyachenko, O. Vinogradova, M. Boyko, S. Galasyuk, T. Doroshenko, M. Kabushkina, N. Kuznetsova, L. Lukyanov, S. Melnychenko, Y. Opanashchuk, H. Roglev, O. Chudnovsky, F. Kohler, M. Porter and others. However, despite the depth of scientific research, the issues of hotel business development

strategies have not been fully covered in scientific papers. Each hotel is unique, so the process of developing a strategy for each hotel business is unique, it depends on the company's market position, dynamics of its development and potential, behavior of competitors, characteristics of goods or services, economy, cultural environment and many other factors. Thus, there is a difficult task - to develop theoretical and methodological aspects and to form practical tools for strategies for the development of the hotel business.

The purpose of the study. The aim of the work is to study the theoretical and methodological provisions and determine the strategic guidelines for the development of hotel business enterprises. To achieve this goal, the following tasks were set and performed:

– to analyze the theoretical and methodological approaches to developing a strategy for the development of the hotel business;

– generalize methods for evaluating enterprise development strategies;

– to monitor the competitive environment of hotel business enterprises;

– to conduct a strategic analysis of the hotel business;

– to develop a system of development strategies of L.A.R.K. Ltd (London Hotel);

– to determine the economic feasibility of the proposed measures.

The object of research is the process of strategic management of the hotel business. **The subject of research** – theoretical and methodological and practical aspects of forming a strategy for the development of hotel business.

The methodological base of research. During the study of the strategic management system were used: a systematic approach, which allowed to explore the development strategies of the hotel business; method of comparison – to compare international and Ukrainian experience and identify opportunities for implementation of best practices in the activities of enterprises at different levels; systematization and generalization – to determine further prospects for the development of the hotel business; system-search and problem-search – to find the necessary sources of investment to implement a system of strategic development; theoretical analysis, synthesis and generalization – to form approaches and highlight current trends in the strategic development of the hotel business. The source base of the study consists of laws and regulations of Ukraine, official statistics of the UkraineState Statistics Service, statistical and financial reporting of enterprises, Internet resources, scientific works of domestic and foreign scientists, periodicals, other reference sources.

Approbation of scientific workresults. The main provisions and results of the work were considered and approved by student and international scientific-practical conferences: III All-Ukrainian Student Scientific-Practical Conference "Actual aspects of socio-economic development of Ukraine April 6-7, 2021 Odessa, II All-Ukrainian Student Scientific-Practical Conference "Current aspects of socio-economic development of Ukraine: The view of youth.

Key words: hotel business enterprises, strategies, development, tourism, investment costs.

II. THEORETICAL AND METHODOLOGICAL FUNDAMENTALS OF ENTERPRISE STRATEGY DEVELOPMENT

2.1. Theoretical and methodological aspects of concept definition "Enterprise strategy"

The current economic situation is characterized by a high degree of uncertainty and risk. Limited financial opportunities of the vast majority of Ukrainian enterprises and insufficient provision of specialists of the required level lead to limited formation of business development strategy in enterprises. In this regard, it is considered appropriate to study the methods and techniques of developing enterprise strategies based on assessments of the external environment and the enterpriseexisting potential. So, let's find out the origins and content of the "strategy" and "development strategy" categories. The term "strategy" (from the Greek. Stratos - army, ago - lead) is of military origin. The concept of "strategy" entered the management terms in the 50s of the twentieth century. Strategy is often understood as a policy implemented by the company, which is a possible solutions set [1]. The following definitions are given in economic dictionaries: "the art of leadership, the general plan of work based on the situation at this developmentstage"; "Long-term, the most fundamental, important attitudes, enterprisesmanagement plans in terms of production, income, expenses, budget, taxes, investments, prices, social protection."

The concept of strategy was first developed in the 60s of the twentieth century. I. Ansoff, A. Chandler. The meaning of the concept of strategy has changed under the influence of economic development of society. The strategy began to be considered not only the implementation of proper resource management, but also the correct definition of activities in the market. To date, many definitions of "strategy". According to A. Chandler, the strategy is "the definition of the main long-term goals together with the appropriate action plan and allocation of resources to achieve these goals" [2]. I. Ansoff gives the following definition "strategy is a set of rules for decision-making, which guides the organization in its activities" [3]. T. Primak believes that the strategy is "a general comprehensive program of action that identifies priority issues for the company, its mission, the main and the allocation of resources to achieve them" [4]. Z. Shershneva considers strategy as "a set of programs that the company expects to significantly improve its market position" [5]. After analyzing the definition of "strategy", the authors concluded that the strategy is "the chosen vector of enterprise activity, developed for a long period, compliance with which will allow to achieve the mission of the enterprise."

To define the category of "development strategy", it is advisable to explore the definition of "development". The study of the essence of the category "enterprise development" in the theoretical and applied context is the work of E. Korotkov [6], who defines enterprise development as "a set of changes that lead to new quality and strengthening of the living system . V. Kifyak [7] notes that the development of the enterprise is "quantitative and qualitative changes that are formed as a result of the interaction of subsystems, prerequisites, factors and principles aimed at achieving the priorities of the enterprise." One cannot but agree that such an understanding indicates the need to manage the development of the enterprise.

N. Afanasyev, V. Rogozhin, V. Rudyka consider the concept of "enterprise development" as an objective change only in the qualitative characteristics of the system, due to the fundamental laws of nature, and identify three main areas of development: increasing consumption of economic resources - quantitative aspect; changes in the composition of elements and their combinations - the structural aspect; shifts in the consumer characteristics of the elements, in their individual and integral usefulness - a qualitative aspect [8]. V. Zabrodsky and M. Kyzym [9] give a broader definition of development, specifying it in relation to the economic and production system. In our opinion, we can agree with this definition if we clarify that complicating the structure and composition of the system is not always effective.

Thus, considering the meaning of "strategy" and "development", we can conclude that these categories are closely related. Well-known business development strategies can be classified into groups [10]: 1). Strategies for concentrated growth: strategy to strengthen market position; market development strategy; product development strategy; 2) Strategies for integrated growth: strategy for vertical integration; vertical integration strategy; horizontal integration strategy; 3). Strategies for diversified growth: strategy of centered diversification; conglomerate diversification strategy; horizontal diversification strategy; 4) Stabilization strategies: market share protection strategy; strategy to support production capacity; product modification strategy. 5) Restructuring strategies: growth strategy through acquisitions; product and market reorientation strategy; strategy of organizational change. 6) Reduction strategies: cost reduction strategy; harvest strategy; reduction strategy; liquidation strategy.

2.2. Methods of evaluating existing enterprise development strategies

The presence of various approaches to the formation of enterprise development strategy contributed to the emergence of methodsset and models for choosing a specific development strategy, which, in turn, created the problem of optimal search for ways to improve them. A detailed analysis of each approach shows the presence in their structure of restrictive conditions that are used to form typical development strategies that operate in different models. In the future we will consider models of development strategy formation.

1. The BCG model is one of the most well-known business management tools. The purpose of the matrix is to analyze the relevance of the company's products and services depending on market growth and market share [11]. Ansoff's Product-Market matrix is used to develop an enterprise growth strategy. One of the advantages of the matrix is that each strategy is aligned with the degree of risk of the enterprise [12]. Porter's 5 Competitive Forces Model reflects the potential impact of the external environment on a firm's business. The key factors are considered to be the industry or industries in which the company is competitive. McKinsey uncertainty model - is a matrix consisting of 9 cells to reflect and comparative analysis of strategic positions of the organization. The Shell/DPM (Direct Politic Matrix) matrix is a two-dimensional matrix consisting of quadrants (3x3). Its parameters are the competitiveness of the GCC and industry attractiveness as a general measure of the state and prospects of the industry [12]. The Minzberg configuration model is defined as a ways simple set in

which the work process is first divided into individual work tasks, and then coordination is achieved to solve them [13]. Table 1.1 systematizes methodological approaches and enterprise development strategies formation models.

Table 2.1. Approaches and models of formation of enterprise development strategies

Approaches to strategy formation	Models strategy selection	Key principles methodological approaches
Oriented to the external environment	BCG model. M. Porter's model of competitive strategy	− the development strategy choice is determined by the characteristics of the market and a certain position occupied by a large enterprise in it; − growth of the norm and the amount of profit is the target function of the business;
	Porter's 5 competing forces. Matrix "Commodity Market" Ansoff. McKinsey uncertainty model.	− the choice of development strategy is closely related to solving the dilemma of "adaptation / change" of the external environment − the level of uncertainty determines the choice of potential alternatives to the development strategy;
Balanced	GE / McKinsey. Matrix Shell / DPM. Balanced scorecard system. ADL life cycle model. Model Hofer/Schendel. Hierarchy analysis method.	− for the vector of directions of development of activity of the big enterprise dependence on external and internal factors is characteristic; − higher-level strategic goals are detailed into lower-level goals through a system of causation.
Resource	Cost accounting by type of activity. Minzberg configuration model. Model 7S McKinsey. Grainer's development model. Franchon-Romane model of financial equilibrium	− the development strategy goals should be focused on reducing potential costs and improving quality; − strategic management is characterized by cyclical nature; − the activity of the hotel enterprise in the process of its development is of a deterministic nature; − the hotel in the process of its development goes through successive stages affect the development strategychoice; − theenterprisedevelopment is characterized by features determined byorganizational structurespecific type.

Source: developed by the author

Developing an enterprise strategy is an integral part of the strategic management process. The main aspects of strategic management are responding to changes in the environment and the allocation of resources of the firm in such a way as to improve its competitiveness [14]. Constant monitoring of changes in the environment is necessary for survival in a dynamic competitive environment. The second important aspect is the internal reaction to the new program of actions invested in strengthening the competitive position of the firm. Thus, the study concluded that companies that have a strategy and implement strategic management, always have the opportunity to behave consistently and systematically in a dynamic market competitive environment. Business structures to respond changes and contributes to a sound, coordinated solution to both current and strategic problems.

III. STRATEGIC ANALYSES AND EVALUATION OF THE COMPETITIVE ENVIRONMENT OF HOTEL BUSINESS ENTERPRISES

3.1. Analysis of the impact of the macro-environment of the enterprise on its strategy

The hotel industry in the world accounts for at least 6% of total gross national product. European countries account for up to 43% of the hotel business. This provision provides business with the potential for sustainable development [15]. However, political and economic developments in recent years have had a negative impact on Ukraine's hospitality sector. Optimistic expectations for 2020 did not come true: the pandemic made its adjustments. Quarantine restrictions have led to the forced temporary closure of a large number of hotels. Note that in 2019, 5-star hotels were booked by 45%, and 4-star and 3-star - by 60%. According to statistics, in 2020, hotels in the high price segment were filled by 22%, medium - by 25%, occupancy of hotels in the European market over the same period decreased by 54% to 33% [16]. According to research by Hotel Group companies, economic losses for the period under study ranged from 3 to 8 million UAH. The data from Table 2.1 show a tendency to decrease the financial indicators of the hotel business world's players.

Table 3.1. Financial results of Accor and Hilton hotels in 2020

Characteristic	Accor (France)	Hilton (USA)
Net loss, € billion	1,99	0,43
Revenue from sales of services, € billion	decreased by 61 % (14,14)	decreased 58 % (5,64)
Income from one room, %	decreased by 62	decreased by 59

Source: built by the author based on [15, 16]

According to the State Statistics Service of Ukraine, in 2019 the number of collective accommodation facilities was 4,719 units. The number of collective accommodation by region in 2020 amounted to 1591 units, of which hotels are 1073, other accommodation - 1053 units [17]. The largest indicators are in Odessa oblast - 177 units, Kyiv oblast - 150, Lviv oblast - 129 units, which testifies to the significant tourist potential of this industry in these oblasts. We have identified factors that contribute to the development of the hotel business in the city of Odessa: 1. Mild climate. The presence of the Black Sea attracts vacationers in the summer season and fills hotels in the center and on the outskirts of the city. 2. A large number of hotels for all types of consumers. 3. Specialization in different types of tourism: leisure, business tourism and mice-tourism. 3. The presence of international and Ukrainian hotel chains helps to attract foreign tourists. 4. Attractive architecture of the city. 5. Availability of developed infrastructure (airport, railway, highways). 6. Development of event tourism.

According to the number of objects that make up the tourist cultural resources (350 objects of history, culture and leisure, including 13 museums, 9 theaters; 201 monuments of history and culture, 700 monuments of architecture, 148 monuments of monumental arts, cultural and leisure institutions, sports facilities, etc.), Odessa is one of the top three cities in Ukraine. In table 2.2. the analysis of influence of factors of external environment on activity of the enterprises of hotel business is resulted.

Table 3.2. Analysis of environmental factors

Group of factors, state of the factor	Trends in change	The nature of the impact of the factor on the enterprises of the industry "+" - positive; "–" - negative
Economic factors		
Rising inflation	The purchasing power of Ukrainians in 2020 has fallen sharply. It was expected that the nominal GDP per capita would be 109.04 thousand UAH, in reality this figure was 100.47 thousand UAH.	(–) Decrease in demand for services. (–) Simple hotels. (–) Increasing currency risks. (+) The possibility of a positive impact of exchange rate differences. (–) Reducing the number of foreign guests. (–) Increasing the cost of compliance with sanitary norms. (+) Reducing the tax burden.
Reduction of consumer income	The trend is changing.	
Rising inflation	Vaccination is expected to boost the economy	
Reduction of taxation	In 2020, VAT for hotels will be reduced to 7%.	
State and political factors		
Unstable political situation	Stabilization is possible	(–) Decrease in GDP from the hotel industry. (–) Reducing the number of foreign tourists in the country. (–) Simple room stock (+) Increasing the cost of foreign tourists after the opening of borders. (–) Elimination of hotel facilities in the east.
Instability of legislation	Stabilization is possible	
low investment attractiveness of the country	Stabilization is possible	
Closed borders	The trend is changing	
The war in the east	An unpredictable trend	
Legal factors		
The only national classification of star rating in the hotel industry.	Trend of implementation	(+) Compliance with international standards. (+) Increase in the number of foreign tourists from countries where casinos are not legalized.
Legalization of gambling.	Trend of implementation	
Technical and technological factors		
Increasing the number of innovative enterprises.	The trend is not clear	(–) Automation of internal business processes. (–) Not all hotels will be able to switch to full automation. (+) Increasing the speed and quality of service in the hotel. (–) Simple room stock in low seasonautomation
Setting high prices for innovation.	Stabilization is possible	
Ability to use the latest technologies, equipment.	Trend of implementation	
Seasonality of demand.	The trend is not clear	

Source: built by the author

Based on the results of the analysis of the internal and external environment of the enterprise, strategy planning, evaluation of strategic alternatives and decision-making are carried out, which also involves the use of certain methodological techniques of strategic analysis.

3.2. Analysis of the impact of the microenvironment of the enterprise on its strategy

Hotel London is one of the oldest hotels in Odessa, always famous for its high level of service and provision of services. Today the hotel is confidently modernizing the number of rooms, as well as developing special offers that allow you to be recognizable despite the rapid growth of 4* hotels in Odessa. Suppliers play an important role in the operation of the hotel. Business relationships between suppliers and hotels can be direct and indirect, long-term and short-term. Suppliers of the Hotel London include MARGO furniture hypermarkets, METRO products, Rozetka, Citrus electronics, NATALI BOLGAR and Mango clothing.

Excursion services are provided by Albatross. Managers provide an individual approach to each guest request, speak different foreign languages, have professional education and experience in tourism. PE Fokin VP is a transport company that offers all possible transport services. The company provides comfortable trips, transfers of hotel guests, as well as offers car rental, English-speaking driver, guide driver and more. The hotel also works with other beverage and food companies and utilities.The components of the microenvironment are: customers, suppliers, competitors, partners and contact audiences: sponsors, media, banks and government agencies.

Buyers. London offers not only accommodation for its customers, but also events of various formats. The following types of consumers are distinguished in the London Hotel: individual guests + online, tour operators and travel agents, corporate clients. Individual guests + online guests: travel independently, choose rooms based on information from the official website of the hotel or global booking systems such as booking.com, Hotelbeds, Expedia, Travko. This type of guests pays more attention to the presence of the spa area, a convenient and convenient location, the historical value of the building in which the hotel is located.

Tour operators and travel agents: usually have a contractual relationship and special rates for accommodation of guests for whom rooms are booked. When accommodating a group or individual tourist pay attention to the number of rooms, location, parking, as well as a range of additional services. Corporate clients and MICE agencies: usually have a contract with the hotel, sometimes even special rates or limits on accommodation for events. They act as an intermediary between the hotel and the end customer. Competitors. Odessa has a very strong base of hotels of different categories. The main characteristics that can be used to choose a hotel are: the size of the room stock, location, belonging to the hotel chain, a range of additional services, compliance with category standards, consumer segments.

The main competitors of the London Hotel are Mozart, Black Sea, OK Odessa and Gagarin Hotel. Characteristics of competitors' hotels are given in table 2.3.

Based on expert assessments, the integrated indicator of competitiveness of the London Hotel was calculated, for which four hotels of **** category in Odessa were selected: Mozart, Black Sea, OK Odessa and Gagarin. To analyze the competitiveness of hotel chains considered: pricing policy, quality of service, location, room equipment, season length, range of additional services, brand credibility, marketing policy. Each of the above indicators was assigned a weight of 1.0 or 100%. The evaluation of parameters took place on a 10-point scale. The proximity of the integrated indicator to

"10" indicates a high level of competitiveness, the distance from "10" means that the company has significant reserves to increase the level of competitiveness. Thus, the highest indicator of integrated competitiveness is the hotel "Black Sea" (9.16), in second place - the hotel "London" (8.44), in third place - "Mozart" (8.29), in fourth place - "Odessa" (7.26).

Table 2.3. Characteristics of competing hotels

Analysis of the competitive environment	Mozart	OK Odessa	Gagarin Hotel	London
The state of the business	It is growing	Stable	Stable	It is growing
What target segment is served?	1. Individuals. 2. Business groups. 3. Corporate clients. 4. Artists. 5. Athletes.	1. Individuals. 2. Business groups. 3. Corporate clients. 4. Artists. 5. Athletes.	1. Individuals. 2. Business groups. 3. Corporate clients. 4. Artists. 5. Athletes.	1. Individuals. 2. Business groups. 3. Corporate clients. 4. Artists. 5. Athletes.
Unlike the Hotel London.	1. Updated number fund. 2. Chain hotel.	1. Availability of more space for events of different formats. 2. Large number of rooms	1. Greater opportunities in the complex placement of the group and location for the event with food.	
How is their brand perceived in the market?	1. As one of the chain hotels 4 * medium level. 2. Location for conferences of small scale.	1. As a hotel with a large number of rooms and a powerful location for large-scale events.	1. As a hotel with a powerful number of rooms and a conference area with a high level of service and work with accommodation of artists.	1. As a historic hotel in the city center. 2. As a premium SPA hotel. 3. As a location for events of various formats. 4. As a hotel with an average number of rooms. 5. As a hotel with good lucklocation and parking.
The main difference in market positioning relative to the Hotel London?	Positioning as a hotel of European category.	Positioning as a hotel with an integrated approach: accommodation, meals, event.		
How to increase your advantages over competitors?				Number fund renewal, improvement locations for events of various formats, upgrades of equipment for events.

Source: built by the author

The internal environment of the enterprise is formed by managers in accordance with their ideas about what elements will ensure effective and efficient operation and development. The staff of the Hotel London depends on the season. The average number of staff in 2019 is 95 employees. There are three categories of staff at the Hotel London: officials who directly manage the hotel and its staff: have higher professional education or higher education and special professional training or management experience in the field of hotel services for at least three years. For example, Regional Director, Chief Operating Officer, Director of Sales, Director of Marketing, Director of Human Resources, Director of Security and Hotel Manager.

Employees of the London Hotel are required to undergo general corporate training, such as: 1. The service culture in the hospitality industry. Vertex Hotel Group standards. 2. Introduction to the hospitality industry. 3. Work with feedback. 4. Time management. 5. Basic rules and standards of customer service in the restaurant.

The purpose of the marketing department of the hotel is to provide temporary accommodation services for residents and guests of the city. There are 3 main methods of selling products in the hotel: direct - the hotel company directly sells its products to consumers. Most often, this consumer is an individual guest who makes a reservation by calling or writing a letter to the hotel's booking department or reception. Indirect - sales of products, organized through independent intermediaries. Tour operators can act as independent intermediaries. Combined - the sale of products is carried out through the organization with the total capital of the manufacturer and an independent company.

The main sales channels at the Hotel London are:

1. Direct sales through own reservation center (call-center, reservation department), carried out by the booking department or sales department.

2. GDS - global distribution systems (Amadeus, Saber, Worldspan, Galileo), which unite thousands of hotels around the world.

3. IDS - Internet Distribution Systems (Internet Distribution Systems). Currently, there are a sufficient number of hotel companies that sell rooms online;

4. Own booking portal.

5. Classic travel agencies, CRS sites and travel agencies that help load hotel businesses.

Provision of services. The annual turnover of the hotel's room stock in 2020 amounted to 14,287 rooms, which is 60% of the possible turnover of the room stock. According to the booking site booking.com, the hotel has 8.6 points out of 10.0 possible and 1000 registered reviews.

For continuous operation at a high level, the hotel is equipped with an electronic key registration program "MF57", for work with the number fund - the program Fidelio 8, to record the arrival/exit of the object - electronic buttons. For the analysis of the internal environment we use the method of SWOT-analysis. The proposed SWOT-analysis solutions can be used to support the chosen strategy of concentrated growth of the Hotel London.

After conducting a SWOT-analysis of the internal environment, the strengths and weaknesses of the London Hotel were analyzed, hidden threats, potential opportunities were identified.

Table 2.5. SWOT-analysis of the hotel "London"

Strengths (S)		Weak (W)
Qualified staff; High level of organizational culture; Individual approach to each guest; Availability of a location for events of various formats; Favorable location; Availability of special offers; Compliance of the number fund with international requirements; The image of a premium hotel; Own SPA center; The hotel has its own website; Flexible system of discounts.		Imperfect organizational structure; Inefficient system of bonuses and incentives for employees; High prices for accommodation for individual tourists; Low speed of service in some departments; Small area of the hotel; Lack of financial resources for the reconstruction of the number fund; No elevator on all floors.
Opportunities (O)	(S*O)	(W*O)
Integration of Ukraine into the world community, increase of business relations with the countries of Western Europe; Adoption of legislation in support of tourism in Ukraine. Development and implementation of modern programs for the development of hotel business in the city of Odessa; The emergence of international hotel chains. The growth of business activity, which will increase the flow of tourists	Creating a positive image of the company. Reconstruction of part of the number fund in the style of the 18th century. Entering the international market. Creation of technological business centers. Joining the international hotel chain. Growing flow of business tourists.	Increase additional services Loyalty for individual tourists. Reduction of time during the eviction of the guest.
Threats (T)	(S*T)	(W*T)
Influence of seasonality factor; Increasing pressure from competitors; Decrease in demand for hotel services; Unstable political and economic situation in Ukraine; Imperfect and frequently changed legal framework; Difficulty in regulating export-import operations and operations with foreign currency. Imperfect tax policy; Unstable pricing policy in Ukraine, in particular in the field of electricity and energy consumption. Closing the borders caused by the pandemic.	Intensification of marketing activities in the Odessa market and cooperation with local governments. Presentation of the hotel at international profile exhibitions, workshops, forums. Concluding agreements with international public organizations. Introduction of contactless service	Attracting an investor; Increasing the hotel area; Attracting additional support for business development (from partners).

Source: developed by the author

The main threats to the operation of the London Hotel in Odessa are the seasonality factor, the impact of the pandemic, the closure of borders for foreign tourists, the minimization of business trips between cities and increased pressure from competitors. Thus, the main strategic directions of development of the hotel "London" will be (table 2.6).

Table 2.6. The main strategic directions of development of the hotel "London"

Basic development strategies		
Concentrated growth	Integrated growth	Diversified growth
Market absorption	Vertical integration	Centered diversification
Market development	Horizontal integration	Related diversification
Product development		

Source: developed by the author

Strategies (S*O): concentrated growth strategy (market deepening). Creating a positive image by participating in specialized exhibitions, seminars, symposiums and round tables. Involve local on national television to collaborate and promote hotel.

Concentrated growth strategy (market development by adding a new consumer segment). Reconstruction of the number fund in the style direction of the 18th century. This will make it possible to integrate work with travel agencies, offer accommodation in thematic rooms for foreign and national tourists. Integration with event agencies in the direction of thematic evenings and other events.

Concentrated growth strategy (market development). Entering the international market through participation in international exhibitions in Ukraine and abroad allows to strengthen contractual relations with foreign companies, signing new agreements. Involvement of foreign specialists to train hotel staff to international service standards.

Centralized diversification strategy. The creation of technological business centers at the hotel will attract more business tourism. The business tourism segment is now also present in the hotel, but outdated halls and equipment for business meetings are not competitive. Working in this strategic direction makes it possible to reduce the time for the logistics of guests, as well as directly affects the pleasure of staying in the hotel and in the city.

Horizontal integration strategy. Joining the international hotel chain. The London Hotel is part of the national Vertex Hotel chain.

Strategies for vertical integration (increasing the flow of business tourists). In order for the choice of this strategic direction to be effective, the hotel should have partnerships with intermediaries between companies that send employees on business trips, namely, travel agents, operators or MICE agencies. The largest intermediary companies with which we recommend cooperation: "Sun event", "Rocke", "Worldservice", "Global Event".

Strategies (W*O). Strategy of related diversification (increasing the number of additional services). Today, the London Hotel offers the following additional services: booking transfers, city tours and use of the spa. After analyzing the European hotel business market, we came to the conclusion that the greater the range of additional services, the more loyal the guest and the greater the likelihood of his return on the next trip. Thus, we offer to add services for flower delivery, prompt booking of seats in other institutions of the city with a discount on the menu, prompt ordering of air and train tickets, as well as concert tickets and more.

Concentrated growth strategy (market development). Loyalty for the individual tourist can be shown in various formats, from an additional discount on accommodation to a compliment in the room. It should be noted that it is necessary to

establish the warmest contact with the guest. This will allow you to identify his wishes, intentions and in the long run to prevent his expectations from staying at the hotel. For example, special treatment for vegan guests and those who choose gluten-free or lactose-free food.

Concentrated growth strategies (deepening the market. Reducing the time during the eviction of the guest. During the work it was determined that this is one of the main processes of staying in the hotel. During the eviction process is not only In various cases, this component can take from 5 to 30 minutes. these are the maids and the security service, as these services are involved in the process of evicting the guest from the hotel.

Strategies (S*T). Vertical integration strategies and concentrated growth strategies (alternatives - deepening the market). Intensification of marketing activities in the Odessa market and cooperation with local governments. Interaction with local governments - the opportunity to participate in various activities.

Vertical integration strategies. Hotel presentation at international exhibitions, workshops, forums is a great opportunity to present the hotel and enter into direct contracts with representatives of international travel agencies for operators.

Concentrated growth strategy (market deepening). Introduction of contactless service. During the pandemic, when everyone was in limited contact with each other - contactless service is one of the opportunities to provide service to guests, we offer to diversify the serving of the food area in the hotel, the placement of antiseptics in visible places.

Strategies (W*T). Concentrated growth strategy (market deepening). Attracting an investor will allow you to get financial investment to repair the number of rooms.

Strategy of related diversification (concentration). Increasing the hotel area will allow you to expand the number of rooms, create an additional hall for events, create a playroom for children and more.

Strategy of vertical integration and related diversification Attracting additional support for business development (from partners) by accepting the integration of travel agencies, event agencies, photographers (for example, creating a photo location based on one of the rooms).

After performing a strategic analysis of L.A.R.K. LLC (London Hotel), micro- and macro-factors, the hotel's internal environment were analyzed. The main macro-factors are the political environment, demographic, economic indicators, scientific, technical and social environment that has an impact on the micro-factors of the hotel environment.

The microfactors on which the functioning of the enterprise depends are consumers, suppliers, competitors and partners. The section analyzed the work of competing hotels and on the basis of this analysis revealed which dominant auxiliary strategies they work on.

Analysis of the internal environment of the hotel "London" allowed to determine the place in the market of hotel services, identify strengths and weaknesses, opportunities and threats.

The main strategic directions of development of the London Hotel have been identified.

IV. PROPOSALS FOR IMPROVING STRATEGIC ENTERPRISE DEVELOPMENT MANAGEMENT

4.1. Development of MICE-tourism as a direction of strategic development of hotel business enterprises

At present, the concept of MICE-tourism has become widely used in the tourism industry. The abbreviation MICE mean four directions of business tourism: Meetings - business meetings; Incentives - incentive or motivational tours and programs, team building, staff training, corporate holidays; Conferences - conferences, congresses, congresses, forums, seminars, etc.; Exhibitions - exhibitions, corporate events. According to the Pacific World Destination Index, the most popular MICE destinations in 2018 were Italy, France and the United Arab Emirates, South Korea, Indonesia and Hong Kong (in Asia). In 2019, the leading intermediate popularity index was already other countries - Portugal, Monaco, Indonesia, Hong Kong and Singapore [18].

According to the ICCA Statistics Report, in 2019 the leader in the number of corporate events was Paris (214). The top 20 cities with the highest MICE rates were Vienna (202), Madrid (200), Berlin (193), Barcelona (182), London (166), Singapore (142), Amsterdam (133), Istanbul (130), Prague (118), Brussels (112), Lisbon (109), Copenhagen (105), Beijing (104), Seoul (99), Hong Kong (98), Budapest and Rome (97 each), Stockholm (95), Taipei 92) [19].

The segment of MICE-tourism in Ukraine is not sufficiently developed and popular - so far in our country there are few travel agencies that are ready to take responsibility for the quality of services in the field of business-travel. Organizing business trips that take place with the obligatory entertainment program is quite a difficult task. Foreign tourists and travel companies note a number of shortcomings that negatively affect the potential demand for tourist trips to Ukraine. In addition to the difficult political, social and economic situation in our country, there are limited material and technical base, lack of proper hotel industry, which has only just begun to develop properly. However, it is hoped that in the context of European integration and expansion of international business contacts will determine the development of this industry [20].

Business tourism is very profitable, because a person who went on a business trip can spend not only their finances, but also the money of the company that sent him. This allows the business traveler to spend more money than the average tourist.

A typical tourist traveling for business purposes is a middle-aged man with a higher education, a qualified specialist or manager, a business owner. Businessmen are increasingly looking for and finding business partners abroad. But when embarking on such a journey, they do not just want to visit an exhibition, seminar, conference - they are looking for new opportunities for their business. Business people working in various fields, including science, expect business trips not only to conclude new lucrative contracts, but also to increase creative activity as a result of changing circumstances and gaining new unforgettable impressions of the host country, which can only be provided by national specifics. In addition to accommodation, conference rooms, tours, customers want to see exclusive offers. For example, a trip to Chernobyl is a fashionable idea for guests from Asia and America.

Organizing business trips is a difficult task. However, many Ukrainian companies are already engaged in this business. Their professionalism grows, experience is gained. This fact, together with the growth of international contacts of domestic businessmen, gives hope for the full development of business tourism in the near future. According to business travel specialists, most often business travelers visit Kyiv and major regional centers: Kharkiv, Donetsk, Dnipro, Lviv, Odessa. A modern Ukrainian hotel should combine the capabilities of the infrastructure of the business center, leisure center, as well as trade and services. An exemplary list of services for business tourists includes telecommunications services, the ability to receive and transmit information, communication and good technical equipment the temporary residence place. Technical solutions for the provision of telecommunications services must take into account all the latest and most popular ways of exchanging information. The services of Ukrainian business centers must meet the highest international requirements, create a comfortable environment for foreign business tourists, not create a feeling of discomfort in them. This means that a mini-office should be set up in the room for such a tourist: a spacious table with good lighting, a computer with Internet access, a multifunctional direct dial telephone, it is necessary to provide in the room fax with individual number. The life of business guests also needs special attention. A busy person should have a good rest, look good and not be distracted by household chores. Studies show that the quality of service in hotels is rated by business tourists 4 times higher than the adequacy and price reasonableness, and 1.2 times higher than the quality of the tourism product [21].

The complex of problems related to the reception of business tourists in our hotels can be solved, first of all, by creating large national hotel chains, and later international chains, including high-class hotels. Given that currently Ukrainian hotels are in different forms of ownership and management, franchising, which does not require a change of ownership, should be widely used. An organization capable of consolidating hotels in a chain does not have to have its own accommodation. The hotel main advantage in the chain is the total costs reduction. In addition, it will allow chains to penetrate international markets, expanding their influence sphere [22]. There is a great shortage in our country and the relevant staff of business tourism. It is necessary to train highly qualified employees of hotel conference services, who would be able to serve at the appropriate level not only forums, conferences, seminars, congresses, presentations, etc., but also to organize corporate cultural and entertainment events, "company days", holidays, parties, city trips, etc. It is impossible to effectively organize leisure in hotel facilities without talented animators. The main problem for young professionals is usually the lack of practical experience, flexibility and creative thinking, inability to use the acquired knowledge and skills in practice. Therefore, today the organizers of leisure in the tourism industry have the following requirements: higher education, work experience, the desire to improve their skills, the presence of relevant personal qualities [23].

Business tourism in Ukraine should be developed on the basis of special Ukrainian national specifics, at a conscious level of reproduction of the national environment, a certain color and atmosphere. Under such conditions, a boring and exhausting trip will turn into a holiday that can really increase efficiency and creativity.

The main thing here for the host country is the friendly attitude of business tourists to Ukraine and the desire to visit it again. Unfortunately, the current conditions of business tourism in Ukraine do not cause such a desire in many cases.

4.2. Economic efficiency of the proposed measures

Hotel "London" has a good location because it is located in close proximity to the most popular tourist attractions of the city: the Potemkin Stairs and the Sea Station. At the same time, a good transport interchange allows you to drive to the hotel entrance and park in front of the hotel. The main services provided at the Hotel London are accommodation, meals and transfers. Among the additional ones - excursion service, organization of walks on the sea, photo sessions, etc. Hotel "London" has the opportunity to develop a conference service because it has two halls with a total area of about 300 square meters. So, our business idea is to implement a high-tech business center based on hotel halls. At this stage, London is pursuing a strategy of concentrated growth, which flows into a strategy of integrated growth. The introduction of a high-tech business center will be a measure to implement a strategy of vertical integration. A business center is an organization that provides a full range of business services. It is absolutely obvious that the role of business centers and business hotels in the business infrastructure of Ukraine, the demand for office space and high-end business services will continue to grow. Therefore, it is extremely important in the prospects of development to take into account the principles of creating a modern tourist infrastructure, important and relevant concepts for the formation of a single information space.

The main items of expenditure for the reconstruction of the Aivazovsky and Bofo halls in the London Hotel are the costs of repairs, marketing, high-tech equipment and specialized personnel. Reconstruction costs amount to UAH 435,000. The contractors for this work were AtmosOd, SKY Cleaning and The Nest.To implement an advertising campaign to promote a new service, it is recommended to cooperate with Megapolis Advertising Holding - a full-cycle advertising company with extensive experience in the field of advertising in Ukraine. The marketing budget is 53.50 thousand UAH. Investment costs amount to UAH 1,207.9 thousand. It is planned that after the introduction of the business center in the hotel "London" in the first year, sales revenue will increase by 7% and will amount to: 2479.89 thousand UAH. The net present income from the project implementation will amount to UAH 2,372.1 thousand. Yield index 2.96. The payback period of the investment is 1.68 years. Thus, according to three indicators of investment attractiveness, the project is cost-effective and it is advisable to implement it. The introduction of a high-tech business center on the basis of the Hotel London is a way to attract the attention of a new target audience that visits the city and travels to Ukraine - it's business travelers, representatives of the IT industry at the entrepreneur. The implementation of this measure will also make it possible to neutralize the seasonality factor, which has a very large impact on the hotel business as a whole. Indicators of investment attractiveness indicate the feasibility of the project.

V. CONCLUSIONS

During the study, the theoretical and methodological foundations of the development strategy of the enterprise were analyzed, a strategic analysis of the London Hotel was performed, and measures aimed at maintaining the strategy of concentrated and integrated hotel growth were proposed.

It is proved that in modern economic conditions the enterprise will not be able to function effectively without the development and implementation of economic development strategy. It determines the direction of the organization, formulates the mission and goals, ensures the efficient use of available resources.

After performing a strategic analysis of L.A.R.K. LLC, micro and macro factors, as well as the internal environment of the hotel were analyzed. The microfactors on which the functioning of the enterprise depends are identified, namely: consumers, suppliers, competitors and partners. The analysis of competitors was carried out by constructing a polygon of competitiveness, and the development strategies for hotels in the Odessa market were determined.

Analysis of the internal environment of the hotel "London" allowed determining the place in the market of hotel services occupied by the hotel and identify its strengths and weaknesses using the method of SWOT - analysis.

It is established that today London ranks high among hotels in its category. It is noted that among the main advantages over other hotels are: belonging to the Vertex Hotel Group; favorable location; number fund in 70 numbers of different categories; availability of restaurants, halls for banquets and conferences; work of highly qualified personnel to provide a high level of service.

Along with the advantages, a number of weaknesses of the hotel were identified: imperfect organizational structure; inefficient system of bonuses and incentives; high prices for accommodation for individual tourists; low speed of service in some departments; small hotel area; lack of financial resources for the reconstruction of the number fund; no elevator on all floors. imperfect technical equipment of conference halls at the hotel. The analysis of weaknesses made it possible to formulate proposals for the implementation of a high-tech business center on the basis of existing conference rooms. The introduction of such a center will make it possible to consolidate the hotel's position among the competitive range of hotels in the city, as well as enter the market with an exclusive offer, because none of the competitors offers a full business center. Calculations of costs for the implementation of measures proved their feasibility, and also showed that their implementation will not be necessary to attract credit.

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DIRECTIONS OF SMALL BUSINESS SUPPORT IN UKRAINE IN THE CONDITIONS OF THE COVID-19 PANDEMIC

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Abstract. *The scientific paper is devoted to the problem of supporting small businesses in the context of the COVID-19 pandemic and the evaluation by small business representatives of the implemented measures in Ukraine.*

In the scientific paper, theoretical approaches to the interpretation of concepts of "small business" and "small entrepreneurship" according to the law were investigated and the role of small business in economic development was analyzed.

Small business support measures operating in Ukraine based on the State Support Program were analyzed and their qualitative assessment was carried out (using the Delphi method and the developed questionnaire). The obtained results were used for the development of appropriate recommendations for effective small business support mechanisms in Ukraine. The context of the formation of opportunities for the effective functioning of small businesses in new conditions was also considered.

Recommendations for improving the effectiveness of implemented measures to support small businesses in Ukraine in the context of the COVID-19 pandemic and their prolongation in the post-quarantine period were proposed.

Keywords*: small business, small entrepreneurship, COVID-19 pandemic, quarantine restrictions, small business support, state support.*

I. INTRODUCTION

Dynamic growth of the national economy in modern conditions is impossible without the development of the small business that acts as an activator of the economy. International experience shows that small business contributes to the restructuring of the economy, strengthens the industrial and economic base of the regions, increases total production and turnover, stimulates the competitive environment, provides employment, promotes the introduction of scientific and technological progress. The COVID-19 pandemic and the introduction of significant restrictive measures have caused crises in the economy, which has affected small businesses as well. Such restrictions have become critical for most small businesses, and their prolonged nature has had catastrophic consequences. All this required the state to implement measures that could support small businesses.

The purpose of the scientific paper is to study the impact of the COVID-19 on small businesses and assess the directions of small business support in Ukraine in the context of the pandemic.

To achieve the purpose of the scientific paper, the following tasks were set:

- to study theoretical approaches to the interpretation of concepts of "small business" and "small entrepreneurship";

- to analyze the role of small business in the economic development of the country;
- to analyze small business support measures to counter the impact of the COVID-19 pandemic and its consequences, taking into account international experience and evaluation by small business representatives in Ukraine;
- to develop recommendations for improving the effectiveness of measures implemented to support small businesses during the COVID-19 pandemic.

II. LITERATURE ANALYSIS

Studies of various aspects of small business were covered in the works of S. Brew, H. Millenbusch, M. Meskon, S. Parker, D. Rechman, P. Heine, A. Hosking, J. Schumpeter, Z. Varnaliy, T. Kovalchuk, I. Mazur, E. Panchenko, V. Syzonenko, N. Sobol, L. Chuprina, S. Yuzovytska and others. The scientific works of O. Krasota, N. Lukyanov, O. Zaitsev, N. Geiko are devoted to the impact of COVID-19 on small businesses and ways out of the crisis. Despite the available publications, there is no assessment of the implemented measures by representatives of the smallest businesses in Ukraine, which determined the choice of the research topic.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of the scientific paper is a small business in the conditions of the COVID-19 pandemic.

The subject of the scientific paper is the evaluation of small business support measures in the context of the COVID-19 pandemic.

To achieve the determined goal and solve set tasks, in the process of the research, the following methods were used: system method – to study aspects of small business in modern conditions; method of theoretical generalization – to clarify the conceptual apparatus of international business; graphic method – to interpret the achieved results; method of induction – to generalize the trends of international business; monographic method – to determine the practical aspects of organizing small business support activities during the pandemic.

The information basis of the scientific paper consisted of laws and regulations of Ukraine (namely, of the Ministry of Economic Development, Trade and Agriculture of Ukraine), the State Statistics Service, scientific publications, information resources of the Internet. Processing of economic information, construction of tables, graphs were carried out in Microsoft Excel.

On the topic of the scientific paper theses were published: “Small business support tools in the COVID-19 pandemic: international and national practice” in the collection of materials of the II All-Ukrainian Student-Student Scientific and Practical Conference “Prospects for the Development of Ukrainian Economics, Business and Entrepreneurship in Globalization” on November 26, 2021, Kharkiv, Zhukovsky NAU “KHAI”.

IV. RESULTS

4.1. Theoretical aspects of the functioning of small businesses in Ukraine.

International experience shows that small business is a leading sector of the economy. According to the European Charter (June 19, 2000), small businesses are

seen as a key source of jobs, as a basis for business ideas, and as a driving force for innovation, employment, and social and local integration in Europe [1].

Since the purpose of the scientific paper is to study the impact of the COVID-19 pandemic on small business as an entrepreneurial form, it is necessary to understand the interpretation of the definitions of "small business" and "small entrepreneurship".

The analysis of the scientific sources revealed that in Western European literature the term "small business" is used more often. However, in Japan and Western Europe the term "small and medium enterprises" is used instead, in France – the common abbreviation PME ("petites et moyennes entreprises"), in Germany – small and medium enterprises are not considered separately, so enterprises are defined by a single concept "Mittelstand" (middle layer).

In world practice, considering the concept of "small business", there are different approaches and criteria for the classification of the subject, namely: quantitative, qualitative, and combined to define small and medium business [2]. In Ukraine, the legislation does not separate the definition of "small business", but in practice, the concepts of "small business" and "small entrepreneurship" are identified, falling at the legislative level under the interpretation of "entrepreneurship". Thus, the Economic Code (Article 42) uses the term "entrepreneurship" as a separate, initiative, systematic, own-risk economic activity, carried out by business entities (entrepreneurs) with the purpose of achieving economic and social results, and generating profit [3]. In scientific sources, the following interpretations are the most thorough (Table 4.1.)

Table 4.1. Approaches to the interpretation of the definitions of "small business" and "small entrepreneurship"

Author	Interpretation
L. Vasilieva [4]	Small business is not just a part or sector of the national economy, which can be statistically distinguished in terms of employment, turnover, fixed capital, and the like. This is an economic segment, which has fundamentally new qualitative characteristics, namely: the unification of the owner and entrepreneur in one person, the focus on innovation, simplified communication and information systems.
G. Kozachenko, A. Voronkova, V. Medyanik, V. Nazarova [5]	Small business is any activity of small enterprises and individuals that does not contradict the law and is aimed at making a profit.
Z. Varnaliy [1]	The concepts of "small business" and "small entrepreneurship" are distinguished only by the qualitative component, giving a small business a greater degree of risk and innovation.
O. Panuhnik, N. Golich [6]	The category "small business" is broader in characteristics than the category "small entrepreneurship".

In our opinion, the most complete interpretation of "small business" is a special organizational form of entrepreneurship, which is realized based on business ideas formed by the entrepreneur and implemented in the environment according to national standards (number of employees, production, etc.). And the concept of "small entrepreneurship" is broader and includes micro, small and medium enterprises.

Interesting to observe is the scientific developments of the English researcher H. Velu, who, studying the processes of enterprise development, identified a list of characteristics inherent in enterprises of different sizes - from small to large. Since small and medium-sized businesses are considered as one category in the scientific literature, it is expedient to make a comparative description of these two types of business, their distinctive quality parameters, as was proposed by H. Velu (Table 4.2).

Table 4.2. Comparative characteristics of qualitative parameters for determining the size of the enterprise according to H. Velu [7]

Parameter	**Business type**	
	Small	**Medium**
Goal	Determined by the market intuitively	Adjusted for market and strategy
Management	Personal, authoritative, direct	Personal, consultations with key partners and specialists
Product	No planning, no marketing research	Short-term planning without marketing research
Personnel	“Manager-employee” relationship on the principle of “big family”, a high degree of motivation and involvement, the weak influence of trade unions, no labor collective council	“Employer-employee team" relationship, an average level of involvement, low influence of trade unions, no labor collective council

Qualitative criteria for classifying enterprises as small, medium, or large is, in fact, subjective, which leads to limited application in practice. Most often, both in the world and in Ukrainian legislation, the division into small, medium, and large enterprises (businesses) is based on certain economic and statistical indicators of enterprises by size.

In Ukraine, the classification of enterprises is carried out according to the Economic Code of Ukraine, which came into effect on 01.01.2004 [3] and the Law of Ukraine “On Accounting and Financial Reporting in Ukraine” of 05.10.2017 [8], which states that all domestic enterprises can belong to micro, small, medium, or large enterprises (Table 4.3).

Table 4.3. Classification of enterprises by quantitative parameters and scale of activity under the legislative and regulatory framework of Ukraine

The Law of Ukraine “On Accounting and Financial Reporting in Ukraine”	**Economic Code of Ukraine (Article 55)**
Micro-enterprises	
The book value of assets is up to 350 thousand euros (11 250 015 UAH). Net income from sales of products – up to 700 thousand euros (22 500 030 UAH). The average number of employees is up to 10 people.	Annual income from any activity does not exceed 2 million euros (64 285 800 UAH). The average number of employees is up to 10 people.
Small enterprises	
The book value of assets is up to 4 million euros (128 571 600 UAH). Net income from sales – up to 8 million euros (257 143 200 UAH). The average number of employees is up to 50 people.	Annual income from any activity does not exceed 10 million euros (321 429 000 UAH). The average number of employees is up to 50 people

Medium enterprises	
The book value of assets is up to 20 million euros (642 858 000 UAH). Net income from sales – up to 40 million euros (1 285 716 000 UAH). The average number of employees is up to 250 people.	All others belong to medium-sized enterprises (except for the 2 previous groups).
Large enterprises	
The book value of assets is over 20 million euros (642 858 000 UAH). Net sales revenue is over 40 million euros (1 285 716 000 UAH). The average number of employees is over 250 people.	Annual income from any activity exceeds 50 million euros. The average number of employees exceeds 250 people.
The official exchange rate of the hryvnia to the foreign currency (average for the period), calculated based on the NBU exchange rates set for the euro during the respective year, was used for the assessment in the national currency.	

(Compiled based on source [3], [8])

Also positive in the context of Ukraine's European integration is the fact that the national basic quantitative criteria generally correspond to their counterparts in the EU and are well correlated with European standards.

4.2. Pandemic impact assessment for small business: international and national practice.

Implemented quarantine measures to combat the spread of the disease affected about half of the world's population and harmed the economies of the countries. According to experts, in 2020 world GDP decreased by 4.36% compared to the previous year. In particular, EU GDP in 2020 decreased by 7.4%. The economies of countries such as Spain and the United Kingdom have suffered the most, with GDP falling by 12.4% and 10.3% respectively [9]. Quarantine measures affected all types and forms of enterprises that needed state support, including small businesses, which own a significant segment of market economies.

In most countries, small business has always been a public policy priority and has had some support tools before quarantine (Table 4.4).

Table 4.4. International experience in supporting small business

Element of state support	Country of implementation
Providing special conditions for guarantees for startups	Canada, Denmark, the Netherlands, South Korea
Increasing support in the form of guarantees for small and medium business loans	Canada, Denmark, Finland, Hungary, Italy, South Korea, Netherlands, Slovakia, Slovenia, Switzerland, United Kingdom, United States
Increasing state guarantees for export operations	Canada, Denmark, Finland, the Netherlands, New Zealand, Sweden, Switzerland. Spain, Great Britain
Increasing the share of direct financing of small and medium-sized businesses	Canada, Hungary, Korea, Serbia, Slovenia, Spain, France
Expanding and improving the systems of specialized government agencies and organizations with state or mixed capital that coordinate the implementation of tasks in the field of small and medium business support	United States - Small Business Administration; Japan - Agency for Small and Medium Enterprises; United Kingdom - Small Business Service; Canada - Business Services Network; Poland - Department of Handicrafts, Small and Medium Enterprises, etc.

However, during the COVID-19 pandemic and the restrictive measures imposed, small businesses found themselves in a slowdown in economic activity and total uncertainty, so state support increased and took other forms. For example, the Finnish government has allocated 15 billion euros to save the economy, and entrepreneurs, including freelancers, have been granted the right to temporarily receive unemployment benefits. It was also accepted to postpone pension contributions and tax payments [10].

The German Bundestag has adopted several social packages to support businesses and citizens during the coronavirus pandemic totaling more than 750 billion euros. At the same time, 156 billion euros were allocated to small businesses, which reduced tax revenues by 33.5 billion euros through payment holidays and 50 billion euros directly to support self-employed citizens and small businesses [10].

The French government has allocated 8.5 billion euros to help companies that have temporarily suspended employees due to quarantine.

The UK government has weakened bankruptcy legislation to allow businesses that cannot repay their debts due to the economic downturn during quarantine to continue their operations.

Italy has introduced tax breaks for businesses. To combat the economic consequences of the pandemic, the government has allocated 25 billion euros, part of which was aimed at paying subsidies to those who lost their jobs. The guarantee fund for lending to small and medium-sized businesses has also been increased. The government guaranteed compensation to companies that have lost more than 25% of their profits. In addition, the discount rate was reduced 3 times – from 0.75% to 0.25%.

The United States has allocated 2 trillion dollars to pay American citizens and businesses to prevent economic consequences and give impetus to business development. And 377 billion dollars was spent on helping small businesses [10].

To mitigate the negative impact on small businesses, the Polish government has adopted “Anti-Crisis Shield”, i.e., legislative initiatives aimed at ensuring the financial security of citizens and entrepreneurs, maintaining employment. The estimated total cost of this package is at least 10% of Poland's GDP. In addition, measures have been introduced to support the financial liquidity of entrepreneurs by ensuring their access to cheap loans and guarantors. Guarantees by the national economy bank (a state-owned bank implementing various development projects) provided up to 80% of the loan value. At the same time, the commission on such guarantees was reduced from 0.5% to 0% [11].

In total, the G20 countries have announced their intention to invest more than 5 trillion dollars in the global economy. The United States has identified the main priorities as saving lives, protecting income and jobs, and maintaining financial stability [12].

In Ukraine, even before the start of quarantine restrictions, the operating conditions of small businesses had many shortcomings, despite many legislative initiatives to support them. However, according to statistics, small and medium-sized businesses play a key role in Ukraine’s economy, providing about 64% of value-added, 81.5% of employees in businesses, and 37% of tax revenues [9].

Small enterprises that work directly with retailers in the field of tourism, restaurant, hotel business, event organization, entertainment, etc. have become the most sensitive to the introduction of quarantine measures. In general, it is possible to identify

such problematic aspects of small businesses during quarantine and restrictive measures, the solution of which is not possible without the active support of the state (Table 4.5).

Table 4.5. Key problems of small business in the conditions of quarantine (author's development)

The period of validity of the problem	The problem of small business	Impact assessment in case of the problem
during quarantine and in the post-quarantine period	small businesses do not have the resources to stay active	threatening for the state of small business, and in case of prolongation of quarantine - critical
	small businesses cannot retain key assets and personnel	threatening, as key assets and personnel are needed for rapid recovery in the post-quarantine period
	small businesses cannot develop new products and business ideas	threatening, as small businesses do not have the resources to rapidly scale (including export) new products
during quarantine	most small business workers are forced to retrain	critical, because it is about the loss of specialists and the loss of capital (intellectual, creative, industrial)
	small businesses in vulnerable industries (hospitality, tourism, retail, event business, hubs, and coworking) cannot withstand slow demand	critically, as small businesses can go bankrupt
	contractors working in small businesses (managers, waiters, cooks, seamstresses, etc.) lose their jobs or are transferred to part-time work	threatening, because contractors can emigrate, move "into the shadows" or work with less added value; small businesses will not be able to recover quickly after the removal of quarantine measures due to lack of staff; the tax base of local budgets will decrease

During the quarantine restrictions, the Government of Ukraine implemented some measures to support small businesses and the economy in general and prevent a recession. Ukraine has adopted the State Program of Economic Stimulus to overcome the negative consequences of restrictive measures to prevent the spread of acute respiratory disease COVID-19 caused by SARS-CoV-2 coronavirus for 2020-2022, which includes several components (Figure 4.1.) [13].

Figure 4.1. Forms of small business support in Ukraine in the pandemic

The implemented program provides support to small businesses: solving the problem of liquidity of small businesses by implementing measures to save jobs, simplify access to finance and reduce business costs (program “Affordable loans 5-7-9%” and payment through employment centers for employees of small businesses in the amount of 8 thousand UAH); expanding access to markets by involving small businesses in the implementation of measures for socio-economic development of individual territories; optimization of regulation and simplification of administrative procedures for small businesses, accompanied by the creation of an effective infrastructure to support it; creation of the State Fund to attract foreign direct investment in the development of the small business as a result of consultations with the European Investment Fund.

4.3. Directions for improving small business support measures in Ukraine.

As it was determined, state support measures in the context of the COVID-19 pandemic are implemented in such areas as payment holidays, tax preferences, support for small and medium-sized businesses, support for agribusiness, and information support for business. However, the question is how effective the implemented measures are from the point of view of the business representatives. Thus, to evaluate support measures in the conditions of the pandemic, the Delphi method was used.

In general, the Delphi method is one of the tools of selection and evaluation. One of the main features of the Delphi method is the independence of experts from each other, which helps avoid such negative aspects as the pressure of authorities, internal disputes, the desire to join the majority [14]. The Delphi method has three specific characteristics: the anonymity of experts, adjustable feedback, statistical processing of survey results, and group response formation.

Representatives of small businesses in Ukraine, of different industries with different income levels, were chosen as experts. In addition, they were selected from different age categories and regions of Ukraine. In total, 100 experts were selected for the survey. Thus, we believe that the group of experts is reasonable, and the results can be considered representative. Experts were asked to answer a list of questions, which later (in the second stage of the Delphi method) during processing and analysis helped to draw conclusions and provide recommendations for improving small business support in quarantine and post-quarantine periods. To conduct the survey, a questionnaire that included key questions on assessing the impact of the pandemic on small businesses and the effectiveness of measures taken by the state was developed. The results of the survey are presented in Table 4.6.

Based on the results of the survey (the first stage of the Delphi method) and statistical analysis, certain conclusions were drawn (the second stage of the Delphi method), namely:

1. Most respondents felt the pandemic's impact on their small business very strongly (38 - very strongly, 57 - strongly), indicating the critical impact of quarantine and restrictive measures and the inability of small businesses to resolve the situation on their own without government support.

Table 4.6. The results of the survey of small business representatives on the impact of the pandemic and the assessment of state measures to support small business

Questions	Evaluation criteria				
	very strongly	strongly	not strongly	very weakly	difficult to answer
1. How has the COVID-19 pandemic affected your business?	38	57	2	2	1
2. Do you feel state support for your business during quarantine and restrictive measures?	25	42	27	5	1
3. Do you consider appropriate and effective methods of state support for small businesses during quarantine and restrictive measures?	10	54	24	10	2
Questions	**Evaluation criteria**				
	yes	**partially**	**rather no**	**no**	**difficult to answer**
4. Are you aware of such small business support measures as:					
4.1. Tax preferences?	34	44	18	3	1
4.2. Support for small and medium businesses?	41	32	22	3	2
4.3. Payment holidays?	56	31	12	1	-
4.4. Support for agribusiness?	48	39	10	2	1
4.5. Information support for business?	36	46	15	2	1
5. Do you think it is necessary to extend small business support measures in the post-quarantine period until full recovery?	63	30	7	-	-

2. The assessment of tangibility of state support measures by small businesses during the pandemic can be considered satisfactory (67 > 32). Most respondents rate support as significant (very strongly and strongly).

3. A positive signal in terms of the need for the implemented measures to support small businesses is the answer to question 3 of our questionnaire (most respondents consider appropriate and effective government support for small businesses during the pandemic).

4. According to the evaluation of the implemented measures by groups, payment holidays, support for agribusiness and support for small and medium-sized businesses, namely the program “Affordable Loans 5-7-9%” and payment through employment centers for employees of small businesses through the introduction of quarantine measures (partial unemployment for the period of quarantine) aroused the greatest interest. However, a significant group of respondents considered it insufficient (22%).

For a visual demonstration, Figure 4.2 shows the diagram of the results of the survey on the impact of the COVID-19 on small businesses in Ukraine.

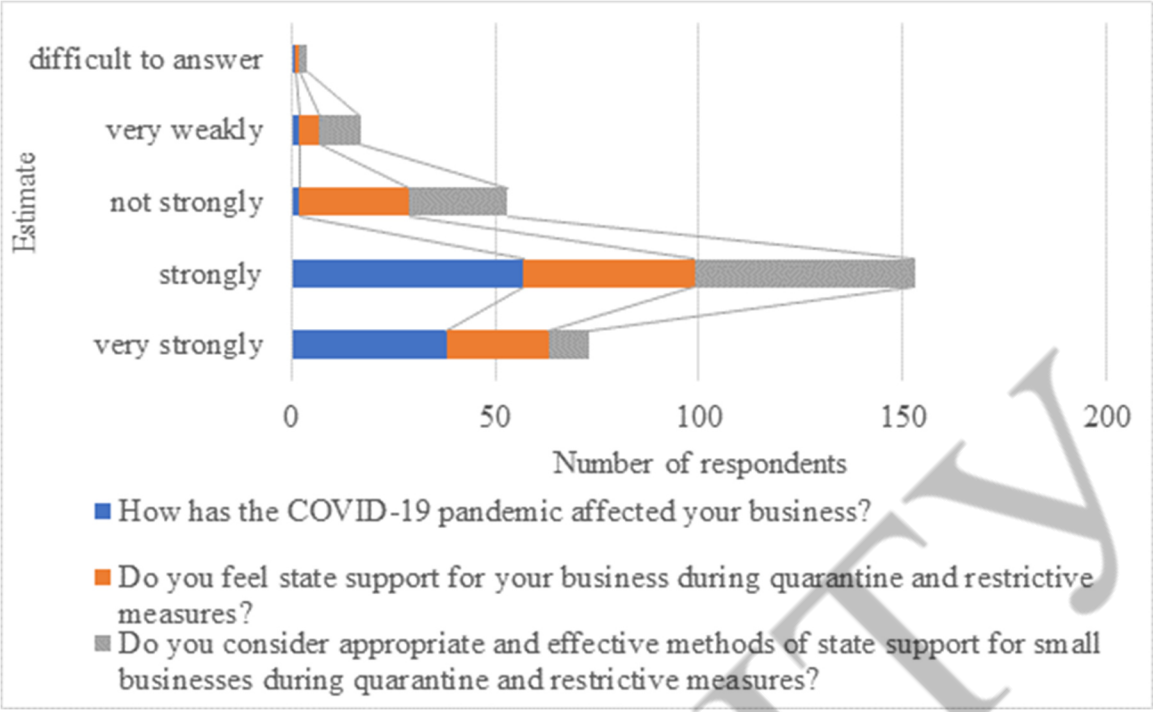

Figure 4.2. Diagram of the results of the survey on the impact of the COVID-19 pandemic on small businesses in Ukraine

Noteworthy is such a support measure as information support for business during the pandemic, where most respondents consider it strong, but 18 respondents claimed it to be weak or couldn't answer. It is expedient to further strengthen this work because information support of small businesses is a key element of its development (informing about support measures, the possibility of participating in development programs at the regional, national, and international levels), etc (Figure 4.3.).

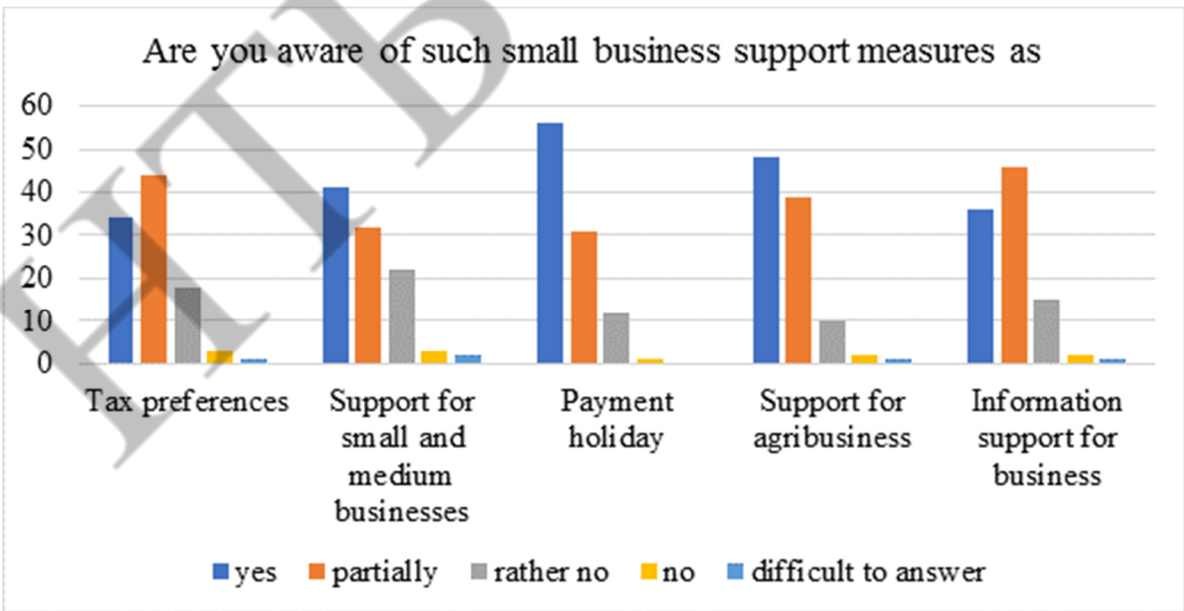

Figure 4.3. Diagram of the results of the survey on entrepreneurs' awareness of existing forms of small business support during the pandemic

Most respondents stressed the need to maintain small business support measures in the post-quarantine period (63%) and 30% of experts expressed the need to prolong only certain forms of support (available loans, moratorium on inspections, postponement of RRO) (Figure 4.4.).

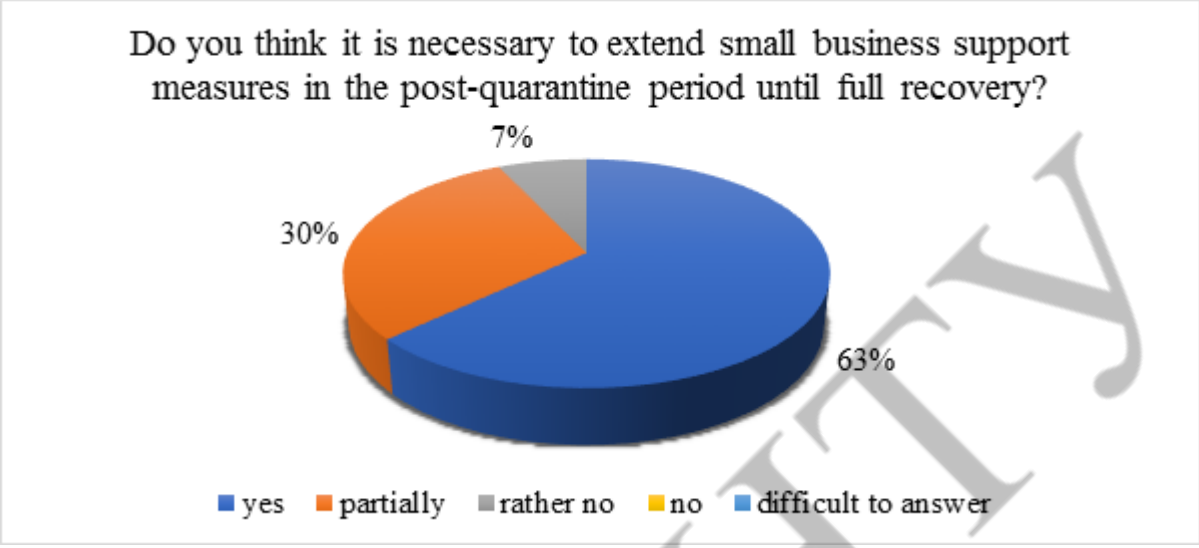

Figure 4.4. Diagram of the results of the survey on the need to extend the measures to support small businesses in the post-quarantine period

It is worth noting that the functioning of small businesses in Ukraine is mainly related to ensuring the implementation of effective mechanisms of political stability, currency, tax, customs policy, economic transformation, etc. The development of small businesses is significantly influenced by positive and negative factors, which we have summarized through SWOT analysis (Table 4.7).

Table 4.7. SWOT analysis of small business in Ukraine

Positive influence	Negative influence
Strengths 1. A high level of entrepreneurial activity. 2. Developed system of higher education, high educational level of the population. 3. Availability of basic business support infrastructure. 4. Unified permitting centers that simplify the procedure of starting a business. 5. Availability of free sites, recreational and raw materials.	**Weaknesses** 1. Uneven development of small business in the territorial context. 2. A small part of small businesses in the field of production. 3. The difficulty of obtaining credit resources for doing business. 4. Low level of investment attraction in small business development. 5. Lack of efficient cluster systems. 6. Insufficient level of social activity of the business.
Opportunities 1. The presence of large enterprises as potential customers of small business services. 2. Creation of new jobs in the small business sector through public financial	**Threats** 1. Probability of military conflict. 2. Imperfect legislative and regulatory framework for business development. 3. Excessive tax pressure.

support (implementation of public-private partnership). 3. Formation of a developed infrastructure to support small businesses. 6. Implementation of the state and regional strategies for small and medium business development. 7. Business digitalization.	4. The presence of administrative barriers to entrepreneurship. 5. High level of shadowing of business and the economy, the presence of corruption and bureaucracy. 6. Insufficient financial support of small business support programs and the level of social activity of the business. 7. Lack of available financial resources in long-term planning.

However, the quarantine measures implemented to overcome COVID-19 had a significant impact on small businesses. The study on the functioning of small businesses in the context of the COVID-19 pandemic allowed us to formulate the risks that arose, namely: cessation of activities, liquidity deficit, large-scale reduction in consumer demand, breakage of the chains of value-added and supply, loss of the domestic market, uncertainty in foreign markets.

V. CONCLUSIONS

The analysis of small business support measures in the context of the COVID-19 pandemic provided an opportunity to assess the effectiveness of the implemented support measures and formulate the following recommendations:

1. The state must prevent the spread of the crisis of small businesses through the introduction of effective mechanisms, considering the international experience and national specifics. Only under such conditions can small businesses adapt quickly enough to new challenges in the context of the COVID-19 pandemic.

2. It is necessary to further disseminate information support for small businesses and information on state, regional, international programs, competitions, grants for small businesses. Facilitating the participation of small businesses in international projects, grants will speed up the recovery of small businesses and form opportunities for their development in new areas.

3. It is advisable to expand access to markets by involving small businesses in the implementation of measures for socio-economic development of individual territories (inclusion of small businesses in urban, regional programs; inclusion of small businesses in clusters at the regional level).

4. It is necessary to continue small business support programs in the post-quarantine period while maintaining such preferences as affordable loans, a moratorium on inspections, and simplification of doing business, which in the opinion of the business itself will contribute to its dynamic development.

5. The assistance to small businesses in the introduction of digital technologies to adapt to new forms should be organized because the presence of digital format and active branding will be of use in the fight for new opportunities (projects, strategic directions, contracts, markets).

6. It is important to change the perspective on the crisis caused by the pandemic and promote the formation of thinking that the pandemic is not only a crisis but also a period for business development, associated with new niches and business strategies, as well as active introduction of digital technologies and electronic commerce.

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SMALL BUSINESS OF UKRAINE IN THE CONDITIONS OF THE COVID-19 PANDEMIC

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Abstract. *The development of small business and micro-entrepreneurship is perceived as one of the main tasks of Ukraine's economy. Despite the active work of various government agencies to implement and improve the existing measures to support small business, a number of various acute problems remain unresolved, which has a negative effect on the desire of young people to start their own business in the country. The relevance of the study lies in the fact that in the current economic crisis caused by the COVID-19 pandemic and the development of various economic processes, the further growth of small and micro enterprises requires in-depth research, especially in implementing effective and flexible regional policies to provide an objective assessment of small business activities during this crisis. Legislative regulation of small business in Ukraine is assessed. Current state of small business in Ukraine is analysed according to various indicators. The main obstacles and challenges are highlighted. Ways to improve the development of small business in Ukraine are offered. The author concludes that one of the most important forms of regulating the development of small business and micro-enterprises is state support through its special tools for doing business, financial mechanism, information and legal measures to ensure decent conditions for business and its development.*

Keywords: *small enterprise, microenterprise, small business, state regulation, state support, pandemic.*

I. INTRODUCTION

Small business today is the most common type of business. It is easier to launch, even having little or no work experience. Gradually, the size may increase to a medium one, due to the increased annual turnover and attraction of more resources. The development of Ukrainian entrepreneurship is only a few decades old and requires more in-depth theoretical research and analysis in general, a clear definition of its place in the society and the state in general, improvement of development paths during the pandemic aimed at overcoming certain economic and social problems as well as crisis socio-economic problems [1].

A vital component of any healthy and prosperous market economy is the active development of the small business sector, which plays a key role in creating new jobs and promoting economic growth and innovation. Small businesses have undergone significant changes over the last two years due to the pandemic. At that time, entrepreneurs tried to find a way out to stay in business and not to go bankrupt. The challenge for small business to survive is the use of digital technology, online business and e-commerce. At the same time, the development of small business has necessitated

the evolution of forms and methods of management at small enterprises, taking into account the peculiarities of their functioning, the use of experience of small enterprises in the developed market economies.

II. LITERATURE ANALYSIS

2.1. The essence of small business and its impact on the economy

Small business is characterized by economic and production as well as socio-economic advantages, namely flexibility, dynamism, rapid adaptation to new technologies, the ability to create and implement innovations, social stability, labour market saturation the with new jobs, open access and ease of entry into the economy sector. In addition, small business has significant socio-psychological benefits that are based on the specific motivation to work, which involves overcoming the elements of alienation and attracting elements of economic and non-economic incentives [1].

The issue of small business formation in Ukraine attracts the attention of domestic scholars who offer different interpretations of small business category. In particular, O. Hetman defines small business as an independent economic activity of small businesses and citizens-entrepreneurs. O. Belorus considers small business as a subtype of entrepreneurship, which consists in the creation and practical implementation of a new economic process. N. Voloshchuk's research emphasizes that this is a special type of activity taking into account the creative abilities of the entrepreneur and innovative approaches. O. Matusova singles out small business as a sector of the regional economy. V. Frolova argues that this is an independent organic element of a market econom. O. Pukalo defines small business as an independent activity related to production, provision of services [2, p. 124].

The researchers agree that the main purpose of small business is to make a profit and ensure social impact. Their studies are still in great demand among novice entrepreneurs and are a base for qualified professionals.

S.Z. Varnaliy notes that the role and place of small business in the Ukrainian economy is best manifested and analysed through a set of the following functions:

- formation of a competitive environment;
- providing flexibility to the market economy;
- promoting rapid development;
- absorption of surplus labour during cyclical downturns and structural shifts in the economy;
- creation of new jobs;
- mitigation of social tensions and democratization of market relations through the formation of the middle class in society [3, p. 60].

According to I.A. Serova, the main economic function of small business is its integral role in the market economic system.

The social function is an opportunity for the general population to realize their organizational, entrepreneurial and creative abilities, as well as to provide themselves with work (Figure 1).

Functions of small business

Economic function	Social function
- mobilization of financial and material resources; - provision of tax revenues; - formation of a competitive environment; - increasing the level of local resources use; - saturation of the market with consumer goods and services; - development of innovations.	- social protection of the population; - employment; - job creation; - creating conditions for the acquisition and consolidation of professional skills; - reducing the disparity in income of different social groups; - growth of incomes, savings, investments of the population; - meeting consumer demand.

Figure 1. Economic and social functions of small business according to I.A. Serova [4, p. 12].

In addition, the economic function of small business is expressed in the functioning of the enterprise and is manifested in the entry of its goods into the market, as well as obtaining sales revenue and increasing budget revenues through taxes and fees. Small business helps to strengthen the economic independence of the population and, consequently, increase the solvency of demand, but the social role of small business can be assessed by reducing unemployment, creating conditions for realizing citizens' potential.

Based on the study, the general functions of small business are identified as follows:

1) the formation of competitive, civilized market relations that contribute to better meeting the needs of the population and society in goods (works, services);

2) expanding the range and improving the quality of goods, works and services. Wishing to meet consumer demand, small business helps to improve the quality of goods (works, services) and service culture;

3) bringing the production of goods and services closer to specific consumers;

4) promoting structural adjustment of the economy. Small business gives the economy flexibility, mobility, maneuverability;

5) attracting personal funds for the development of production. Partners in small businesses invest more in the business with more interest than in large ones;

6) creation of additional jobs, reduction of unemployment;

7) more effective use of creative abilities of people, disclosure of their talents, development of various types of work;

8) involvement in labour activity of certain groups of the population, for which work in large-scale production has certain restrictions (housewives, pensioners, the disabled, students);

9) the formation of the social stratum of owners, owners of enterprises, firms, companies;

10) intensification of scientific and technological progress;

11) development and use of local sources of raw materials and waste from large industries;

12) promoting the activities of large enterprises through the manufacture and supply of components and equipment, the creation of ancillary and service industries.

Thus, small business is an organic structural element of a market economy. It is both a goal and a tool for the development of a market economy. Its dual role is confirmed by the results of the analysis of the functions inherent in small enterprises.

2.2. Legislative regulation of small business in Ukraine

Small business plays a key role in the economy of Ukraine, providing about 64% of value added, 81.5% of employees, businesses and 37% of tax revenues [5]. The main normative legal acts regulating the sphere of small business in Ukraine are the Commercial Code of Ukraine, the Tax Code of Ukraine, the Law of Ukraine on Development and State Support of Small and Medium Business in Ukraine, etc. The main financial instrument that regulates the relations between small business and the state is taxation and the type of tax regime – general or special. It is a special tax regime aimed at stimulating small business, and its system involves only one type of tax: a single tax paid to the local budget and a single social contribution, which is deposited into the accounts of the Pension Fund of Ukraine bodies [6].

The Tax Code regulates a number of benefits for small businesses:

1) simplifies the current accounting and forms of financial reporting;

2) is used instead of various forms of reporting on taxes and fees, which are replaced by a single tax; one form of reporting is filled in;

3) significantly simplifies the calculations associated with determining the amount of taxes.

However, along with the simplified reporting system, some shortcomings hinder the development of small business:

1) limiting the amount of revenue of small businesses;

2) switching to a simplified taxation system by registering as a single tax payer if a number of requirements specified by law are met;

3) the amounts of the single tax of a natural person-taxpayer are paid in advance for the reporting period (quarter).

The researchers agree that the stable development of small and medium-sized businesses, especially at the initial stage, requires government support. The lack of effective state aid in recent years has led to a decrease in the share of small and medium enterprises, the number of employees and their share in national production [7, p. 31].

The main elements of state support for entrepreneurship are:

1. State legislation to support and develop entrepreneurship in general, which includes law enforcement mechanisms to ensure the rule of law and equality of small business in cooperation with government agencies and other enterprises. It is important to use tools of financial state support, in particular:

1) a certain partial compensation of interest rates on loans that can be provided for the implementation of various economic plans of small businesses;

2) partial compensation of lease payments;

3) providing guarantees for lending to small businesses;

4) providing loans, including small loans, to start and run a business at a low interest rate;

5) providing loans for the acquisition and implementation of innovations;

6) compensation of expenses for the development of cooperation between small business entities;

7) financial support for the introduction of energy saving and environmentally friendly technologies;

8) other types of financial state support not prohibited by the current legislation.

2. The system of certain state institutions, which are responsible for the direct development of small business, ensure the implementation of state policy in this area and regulate the field of small business and infrastructure management.

3. Infrastructure to support entrepreneurship – a system of specialized institutions, both commercial and non-commercial, implementing national programs for the development of all commercial units and regional business development programs [8].

To implement a comprehensive system of new opportunities aimed at stabilization and sustainable development of Ukraine's economy and increase employment by maintaining existing and stimulating the creation of new highly productive jobs with decent working conditions during 2020-2022, the Economic Stimulus Program has been approved to overcome the consequences of the COVID-19 pandemic.

Thus, the purpose of state business support is to create equal conditions for all business entities engaged in business, as well as the alignment of business structures with other areas of social production. State support for small business is important. Nevertheless, the decisive role in the successful operation of enterprises belongs primarily to the personal qualities of the entrepreneur – talent, intelligence, education, organizational skills, perseverance, determination, ability to analyse the situation and take risks.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The aim of the research is to analyse domestic small business activities and identify the ways to improve their efficiency in the conditions of global challenges.

The object of the research is functioning of small business in Ukraine.

The subjects of the research are theoretical, methodological, organizational and practical aspects of small business and micro-enterprises functioning and development, identification of problems and prospects for their development taking into account the transformational changes caused by the global pandemic.

The research methods are comparison, explanation, abstraction, empirical analysis and synthesis, a combined method of similarity and divergence.

IV. RESULTS

4.1. Current state and problems of small business in Ukraine

According to the State Statistics Service of Ukraine, we can see and analyse the number of small businesses and micro-enterprises in 2015-2019 (Table 1).

Table 1. Number of small business and micro-enterprises in 2015-2019, units *

Years	Number of small enterprises		Number of micro-enterprises	
	Units	Specific weight,%	Units	Specific weight,%
2015	327,814	95.5	284,241	82.8
2016	291,154	95.0	247,695	80.8
2017	322,920	95.5	278,102	82.2
2018	339,374	95.4	292,772	82.3
2019	362,328	95.2	313,380	82.3
2020	355,708	95.2	307,871	82.4

**Source formed by the author. [9, p. 51].*

Thus, the number of small businesses at the beginning of 2021 was 355,708 units, which is 95.2% of the total number of enterprises, and micro-enterprises – 307,871, which is 82.4 of the total. We can conclude that compared to previous years the number of both small and micro enterprises decreased significantly in 2020, which negatively affected the country's economy.

During 2015-2019, i.e. before the beginning of some economic instability due to the spread of the COVID-19 pandemic, there is a slight but positive dynamics in the development of small businesses in Ukraine (Table 2).

Table 2. Dynamics of the main indicators of small business entities during 2015-2019*

Indicators	2015	2016	2017	2018	2019
Share of small business in GDP,%	13	14	15	15	16
Number of small businesses, thousand units	1958.4	1850.1	1789.4	1822.7	1923.0
Micro-business entities inclusive	1910.8	1800.7	1737.1	1764.7	1864.0
The share of small business in the business structure,%	99.2	99.2	99.1	99.1	99.0
Number of employees in small businesses, thousand people	1576.4	1591.7	1658.9	1641.0	1746.6
Number of small enterprises per 10 thousand population, units	77	68	76	80	86

**Source: formed by the author [96].*

Thus, according to the data in Table 2.2, we can see that the values of all indicators are quite significant in the economy as a whole. However, the share of small business in GDP is quite low and does not exceed 16%.

Micro-entrepreneurship and small business in Ukraine have always existed in difficult socio-economic conditions. The current situation is primarily caused by the COVID-19 pandemic, and then by the consequences of overcoming the third wave of the economic crisis, which began in 2014 due to the military conflict in the east and the annexation of Crimea.

According to USAID CEU, the complexity of legislation, corruption and insufficient demand was determined as the main obstacle to further small business growth in 2019 (Figure 2).

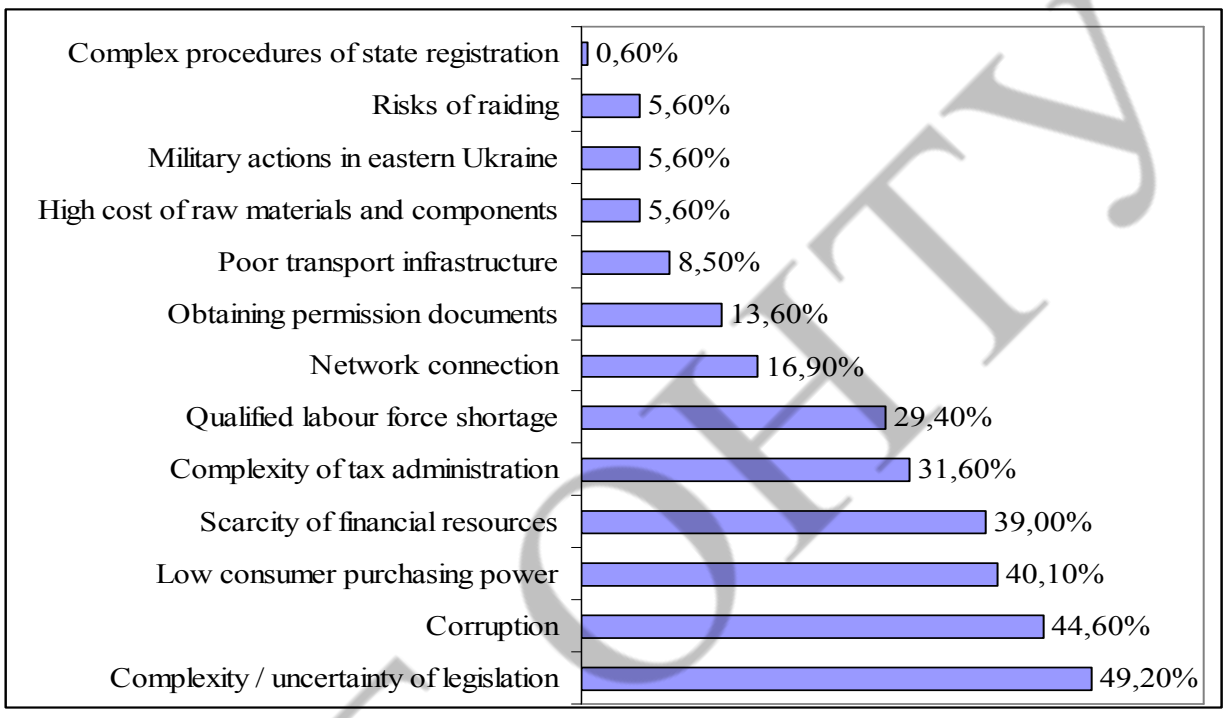

Figure 2. The main obstacles for small business in 2019-2020.
**Source: formed by the author [10, p. 15].*

The development of small business is one of the top priorities of the Government of Ukraine, which is enshrined not only in the European Union–Ukraine Association Agreement [3] but also reflected in the Strategy for Small and Medium-sized Enterprise Development in Ukraine until 2020.

International organizations consider corruption to be one of the factors hindering the development of entrepreneurship in Ukraine, which is confirmed by the Global Competitiveness Index (Table 3).

Table 3. Ranking of countries according to the Global Competitiveness Index *

Rating	Country	Competitiveness index
37	Poland	68.9
43	Russia	66.7
85	Ukraine	57.0
86	Moldova	56.7
96	Kyrgyzstan	54.0

**Source: formed by the author [11].*

Thus, according to the Competitiveness Index for 2019, we can see that Ukraine takes the 85th position out of 141 countries in this ranking. For the last two years, this study has not been made in connection with the COVID-19 pandemic, which means that Ukraine is still in the second part of the list. If we compare 2018 and 2019, we can see that during that time the country had lost two positions in the ranking. Therefore, we can assume that next year we will go down again a few steps lower.

As mentioned before, small business provides a large number of new jobs and we can say that the dynamics of the share of employees of small businesses in the total number of employees of businesses from 2015 to 2019 can be considered quite positive (Figure 3).

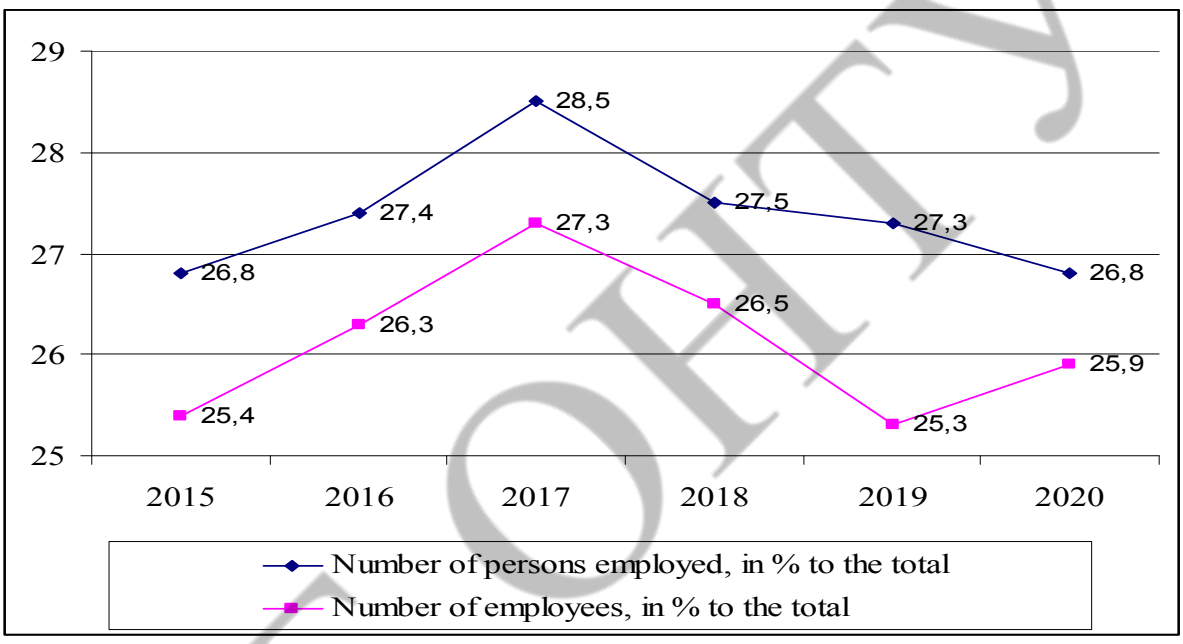

Figure 3. Dynamics of the number of the employed and employees of small enterprises, in % to the total

**Source: formed by the author [9, p. 63].*

According to Figure 3, we can conclude that the dynamics of the share of the employed and employees in small enterprises remained almost at the same level, and illustrate that the value of this indicator is not stable and averages 25-26%.

The problems of small and micro-enterprises, despite the efforts of the state, have remained unchanged for a number of years. For small businesses to function properly, carry out their economic activities and increase their share in GDP, it is expedient to implement a comprehensive socio-economic approach, developing new measures to regulate business, using government regulation tools, consolidating government and local self-government efforts to support its development.

4.2. Analysis of the effectiveness of small business in Ukraine and the world during the pandemic

The global COVID-19 pandemic has not only disrupted the country's economic stability, but also caused one of the world's largest economic crises. Disruption of

economic stability has led to the reduction in economic activity and falling GDP, rising unemployment, disruption of price stability, etc.

The government's restrictive measures necessary to prevent the spread of the virus have been a challenge not only for the country and its citizens, but also for the business sector. The introduction of quarantine measures, which were supposed to settle the situation in the country, led to significant negative consequences for business:

1) partial or full work of some enterprises;
2) complications of logistics;
3) dismissal of some employees;
4) granting temporary non-normatively significant vacations;
5) forced reductions in the length of the working day or week;
6) reduction of profits;
7) destruction of supply chains, etc.

A large number of enterprises in various sectors of the economy, especially small business and micro-enterprises, faced inability to operate and lose their income and found themselves on the verge of bankruptcy and closure, while other enterprises were severely restricted and tightly controlled by the state. Many companies are faced with a difficult choice: keeping staff or keeping their business afloat, so a large percentage of businesses have announced closure at the beginning of quarantine or some time later.

In Figure 4, we can see the data of the analysis of the European Business Association, which was aimed specifically at small business and micro-enterprises against the background of measures to prevent the spread of COVID-19 (Figure 4).

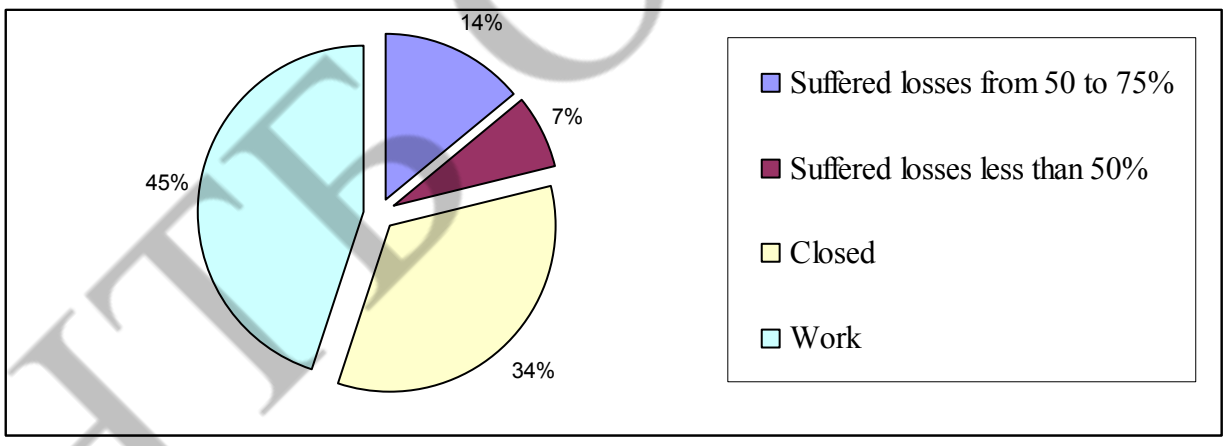

Figure 4. The impact of the global pandemic on small business
**Source: formed by the author [9;12, p. 148].*

Thus, 14% of small business and micro-enterprises suffered losses of 50 to 75% of operating revenue, 7% of enterprises suffered losses of up to 50%, the closure rate was 34% while remaining operating and not bankrupt 45% of all small enterprises. In Ukraine, 277 thousand entrepreneurs have been suspended, and their number continues to grow every day [10], respectively, the number of the unemployed has increased (Table 4).

Table 4. Dynamics of the unemployment rate in Ukraine in 2017-2021

Year	Registered unemployed, thousand people
2017	352.5
2018	341.7
2019	338.2
2020	459.2
2021 (II quarter)	344.8

**Source: formed by the author [9].*

Therefore, in the last almost 2 years, the number of the registered unemployed has increased by almost 100,000 due to the pandemic, because a large number of small businesses could not work in this difficult time and went bankrupt.

At present, small business and micro-enterprises, both in Ukraine and around the world, are making great efforts to adapt to the situation in the world economy. First, it is a question of realization of new opportunities in the organization of labour relations in connection with the introduction of a flexible mode of work and remote (online) work [7, p. 33]. At the beginning of the pandemic, a significant number of businesses changed their sales channels and switched to e-commerce to reach as much target audience as possible and not to go bankrupt.

If we talk about assistance to private entrepreneurs, the state has already provided sole proprietors with support, which means that entrepreneurs who have suffered significant economic losses could receive a one-time aid from the state for UAH 8,000. Enterprises had a tax holiday until May 2021. Part of the tax debt in the amount of up to UAH 3030 has been written off. Temporary tax exemptions for individual entrepreneurs and other tax measures such as the suspension of tax audits, payment of interest to taxpayers and social security payers have also been introduced.

We can say that granting benefits during the pandemic is the right step to help small businesses, so the government should continue doing it and provide more opportunities for entrepreneurs to do business.

Although there is some state support in Ukraine during the pandemic, we lag far behind in this matter compared to the assistance provided in the world, (Figure 5).

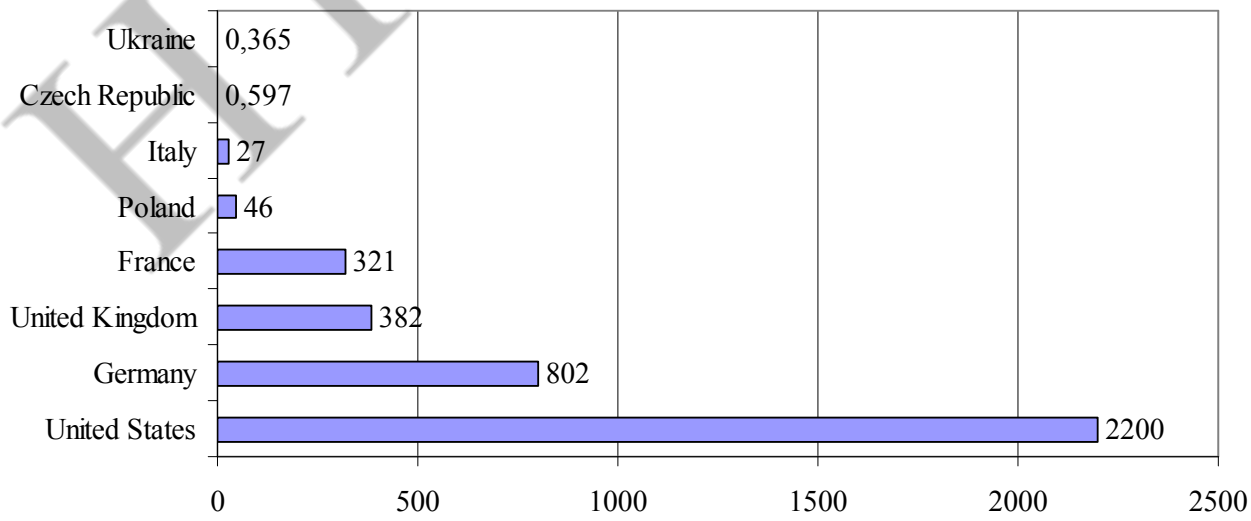

Figure 5. State financial support during the pandemic in 2020, billion dollars USA

**Source: formed by the author [13].*

The main tools of public financial support of the economy from the impact of the pandemic in the EU are:

- postponement or reduction of tax and social contributions;
- financial guarantees;
- wage subsidies;
- direct loans;
- deferment period;
- direct grants for micro-enterprises and self-employed [13].

Taking into account one of the main roles of small business for the modern economy and its improvement, comprehensive support for its development is needed. The main task of national governments is to create a decent "airbag" for small business and micro-enterprises that could work not only online but come back offline, with prospects for further development.

4.3. Ways to improve the development of small business in Ukraine

To improve the development of small business in Ukraine, it is necessary to spread state support. We need to develop programs that would help small businesses in different situations where entrepreneurs could turn to find out the information they need or solve business issues. State support for small business is regional in nature, developed by each region separately, and has its own individual characteristics. So today, there are the following support programs (Table 5).

Table 5. Support programs for small and medium-sized enterprises in Ukraine as of November 30, 2021

Program area	Material assistance, grants	Loans	Training, consultations
Regional	11	2	1
Ukrainian	8	20	0
International	6	2	13
Total	25	24	14

**Source: formed by the author [14].*

In the run, Ukraine must ensure the sustainable development of its own institutional, advisory and legislative framework for small business policy [5]. At the conceptual level, legislation on state support for small businesses should be developed based on the following key provisions:

- maintain a special law on small business, which should establish criteria for small business, as well as the rights of small businesses, different from the rights of other businesses;
- the law should contain norms that guarantee small business entities stable conditions for the development of their activities;
- rules providing support or benefits to entrepreneurs should be rules of direct action, i.e. their receipt should not depend on the subjective decision of any authorized body or official.

At the regional level, attention should be paid to the following tasks that contribute to the formation of the system of state support for small business:

– identification and consolidation of a stable source of budget allocations to support small business, as well as the development of rational mechanisms for the use of allocated funds;

– use of municipal property and property rights in various forms in the interests of small businesses, distribution of property (including land) to accommodate small business support infrastructure, rational use of existing production facilities;

– restricting the activities of judicial, control and law enforcement agencies to protect the interests of small businesses legally, ensure their security and protection of property rights;

– improving education and advocacy aimed at stimulating small business, preparing people to start their own business, forming relevant public opinion and retraining civil servants;

– establishing cooperation of business associations with government agencies, including on the basis of special agreements [14, p. 37].

The second direction of improving small business in Ukraine is to expand the access of small businesses to financial resources to ensure sustainable development and build their capacity. In addition, the model of primary information support of business at the community level and the information point of the entrepreneur (IPP) should be applied in Ukraine. The target audience is mainly microbusiness and potential entrepreneurs of the Community. The problem is the low awareness of entrepreneurs about the available opportunities for state support.

The next direction of improving small business in Ukraine is its digitalization. Digital technologies are at the forefront of today's news due to their widespread use during the COVID-19 outbreak [15]. Digital efficiencies can help small businesses expand their scale. Digital platforms can create new professions and jobs. Small businesses can enter remote markets that do not have the infrastructure. However, small business digitalisation requires significant financial investment, which is why not all small businesses have the opportunity to do it, and crowdfunding can help a lot [7].

The Internet platforms are the main tool of crowdfunding as a source of funding, because they can provide an opportunity to meet all the needs of both parties, developers and investors and greatly simplify the process. Currently, the main platforms are Kickstarter and Indiegogo, Crowdfunder, RocketHub, FundRazr, Ulule, FundedByMe, MyMicroInvest, Symbid, which were created in the leading countries of Western Europe and North America.

V. CONCLUSIONS

One of the most important forms of regulating the development of small business and micro-enterprises is state support through its special tools for doing business, financial mechanism, information and legal measures to ensure decent conditions for business and its development. State aid for small businesses is aimed at financial, informational, consulting support, including support in the field of innovation, science

and industrial production, support for small businesses engaged in export activities, support in the field of training, retraining and advanced training management and business personnel. The introduction of restrictive measures to prevent the spread of the COVID-19 pandemic in Ukraine has led to significant negative consequences for business in general, due to partial or complete closing of some enterprises, complicated logistics, reduced demand and destruction of supply chains. As we can see, in 2021 macroeconomic stability in Ukraine and the world was disrupted again by the spread of the COVID-19 pandemic. Disruption of stability in general has occurred both at the global level and at the level of national economies. Small business and micro enterprises are the most vulnerable in the current context of economic instability, which are more at risk and do not have sufficient support and decent development conditions. The difficulties that arose at the beginning of the pandemic were compounded by the new ones related to the broader aspect of economic instability: significant financial losses, forced staff reductions, job losses, increased risk of bankruptcy, and more.

Thus, at the current stage of development of Ukraine's market economy, small businesses are forced to overcome a number of economic barriers, the main reason being ineffective financial support, excessive tax pressure, and imperfectly developed programs for business during a pandemic and other restrictions imposed by law. Therefore, the main way to overcome these obstacles is to gain equality that means that entrepreneurs themselves should protect the interests of entrepreneurship. The role of the state should be only to improve the necessary infrastructure, create an effective legal framework and oversee the effectiveness of developed programs that would create space and conditions for the development of various public organizations and other associations founded to address small business development in Ukraine.

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THE IMPACT OF UKRAINIAN MIGRATION ON THE ECONOMIC DEVELOPMENT OF UKRAINE AND POLAND

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Abstract. *The work is devoted to the study of the impact of migration processes of Ukrainians to Poland on the development of the two countries. Based on the study of scientific sources and the authors' own research, the reasons of Ukrainian migration on the Polish vector are summarized in the form of Ishikawa diagram. The current state of migration of Ukrainians to Poland is analyzed using official Polish statistics, sociological research, as well as a survey of Ukrainian migrants conducted by the authors. The impact of migration processes on the economic development of Ukraine and Poland has been assessed. Both positive and negative consequences for both countries are highlighted. Measures aimed at improving the regulation of migration processes to deter emigration and return of migrants, which are consolidated by the areas of change in the country, stimulating business, stimulating workers, are justified.*

Keywords: *migration, labor migration, educational migration, emigration of Ukrainians, economic development, Ukraine, Poland, migration policy.*

I. INTRODUCTION

One of the main trends and problems of Ukraine's progress in recent years is the emigration of the population, which has become significantly more relevant with the growing openness of society and deteriorating living conditions. The instability of the political and economic situation, the lack of faith in a better future of the country force Ukrainians to look for a better life abroad. Moreover, if earlier the outflow of intelligence dominated, today the emigration of workers has intensified. Among the countries to which Ukrainian citizens travel, a special place is occupied by Poland, which solves domestic economic problems at the expense of immigrants. As a result of external migration, Ukraine is losing its labor potential, and with it, opportunities for economic growth. At the same time, Poland receives labor resources for the progress of its own economy. In this regard, there is a need to assess the scale of Ukrainian migration and study its impact on the economic development of both countries.

II. LITERATURE ANALYSIS

2.1. Directions of research of the Ukrainian-Polish vector of migration by scientists of Ukraine

A review of the Ukrainian scientific literature showed that a lot of works have been devoted to the problems of Ukrainian migration in general, but not so many ones specifically to the Ukrainian-Polish direction. However, almost every author who studies the directions of migration of Ukrainians in general, emphasizes that the Polish

vector of migration of Ukrainians has become a priority in modern conditions [1-3].

In our opinion, the study of migration processes on the Ukrainian-Polish vector in the Ukrainian scientific literature can be divided into two periods: before 2016 and after. Until 2016, the authors mainly focused on the peculiarities of Ukrainian-Polish migration, the purpose of which was trade or employment, and migration was temporary, reverse, circular in nature, mainly in the western regions; highlighted the problems related to informal employment, social insurance, etc. [4]; analyzed indicators of labor migration, characterized the competitive advantages of Ukrainian labor migrants in Poland [5].

With the intensification of migration processes of Ukrainians to Poland after the introduction of the EU visa-free regime, research by scientists has been intensified. For example, R.L.Lupak and V.V.Polishchuk draw attention to key changes in the qualitative and structural characteristics of migration of Ukrainians to Poland, the growing scale of migration from Ukraine to Poland and its problematic aspects [6].

Most of the works by scientists are devoted to the dynamics and activation of migration flows, identifying the reasons, main trends and problems of migration in modern conditions, the study of new features and changes in the structural composition of migrants [7-9]. At the same time, scientists approach this problem from different angles. In particular, T.L. Nagornyak and Y.V. Pachos, identifying the reasons and identifying important trends, consider the migration of the Ukrainian population to Poland as a result of the implementation of state policy [10]. J. Turchyn, studying the current state of the Ukrainian-Polish migration vector, analyzed the impact of the coronavirus pandemic on the employment of Ukrainian labor migrants in Poland [11].

2.2. The contribution of Polish scientists to the study of the role of Ukrainian migrants in the Polish economy

If Ukrainian scholars consider the migration of Ukrainians to Poland mostly in the context of a general overview of migration processes [4], Polish scholars study this issue in much more detail.

Thus, back in 2015, Polish scientist D. Klimek published a monograph on identifying and assessing the economic role of labor migration from Ukraine to Poland from the point of view of Polish entrepreneurs, described its impact on the labor market and key economic indicators [12].

I.Chmielewska, G.Dobroczek, J.Puzynkiewicz analyzed the main aspects of the new wave of migration of Ukrainians to Poland, its reasons, main trends and consequences [13].

P.Strzelecki, J.Growie, R.Wyszyński on the basis of alternative statistics of the country and data collected in the process of surveying migrants, studied the contribution of Ukrainian immigrants to economic growth in Poland in 2013-2018. They have found out that the increase in migrants by 0.8 % per year leads to an increase in Poland's GDP by 0.5%, i.e. in 2013-2018 about 13% of Polish GDP was created by Ukrainian migrants [14].

J. Stepaniuk devoted her research to the situation of Ukrainian female migrants living in Poland, their integration into Polish society in the legal, institutional, economic, social and cultural dimensions [15].

However, despite increasing attention to the study of migration processes in both countries, the impact of migration on their economies remains insufficiently studied as of today.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The purpose of the study is to analyze the processes of migration of Ukrainians to Poland, to assess their impact on the development of the economies of Ukraine and Poland, and to justify ways to improve the regulation of migration processes.

To achieve this goal, the following tasks were set and solved:

– to summarize the reasons for the migration of Ukrainians to Poland;

– to analyze the current state of Ukrainian migration on the Polish vector;

– to assess the impact of migration processes on the economic development of Ukraine and Poland;

– to justify measures to improve the regulation of migration processes.

The object of the study is the migration processes of Ukrainians to Poland.

The subject of research is theoretical and practical aspects of the impact of Ukrainian migration on the economies of Ukraine and Poland.

To solve the tasks set, general and special research methods are used: system-structural analysis, comparative analysis (to assess the impact of migration processes on the economic development of Ukraine and Poland); generalization, classification and analogies (Ishikawa diagram) (to systematize the reasons of migration of Ukrainians to Poland); empirical and statistical analysis, quantitative and qualitative analysis (to study the current state of Ukrainian migration to Poland); survey (to identify the main trends of migration processes from Ukraine to Poland); graphical method (for visual presentation of statistical information); logical generalization (to justify measures to improve the regulation of migration processes).

The scientific novelty of the work lies in a systematic approach to assessing the impact of migration processes on the Ukrainian-Polish vector on the economies of both countries.

The theoretical value of this research is to summarize the directions of impact of Ukrainian migration on the economies of Ukraine and Poland, which can be used for further work in terms of specific calculations.

The practical importance of the work is to substantiate the recommendations on curbing the migration of Ukrainians and their return to Ukraine.

IV. RESULTS

4.1. Reasons for the migration of Ukrainians to Poland

According to the World Migration Report 2022, in 2020 Ukraine was among the leading countries of emigration, ranking eighth, behind India, Mexico, the Russian Federation, China, Syria, Bangladesh and Pakistan. It is estimated that 5.5-6 million Ukrainians emigrated abroad. One of the most popular destinations for Ukrainians is Poland. Currently, 1.5 million people work there, constituting about 25% of the total number of Ukrainian emigrants [16].

Low living standards and wages, inability to find work, military conflict in eastern Ukraine, frustration with the country's economic policy, lack of security and

uncertainty about the future, desire to ensure a better future for their children, high dependence from foreign geopolitical players, corruption, etc. are among the reasons that motivate Ukrainians to emigrate.

In particular, Ukraine's GDP is still lower than in 2013. In particular, in 2020 Ukraine's GDP amounted to $142.3 billion, while in 2013 it amounted to $183.3 billion. At the end of 2020, the unemployment rate in Ukraine reached 10.1%, being the highest figure since 2014. The poverty rate in Ukraine is 23.3%, 8.8 million people are below the poverty line [17].

According to the annual Happiness Barometer in Ukraine survey conducted by the European Business Association, the majority of Ukrainians (51%) consider their own income level insufficient for a normal life, while less than half of the population (44%) are satisfied with their current job [18].

Assessments of the health care system are split: 58% of respondents are dissatisfied with the state of the system, while 42% assess domestic medicine as satisfactory or positive. Almost 52% of respondents were satisfied with the education system, while 48% mentioned they were completely or partially dissatisfied with it. 72% of respondents are dissatisfied with the security situation in the country and feel uncertain about their own future, 62% of respondents negatively assess the legal framework and regulation in the country [18].

At the same time, Poland today, unlike Ukraine, is a country characterized by general stability, higher living standards, higher wages, working conditions that meet European standards, a developed market, significant employment opportunities, better quality education, etc. Poland's economy has been growing dynamically since the early 2000s, with recent GDP growth of 4-5%. Unemployment before the COVID-19 pandemic was estimated at 5.5% [19].

According to the personnel portal grc.ua, the average salary offered in Poland is UAH 78,100. 50% of employers offer from UAH 44,100 to UAH 103,500; 29% of employers offer from 103,500 to 123,300 hryvnias; 21% of employers offer from UAH 123,300 [20].

Until 2013, Poland was an emigrant country. In particular, in 2002-2013, about 3% of the population (1.2 million people) left the country. Today, more than 2 million Poles work outside their country [21]. Every year, Poland loses qualified workers who go to work in the UK, Germany, the Netherlands, Norway, Belgium, and therefore is forced to liberalize the labor market to attract labor resources from other countries, including Ukraine.

To retain foreign workers whose families have stayed in Ukraine, Polish employers promote family reunification by assisting their members in employment and training.

In addition, Poland is a member of the European Union, and the introduction of a visa-free regime for Ukrainians has increased their emigration in this direction. Convenient geographical location, common border, common historical past, close culture, similar language – all this influences the choice of emigration direction of Ukrainian citizens.

Significant demand for labor from Polish employers allows Ukrainians to easily find jobs, quickly obtain residence permits and seasonal work.

The main reasons that force Ukrainian citizens to emigrate are shown in Fig.1.

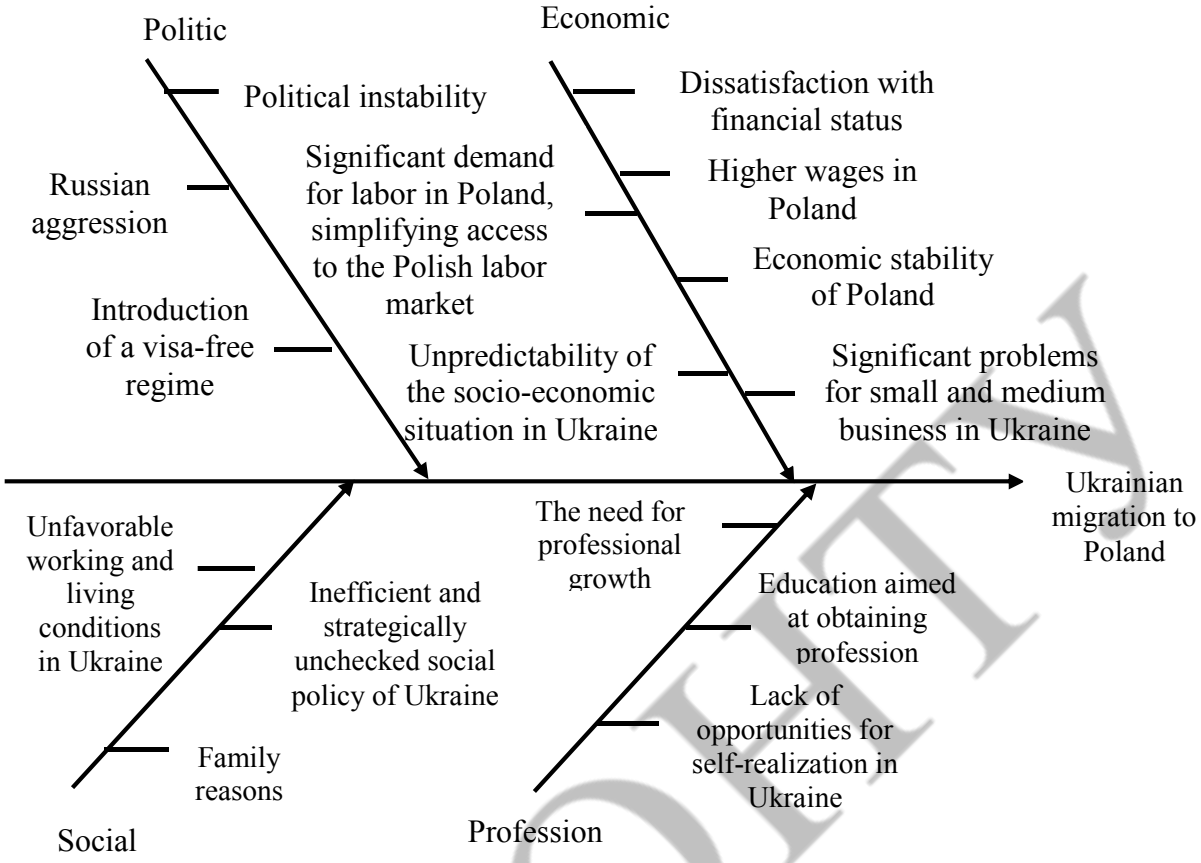
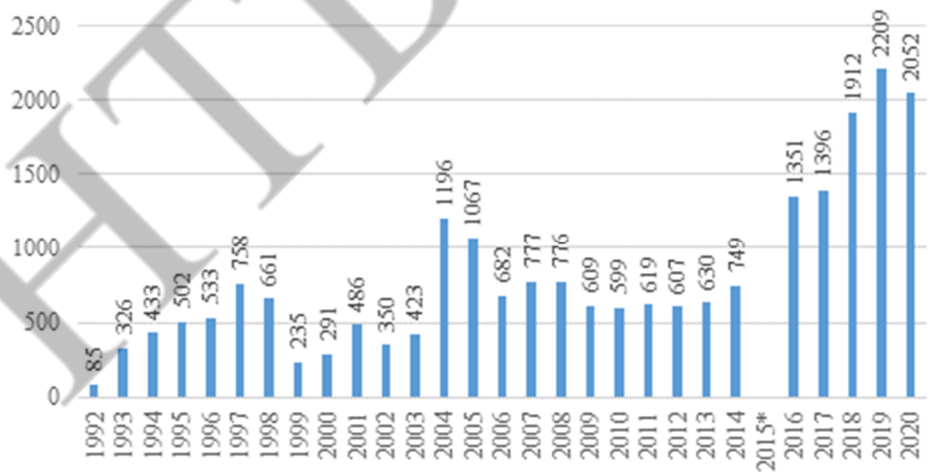


Fig. 1. Reasons for migration of Ukrainians to Poland

Source: formed by authors based on scientific sources and their own research

4.2. Analysis of the current state of Ukrainian migration to Poland

According to the official Polish statistics for 1992-2020, 22,229 Ukrainians emigrated to Poland, given 40% of them did it in 2016-2020 (Fig. 2).



2015* – lack of data

Fig.2. Migration of population for permanent residence to Poland from Ukraine in 1992-2020

Source: compiled by authors based on [22]

As of the end of 2021 the number of Ukrainian citizens with a valid residence permit in Poland exceeded 300,000. About 60% of them were people aged 18 to 40,

children and adolescents under the age of 18 accounted for about 12%, and people over 40 – about 28%. Ukrainians make up almost 57% of all foreigners who have settled in Poland [24].

Most Ukrainians settle in regions with large urban centers that offer job or study opportunities. Thus, in 2016-2020, about 80% of Ukrainians who moved to Poland for permanent residence lived in urban areas. More than 55% of those who emigrated are women [23].

As part of the study, the authors conducted a survey of Ukrainian migrants on the basis of the questionnaire distributed through social networks which is not representative. The survey involved 88 persons, of whom 36 were men (40.9%) and 52 (59.1%) were women. The most active in the survey were respondents aged 19 to 25 (64.7%). Persons aged 26-35 and 36-45 accounted for 14.7% per each group, aged 46-60 - for 5.9%. 35.3% of respondents have higher education; 44.1% – incomplete higher education, 17.6% – vocational education, 2.9% – complete general secondary education. The majority of respondents got their education in Ukraine (61.4%), the other 39.6% – in Poland. 61.3% of respondents named education as the reason for migrating to Poland, the rest came to Poland to earn money. Moreover, 23.5% of respondents just study only, 37.8% study and work. The answers to the question "What did not suit you in Ukraine?" were distributed as follows (several options could be chosen): a) wages (65.7%); b) lack of work (34.3%); c) education (48.6%); d) quality of life (71.4%); e) culture (17.1%); f) political situation (57.1%); g) personal problems (14.3%).

When analyzing the state of migration processes in the Ukrainian-Polish direction, it is important to pay attention to two aspects: migration for employment and educational migration.

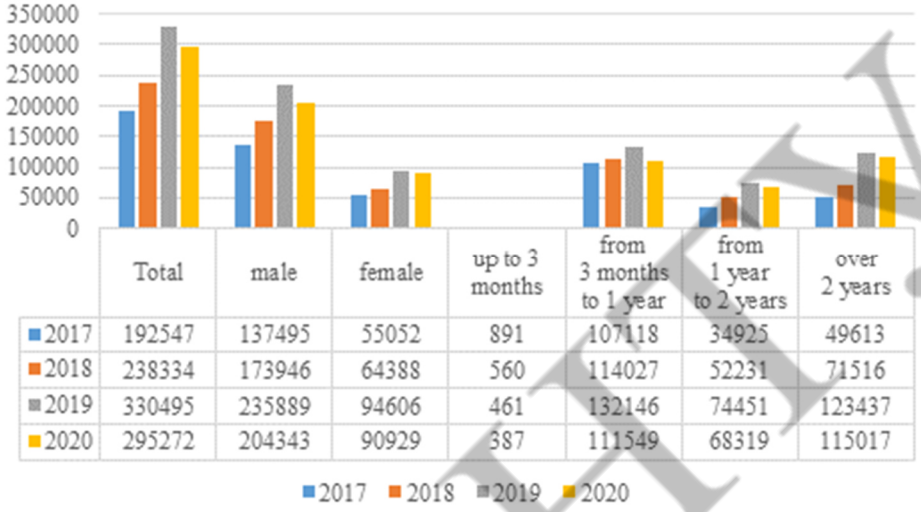
Since 2014, there has been a significant increase in Ukrainian migration, which is mostly related to the desire to work in Poland. Almost 84% of Ukrainian citizens have a temporary residence permit, which can be valid for no more than 3 years. The vast majority of them are issued in connection with employment – 77% of cases. The next most common goals of staying in Poland are family issues – 12% and education – 2% [24].

The number of Ukrainians who received a work permit in Poland has been growing from year to year, with the exception of COVID-19 year of 2020 (Fig. 3). By the way, men get more permits. While before year 2020 the highest number of permits were issued for visas for 3 months to 1 year, in 2020 it was for visas for more than 2 years.

As a rule, Ukrainians in Poland work in areas that are not very attractive for Polish workers, in particular: agricultural sector, services, industry, hotel and restaurant business, where wages are not very high [19]. 50% of Ukrainian migrant workers are employed in manufacturing, 17-18% - in services or construction, 10% – in agriculture [25].

Among the respondents we surveyed who came for employment, 60% have a permanent job, 20% work under a fixed-term contract, 4% are seasonal workers; 8% work on a case-by-case basis and 8% were unemployed at the time of the survey. 45.8% of persons work in the specialty, 50% – no; and 4.2% are looking for a job in their

specialty. 32% of respondents have been working for less than a year; 48% for 1-3 years; 16% for 3-5 years and 4% for 5-10 years. 60% receive the same salary as local workers; 60% experience competition from local workers; others responded that local workers do not have such kind of job. 68% feel stable at work and do not feel threat of dismissal. 52% are satisfied with their work in Poland, 28% are partially satisfied, others are either dissatisfied or waiting for something better. 68% of respondents would advise their compatriots to come to work in Poland.



	Total	male	female	up to 3 months	from 3 months to 1 year	from 1 year to 2 years	over 2 years
2017	192547	137495	55052	891	107118	34925	49613
2018	238334	173946	64388	560	114027	52231	71516
2019	330495	235889	94606	461	132146	74451	123437
2020	295272	204343	90929	387	111549	68319	115017

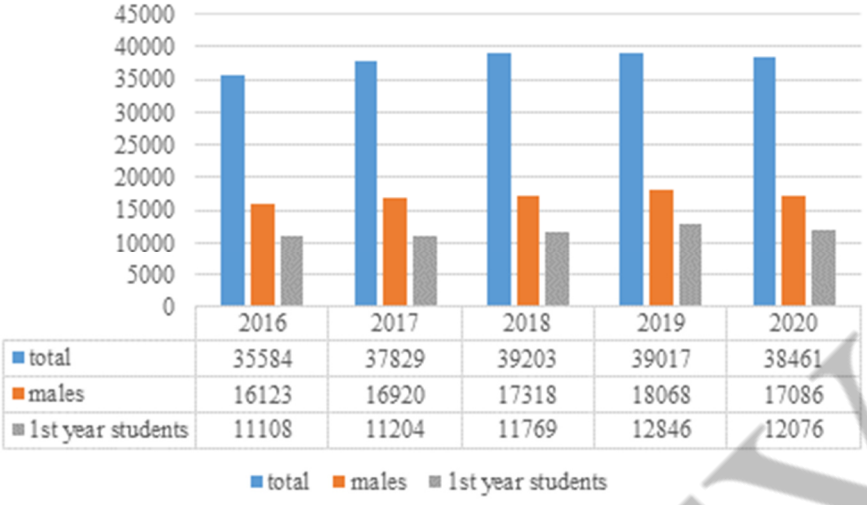
Fig.3. Foreigners who received work permit in Poland from Ukraine in 2017-2020

Source: compiled by authors based on [23]

Ukrainian migration has significantly rejuvenated, with the average age of a worker being 34.5 years [25]. According to the study conducted by the Polish company for employment of foreigners EastWestLink (EWL SA), the largest share of labor migrants from Ukraine is the age group of 26-35 years, however, the youngest age group of 18-25 years is growing dynamically [26].

Among Ukrainian migrants in Poland, men predominate (60%), however, recently the share of women has increased (up to 40%). 36% of workers have higher education, another 41% have vocational or secondary education. Every fifth Ukrainian had held a managerial position in his homeland. Most migrants (60%) come from the central and eastern regions, while just a few years ago mostly Ukrainians from the western regions went to Poland. According to the poll, only 30% of Ukrainian labor migrants intend to return to Ukraine. The rest plan to continue working in Poland or are going to earn money in other EU countries [25].

In addition to labor, the educational migration of Ukrainians to Poland has also intensified. Almost half of all foreigners studying in Poland are from Ukraine [27]. This is facilitated by territorial proximity, low language barrier, low tuition fees, availability of preferential educational programs, recognition of Polish diplomas in Europe, etc. It is also the result of Poland's efforts to develop the system of providing educational services to foreigners. In 2020, 38,261 Ukrainian students studied in Poland, which is 8% more than in 2016, but slightly less than in 2018 and 2019. Most first-year students in the study period fell on year 2019 (Fig. 4).



	2016	2017	2018	2019	2020
total	35584	37829	39203	39017	38461
males	16123	16920	17318	18068	17086
1st year students	11108	11204	11769	12846	12076

Fig.4. Foreigners studying in Poland from Ukraine in 2017-2020
Source: compiled by authors based on [23]

Among the respondents, the choice of Poland where to receive education was due to various reasons (several options could be chosen). 47.4% went to study by the parents' advice, 26.3% by friends' advice; 15.8% have Polish roots; 10.5% got interested by advertising of a Polish university; 68.4% wish to receive a diploma recognized by Europe; 57.9% hope for greater employment opportunities in Europe. 45% of respondents are satisfied with the quality of education in Polish universities, 25% are partially satisfied. However, 57% advised their compatriots to come to Poland to study.

According to the results of the research, only 2% to 16% of Ukrainian students studying in Poland plan to return to Ukraine [28]. Among our respondents there were more such students (28.6%). Another 22.9% said they would return if the situation in Ukraine improved. However, in general, the transformation of educational migration into permanent migration is a significant threat to Ukraine.

4.3. Assessment of impact of migration processes on the economic development of Ukraine and Poland

Population migration has a significant impact on all aspects of society: economy, social sphere, politics, demographic processes, etc.

We shall consider the effects of Ukrainian emigration on the economy of both Ukraine and Poland.

Ukraine is a donor to the progress of the Polish economy, but its economy suffers from critical negative consequences, as due to migration not only surplus labor is lost, but also labor needed for effective economic progress. In particular, the departure of qualified specialists leads to a shortage of workers in some industries and regions, is an obstacle to the creation of new jobs in Ukraine. Thus, today Ukraine needs skilled workers with tools, specialists in maintenance, operation and control of technological equipment, assembly of equipment and machinery, etc. According to NBU experts, construction, industry, agriculture, transport and communications suffer most from outflow of labor resources [29].

Losses for economic progress are both direct – underpaid taxes and social security contributions, and indirect – inefficient use of state and local budgets (spent on training), reduction of the quality of services provided to the population of Ukraine [8].

There is a high probability of failure to return of highly qualified migrants and young professionals. This negatively affects the age and educational structure of the workforce and restrains economic growth. Migrants' earnings directed for consumption provoke prices increase, inflation, and import increase. In addition, labor migration has a negative impact on family relationships, raising children, birth rates, which also negatively affects the progress of the country's economy.

Significant problems from educational migration to Poland are experienced by Ukrainian higher education institutions, which are losing potential students.

At the same time, external migration has not only negative consequences. First of all, labor migration contributes to the well-being of many families, ensures additional foreign currency transfers to the state, is a source of new knowledge and experience that can contribute to the progress of the country.

In recent years, labor migrants have transferred the most money to Ukraine from Poland. The dynamics of money transfers from Poland to Ukraine in 2014-2021 (Fig.5) shows an annual transfer of funds in excess of $3 billion, starting from 2017, and more than $4 billion for the three quarters of 2021.

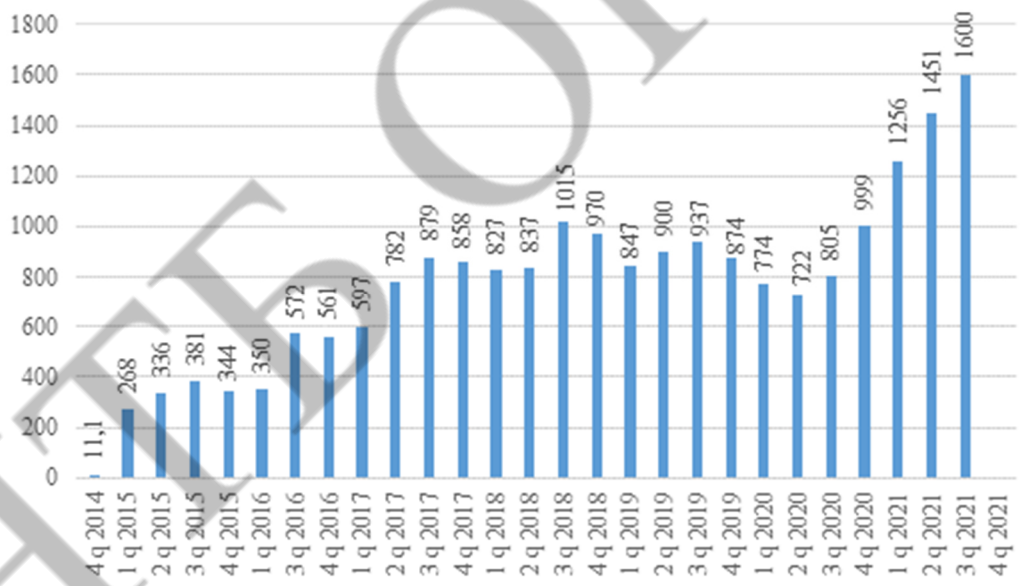


Fig.5. Dynamics of money transfers from Poland to Ukraine in 2014-2021, million dollars

Source: compiled by authors based on [30]

Among the respondents we surveyed, 32% also send funds to Ukraine. 50% of them send from $100 to $300 monthly; 20% – from $350 to $700; 10% – from $750 to $1,000 and another 10% – more than $1,000.

Migrants' money transfers have a positive effect on macroeconomic stability, cash foreign exchange market and progress of the financial and banking system, and create incentives to maintain the state of the economy. In particular, money transfers are received in foreign currency which is sold, strengthening the national currency. In

addition, the expenditure of funds from money transfers in Ukraine stimulates domestic consumption and, respectively, production, which, in turn, contributes to the creation of new jobs. Goods and services purchased for the transfers contribute to the growth of inflow from VAT, excises taxes and duties.

Labor migration also reduces tensions in the labor market, reduces unemployment rate, as some people leave the country and some live on the accumulated funds of migrant workers. In the absence of external labor migration, the unemployment rate in Ukraine in different years would be 1.5-2 times higher than the actual figures [31].

Regarding the impact on the progress of the Polish economy, it should be noted that it is due to Ukrainians that the Polish economy satisfies the demand for labor. Ukrainian migration is a resource for leveling the labor market deficit in Poland.

According to the Central Statistical Office of Poland, until 2014 the impact of immigration on GDP growth in the Republic of Poland remained insignificant (below 0.1%), but during 2014-2019 Ukrainian labor migrants increased Poland's GDP by an average of 0.3-0.9% annually [11].

According to economists from the National Bank of Poland, 11% growth in Polish GDP in 2014-2018 is due to workers from abroad, mostly from Ukraine. Unless the massive flow of immigrants from Ukraine into the Polish labor market, this growth would have been much smaller [8].

The progress of such areas as industry, hotels and restaurants, administration, health care, social assistance, construction, agriculture, etc. is largely supported by Ukrainian migrants.

Ukrainian migrants not only create Poland's GDP, but also pay taxes, buy goods and services on the Polish market, which contributes to economic progress. In addition, Ukrainians create and develop their own business in Poland.

Due to involvement of Ukrainians in Polish universities, the progress of educational institutions is supported, the system of higher education is maintained and developed, which experienced a shortage of applicants due to the demographic crisis and the departure of young people abroad.

Due to Ukrainian graduates from Polish higher education institutions, the country has the opportunity to replenish the country's labor and intellectual resources, as after graduation they can stay in the country for a year to look for a job.

The coronavirus pandemic and lockdown in March-April 2020 created a number of problems for Polish employers and, consequently, for the progress of the country's economy. However, due to the interaction of business with the government, the problem was resolved quickly.

Of course, the immigration of Ukrainians to Poland has not only a positive effect. As Ukrainian workers agree to work for lower wages than Poles, it causes stagnation of their level and increases the likelihood of unemployment.

The impact of Ukrainian migration on the economies of Ukraine and Poland is shown in Table 1.

Table 1. The impact of Ukrainian migration on the economies of Ukraine and Poland

Ukraine		Poland	
Positive impact	**Negative impact**	**Positive impact**	**Negative impact**
increase of money transfers from migrant workers	reduction of the production pace in the country	GDP growth, acceleration of economic development	competition with the local population is intensifying
reduction of unemployment in the domestic market	"Rise in price" of the domestic labor	vacancies are filling	the probability of unemployment rate growth increases
return of part of the workforce with new knowledge and experience	sectoral asymmetries of the labor market, change of the balance of highly qualified and low qualified personnel	migrants do not need training	conflicts, cross-cultural misunderstandings may arise
	additional state expenditures for the training of new specialists	reduction of the average market rates of wages	risk of illegal migration increases
	there is an "aging" of the nation; the need to import labor resources from abroad	stimulation of consumer demand	local labor force start looking for work in another country, market asymmetry arises
	lack of inflow to pension and social funds		

Source: formed by authors

4.4. Directions for improving the regulation of migration processes

The intensification of migration processes in recent years requires special attention of the government of Ukraine and its structures. It is necessary to formulate migration policy in such a way that the knowledge and experience of citizens contribute to the development of their country foremost.

Despite the existence of the Strategy on State Migration Policy of Ukraine for the period up to 2025 [32] and the action plan for its implementation, no significant progress has been made in improving the situation. Some fragmentary government initiatives (for example, the possibility of receiving 5,000 euros from the state to start a business by those who return to Ukraine) did not have the expected effect. According to official statistics, volumes of labor migration in 2021 recovered quickly and exceeded the pre-COVID levels. In the first half of 2021, more than 400,000 employment visas to Poland were issued, and in the whole 2020 only 500,000 ones [20].

Since most Ukrainians go to Poland, the Ukrainian authorities need to pay attention to this direction of movement first.

The development and adoption of comprehensive decisions aimed at eliminating and preventing the reasons of migration requires the joint efforts of all professionals from government institutions, NGOs, self-government bodies, researchers working in this field, migrating, maintaining contacts with migrants, etc.

In our opinion, it is important to form an effective system of motivation aimed, on the one hand, at curbing the migration of Ukrainians, and, on the other hand, at the return of migrants to Ukraine. However, such a system can work only if there is strong socio-economic development of the country. Therefore, today it is necessary to maintain a circular model of migration with the hope of migrants return.

The table 2 presents the main ways to curb migration processes and return migrants.

Table 2. The main ways to improve policies to curb migration and return migrants

Directions of improvement	Ways of improvement
changes in the state	– stabilization of the situation in the country, cessation of military conflict; – reducing the level of corruption in state authorities; – real reform of the economy, its restructuring; – stimulating the transition to high-tech production by supporting relevant industries and training the necessary staff; – increasing the level of investment attractiveness of Ukraine; – ensuring high rates of economic growth and stimulating wage increases in line with economic growth rates, – creation of targeted programs for the development of the country and business; – creation of a capacious and attractive internal labor market; – creation of additional jobs; – increasing living standards; – introduction of an effective monitoring system for migrants working in Poland officially and informally; – termination of companies activities that promote illegal employment; – support of Ukrainian higher education institutions for the preservation of scientists and students; – development of legislation on the mechanism of payment of pension savings of migrant workers;
stimulating business development	– reducing the tax burden for small and medium-sized businesses; – improving the conditions for doing business through the creation of favorable conditions for investment; – creating incentives to start your own business in Ukraine; – further implementation of corporate social responsibility practices, – reduction of the amount of payment of social contributions of employers; – increasing the share of labor in the cost of production; – creating attractive working conditions and wages; – providing benefits to entrepreneurs for business development; – attracting migrants to invest in starting their own business through the provision of benefits
incentives for employees	– ensuring «white» wages, social packages; – improving the welfare of citizens; – increasing the level of employment; – improving the social security of the population; – compliance by employers with current legislation on social protection of employees; – providing social guarantees for migrant workers; – formation of self-employment culture, – increase of financial literacy

Source: formed by authors

It is important to create a special center in the country that would work with people who have gone abroad to earn money and want to return home.

With the passivity of the Ukrainian government, Poland is actively working to attract Ukrainian migrants on the basis of a smart policy. There was no mass outflow of Ukrainian workers back home, even during the quarantine period. The Polish authorities responded quickly to business appeals, extending the legality of visas. Dismissed workers in industrial production and restaurant and hotel business quickly became involved in logistics and e-commerce [19].

At the end of 2021, the Polish Sejm amended the laws and made it easier for migrant workers to stay and work in the country. Changing the nature and length of stay of migrant workers from the short to medium and long term will further increase the flow of migrants from Ukraine.

Moreover, special programs have been developed in Poland to support the opening of business by Ukrainians, the purchase and construction of housing in Poland, the promotion of family employment. Such a policy poses a threat to Ukraine's national security, requiring the state to reconsider its own state policy as soon as possible.

In our opinion, Poland needs to work not only to attract foreign workers, but also to preserve its own human capital, creating conditions to reduce the outflow of labor resources to other countries in order to protect national identity.

V. CONCLUSIONS

Based on the conducted study, the following conclusions can be made.

1. The reasons for the migration of Ukrainians to Poland can be classified by economic, political, social and professional aspects. Dissatisfaction with the economic and political situation in the country, the level of material security, social protection, lack of favorable conditions and opportunities for personal development and self-realization force many citizens of Ukraine to migrate to Poland. Poland, on the other hand, with much higher living standards, a stable political and economic situation, creates all the conditions for attracting Ukrainians.

2. Based on the analysis of the current state of migration processes in the Ukrainian-Polish direction, two main aspects of migration are identified: migration with the purpose of employment and education. The number of Ukrainians obtaining a work permit in Poland is growing every year. Ukrainian migrants work in various spheres of the Polish economy. Ukrainian migration has significantly rejuvenated. The popularity of Polish universities among Ukrainian graduates is growing. The share of people who want to integrate into Polish society is increasing.

3. Ukrainian migration to Poland has ambiguous effects on the economies of both countries. Positive impact for Ukraine is an increase in money transfers, reduction of unemployment, return of part of the labor force with new knowledge and experience; while positive income for Poland is GDP growth, acceleration of economic development, filling vacancies, stimulation of consumer demand, reduction of the average market rates of wages, supporting the development of educational institutions. Ukrainian economy is negatively affected in the form of a slowdown in economic development, loss of valuable labor potential, sectoral asymmetries in the labor market, additional government spending on training new professionals, etc.; while in the Polish

economy, the probability of unemployment rate growth increases, competition increases between migrants and the local population, who start looking for work in another country, conflicts may arise, etc.

4. Migration of Ukrainians to Poland is a complex problem that needs to be urgently addressed. It is important to unite the efforts of all professionals from government institutions, NGOs, local governments and scholars working in this field to curb the flow of migration, especially among young people, and to ensure return of migrants. These problems can be solved only through high living standards and decent working conditions at enterprises, secured due to active economic reforms, support for small and medium-sized businesses, increase of incentives for employment at home and more.

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THE ECONOMIC AND ENVIRONMENTAL ASPECTS OF SHARING ECONOMY FUNCTIONING

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Abstract. *This research deals with economic and environmental issues of sharing economy. The essential principles of the sharing economy are clarified, including market self-regulation, openness, trust, and the use of surplus resources. Technological, economic, social, and environmental aspects are highlighted as the key drivers of the sharing economy's development. The COVID-19 pandemic is thought to have had an uncertain impact on the growth of sharing entrepreneurship. Obstacles to the sharing economy functioning have been identified.*

The impact of the sharing economy's functioning on the environment is explored. It is determined that the positive aspects of the sharing economy (reduction of CO_2 emissions, dematerialization of production) outweigh the negative ones. The development of new technologies is driving the sharing industry forward. The innovative aspect of the sharing economy involves not only a change in the paradigm of consumption, but also the formation of new trends in the labor market. The sharing market was discovered to be a complicated phenomenon with close interactions between its participants.

Keywords: *sharing economy, sustainable development, digitalization, innovative technology, green economy.*

I. INTRODUCTION

In recent years, digitalization (creation of online platforms, development of digital marketing, etc.) has brought the sharing economy to a qualitatively new level. So, today the capitalization of "sharing giants" Uber and Airbnb exceeds $ 25 billion. (Da Rosa et al., 2021). From an environmental point of view, the rapid development of the sharing economy, on the one hand, contributes to the dematerialization of production and, as a result, the reduction of the "carbon footprint", and on the other - excessive demand for shared goods or services can adversely affect the environment.

II. LITERATURE ANALYSIS

Many Ukrainian and foreign researchers (L. Richardson, J. Eckhart, K. Stack, R. Botsman, A. Gura, K. Kraus) have analyzed the economic aspect of sharing. Other scholars have focused on the ecological component of the shared economy, among them - P. Gatszola, F. Bonsu, A. Balgar, L. Melnyk, I. Khymych, N. Tymoshyk. The term "sharing economy" first appeared during the Great Recession (2008-2009), when it was used by Lawrence Lessig, a professor at Stanford University. The main populariser of sharing ideas is the British researcher Rachel Botsman, who in her work "What's Mine is Yours" noted that the transition to Industry 4.0 is not possible without

the development of the sharing economy. However, it is interesting to note that according to recent polls, 73% of Americans have failed to explain the concept of "sharing economy", which raises the issue of dissemination of knowledge about sharing among civil society (Gielen et al., 2019). In addition, comprehensive environmental and economic research on the sharing economy is not enough in modern scientific thought.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Object of the work - economic relations that arise in the management of the sharing enterprise.

The subject of the research is the process of managing a sharing enterprise.

Research methods. Significant methodological tools were used during the study, in particular: general theoretical methods (analysis and synthesis, induction and deduction, comparison), economic-statistical methods (for analysis of existing and forecasting future trends in sharing business).

The **results** of the research were used by PNP "Center for Economic Research" in developing the strategy for the development of Sumy region for 2023-2030 (Appendix 1).

IV. RESULTS

As Rachel Botsman stated, "the sharing economy has no shared definition". Indeed, there is no consensus among scholars on the interpretation of the definition of "sharing economy": the definitions may differ depending on whether they include the following factors:

1) "early" business models based on exchange, but working without the use of online resources;

2) B2C models: some researchers believe that they are the basis of sharing operations, while others are supporters of the "individualistic" (P2P) approach to sharing [1].

3) profitability: among scientists there is a debate about whether to consider activities aimed at making a profit, sharing.

Some of the definitions of the concept of "sharing economy" are given in Table 1.

Table 1. Approaches to the definition of "sharing economy"

Author	Definition
Nelson & Starcher, 2018	Economic system in which goods and services are exchanged between individual consumers
Mazzucato & Semieniuk, 2018	Socio-economic activities in which the exchange of goods and services is carried out through online services
Sen & Ganguly, 2017	Economic model, the essence of which is the exchange of unused assets
Ploetz et al., 2016	The type of economy that is mainly based on the use of digital platforms to provide temporary access to goods
Strachan et al., 2015	Economic culture aimed at exchanging unused assets
Sweeney et al., 2020	Satisfaction of supply and demand in certain goods or services through P2P sales or rent

In our opinion, the most optimal definition is M. Burke, "sharing economy" is an economic system based on the exchange of goods or services (for a fee or free of charge), usually using Internet technologies (Burke, 2018).

To better understand the essence of the sharing economy, it is important to consider its basic principles.

1. "You do not use - so you lose." Proponents of the sharing economy believe that every thing is a capital that should bring income. The time period when the thing is not used means lost profits and reduced value of capital. In this context, the sharing economy can be seen as a circular economy. If more people use one product, the need to buy another will disappear.

2. "Optional to own to use." The current generation of consumers prefers short-term rentals for a small fee rather than full-cost purchases. This approach is closely linked to mobility and a "flexible" approach to life. The sharing economy is a subspecies of the "access economy". An important element of modern consumer trends is the change of views on private property, which was previously perceived as a symbol of status, but now - no. Thus, in the United States, 43% of consumers generally perceive private property as a problem: due to the time spent on product selection, maintenance and storage [8]. In contrast, users of sharing companies are much less dependent on these factors.

3. "Having a certain level of trust in communicating with people." Globalization of the economy and the development of information technologies bring people together. Even today, a person's reputation in the online environment is often enough for successful sharing operations.

4. "The sharing market is self-regulating." The principle of self-regulation is realized through the acceptance by all participants of the sharing of one measure of responsibility both for their actions and for all their possible consequences. If a seller has fulfilled its obligations poorly or incompletely, it will be reduced by the number of buyers (Davidson, 2019).

5. "Openness is the key to success." This principle establishes barrier-free activity, as well as the possibility of forming supply and demand for any, even the most unusual goods and services.

Thus, the most optimal definition of the definition of "sharing economy" given by the scientist S. Curtis is singled out. The basic principles of the sharing economy are clarified, namely: the principle of market self-regulation, the principle of openness, the principle of trust, the principle of using unused resources.

The development of the sharing economy is due to a number of factors. Thus, the main drivers in the development of the sharing economy are economic, environmental, social and technological factors (Table 2).

Thus, the development of information and communication technologies allows anyone to be both a producer and consumer of goods and services. Digital technologies significantly reduce transaction costs, leading to cheaper and easier ways to exchange goods and services. For example, fully automated order processing and online payment systems greatly simplify the search process. The use of such modern technologies as blockchain, the Internet of Things, and artificial intelligence is promising.

Table 2. Prerequisites for the development of the sharing economy

Technological prerequisites	**Social prerequisites**
- Industry 4.0 and digitalization of the economy - Development of online services and digital platforms - Development of payment systems - The emergence of new devices that have the ability to connect to the Internet - The boom of social networks	- Gradual change in the culture of consumption, in particular the attitude to property - Population growth and density - Increase in life expectancy - The trend towards sestanization of social processes
Environmental prerequisites	**Economic prerequisites**
- Increasing environmental problems, in particular related to climate change - Growth of anthropogenic load	- Crisis phenomena in the economy - Emergence of new business ideas and models - Downward trend in transaction costs - Development of a network of venture funds - Improving financial literacy

No less important factors in the development of the sharing economy are socio-economic. It is no coincidence that a significant number of shared companies were established in 2008-2010, during and immediately after the global financial crisis. It is the decline of financial markets and labor market uncertainty that explains the transition from the ownership paradigm to temporary access to goods and services. In addition, the global financial crisis has raised the issue of sustainable consumption, dematerialization of the economy and its service function. Scientists also claim that sharing is cost-effective for both consumers and producers or owners. For example, owners of an unused asset may earn by renting it out. Tenants, on the other hand, can pay less than when buying. It is interesting to substantiate the essence of the sharing economy Rachel Botsman, who noted that the average time of use of an electric drill is 12-15 minutes for its entire life. This statement is a clear example of the possibility of obtaining economic benefits by providing assets.

The COVID-19 pandemic had a mixed impact on the development of sharing business. The sharing economy has, of course, suffered from quarantine restrictions: some consumers have begun to abandon the sharing of goods and have returned to the usual purchase of traditional goods and services. On the other hand, the crisis in the economy has contributed to digitalization, which, in turn, may have a positive impact on the functioning of sharing.

Environmental drivers of sharing are especially relevant. In recent years, public ecological self-awareness has become especially widespread. The world's leading countries have declared a course to "green" the economy, reorienting society to the consumption of environmentally friendly goods and services.

However, there are certain problems in the development of the sharing economy: the "grayness" of sharing companies, unfair competition, danger and legal irregularities.

Sharing companies often work in the "gray", avoiding paying taxes and hiding employment. From a macroeconomic point of view, it is important to ensure budget

revenues through the transition of sharing companies to work in "white". In this context, it is necessary to understand the difference between sharing companies that provide exclusively online platform and resource owners (Gamez et al., 2017). Although accurate data are lacking, experience shows that a significant proportion of individual entrepreneurs and small companies do not declare any or partial income from sharing. The main problem with such transactions is the difficulty in monitoring them, as resource providers are usually not members of the company that owns the platform. Difficulties are also caused by the ambiguity of the actual structure of taxation.

Another problem is the payment of taxes that operate internationally. Such online platforms usually pay a small fee in the country of registration, sometimes in the country where the services are provided. In many cases sharing business models have the ability to circumvent the requirements of entering the market. Because sharing companies tend to have lower costs (including administrative costs), they have an advantage over traditional players. For example, an online food delivery service avoids so many restrictions on its operation compared to traditional restaurants. Some countries (France, Belgium) consider this to be unfair competition and create additional barriers to the entry of shareholders.

Potential dangers in concluding an agreement are an important obstacle to the development of sharing. Of course, large companies provide an opportunity for consumers to transparently assess the quality of service and provide feedback. With large volumes of transactions, the effect of self-regulation is activated (people avoid dealing with low-rated service providers, and the system may even block them). However, small companies cannot provide such reliability that it can endanger the health of consumers or their property.

A significant obstacle to activity is the fact, that sharing companies are legally unregulated. In many cases, companies use legal loopholes for their own benefit, but not always. It is difficult for small sharing companies to adapt to frequent changes in regulations, which leads to negative financial results.

Thus, the main drivers of the development of the sharing economy are identified, which include: technological, economic, social and environmental factors. It is considered that the COVID-19 pandemic had an ambiguous impact on the development of sharing entrepreneurship. Obstacles to the functioning of the shared economy have been highlighted: the "grayness" of sharing companies and legislative irregularities.

The sharing economy has a positive impact on the environment by reducing the total resources required, reducing emissions of pollutants, reducing the carbon footprint. Thus, in 2018 in Shanghai, the joint use of bicycles reduced emissions of carbon dioxide by 25 thousand tons and nitrous oxide by 64 tons. It is important that sharing activities contribute to long-term changes in consumer behavior: for example, instead of buying your own car, a person can use car sharing on a regular basis. In addition, sharing goods and services can help improve health. For example, N. Davidson claimed that more than 10,000 premature deaths could be avoided each year if European cities reached the target of a quarter of bicycle trips.

However, despite these benefits, some studies question the environmental performance of the sharing economy. Thus, researcher K. Stendig found that users of

P2P platforms (HomeExchange and Couchsurfing) stay in tourist places longer (thus polluting the environment) than it would be in the traditional use of hotels. J. Shchor, analyzing the activities of a number of car-sharing companies, proved that their relative cheapness contributes to more frequent use, as a result - increased carbon dioxide emissions.

According to recent studies, in contrast to users of traditional hotels, consumers of home sharing services consume 63-78% less electricity, 44-48% less water, and generally generate 61-89% less greenhouse gas emissions (Gozgor et al., 2020). In July 2019, the BlaBlaCar car-sharing platform (with more than 20 million users in Europe) reported a significant environmental impact from their activities: the prevention of emissions of 1 million tons of CO2, equivalent to 250,000 cars. The main driver of this positive effect is the higher occupancy of cars (2.8 passengers in one car) than in traditional taxi services (1.7 passengers in one car) [15]. However, companies do not have a clear methodology for such calculations, so the validity of these results should be taken with caution.

There are various independent studies of the impact of car sharing on the environment. Most of the data relate to the B2C segment (traditional car sharing) and note that the main essence of sharing is a change in the private psychology of people. Thus, recent research reviews indicate that some people refuse to buy their own car, thereby significantly reducing greenhouse gas emissions.

One of the general issues regarding the environmental friendliness of the sharing economy is the "rebound effect". As a result of cheaper sharing services, real incomes of consumers are increasing. Additional income with a high degree of probability will be spent on other consumer goods. Another open issue is the environmental benefits of sharing small items (such as toys), as the negative environmental impact of transporting and cleaning may outweigh the positive. The sharing economy can be sustainable only through mutual cooperation between government agencies, businesses and consumers.

It is important to analyze the impact of the sharing economy on the transition to sustainable development. It was found that sharing creates a favorable environment for the realization of most of these goals.

Thus, the ecological effect of the sharing economy is considered. It is determined that the positive aspects of the sharing economy (reduction of CO2 emissions, dematerialization of production) outweigh the negative ones.

The advent of new technologies is driving the sharing industry forward. The importance and significance of the sharing economy is reinforced by the fact that over the past 10 years, more than 200 startups (based on sharing) have received funding totaling more than $ 11.5 billion.

Important is the study by PricewaterhouseCoopers, which shows that by 2025 the revenue of sharing companies will reach 335 billion dollars and is almost equal to the total income of traditional rental companies (Fig. 2.1) (Sheikh et al., 2016).

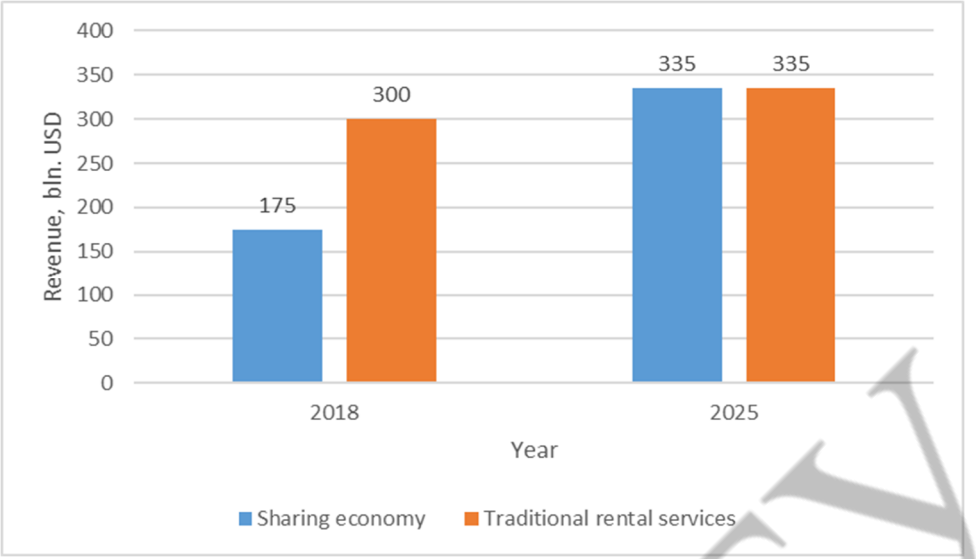

Fig. 1. Income of the sharing economy and traditional models in 2018 and 2025 (forecast value)

Studies show that more than 400 million people in 2030 will use car sharing on a regular basis. IBM estimates that 39% of car owners can abandon them if they have an extensive and balanced car-sharing network (Jebli et al., 2016).

The use of electric cars for sharing is promising. Thus, in 2018, the Polish company TAURON launched the first share of electric cars. A larger project launched in 2019 by Innology is the use of 500 BMW electric vehicles.

Over the last 10 years, car sharing has indeed started to grow exponentially. This can be largely explained by advances in digital technology, which have simplified the process of booking, paying for and accommodating cars, and digital unlocking and verification services have eliminated confusion with car keys. According to S. Miller, as of October 2019, car sharing was operating in 33 countries, five continents and 1,531 cities, covering approximately 4.8 million people, exchanging more than 104,000 vehicles. The number of people using car-sharing services in Europe, the largest car-sharing region, is 46% of all car-sharing people in the world, and the number of cars involved in car-sharing is 56% of the world's total. As of October 2019, 17.6% of car-sharing people use one-way car sharing, 82.4% use roundtrip car sharing. Europe had the highest percentage of one-way car sharing at the regional level, at 31.1%. It is important to note that some European car-sharing companies include electric cars in their fleet. The project to replace conventional cars with electric vehicles received funding from the European Union's Horizon 2020 Research and Innovation Program under grant agreement № 640401.

Currently, the growth of car-sharing services is most pronounced in Belgium, Germany and the Netherlands. For example, in Brussels, in 2018 the number of people using car sharing was 15,000 (for comparison - in 2013 9,000 people). Growth across Europe (and around the world) is concentrated in urban areas. The growth from approximately 400,000 car sharing in 2006 to over 3,500,000 in 2018 shows a significant expansion of the car sharing network. In fig. 2.2 shows the rating of European platforms of the sharing economy in terms of income in 2015 and provides forecast values for 2025.

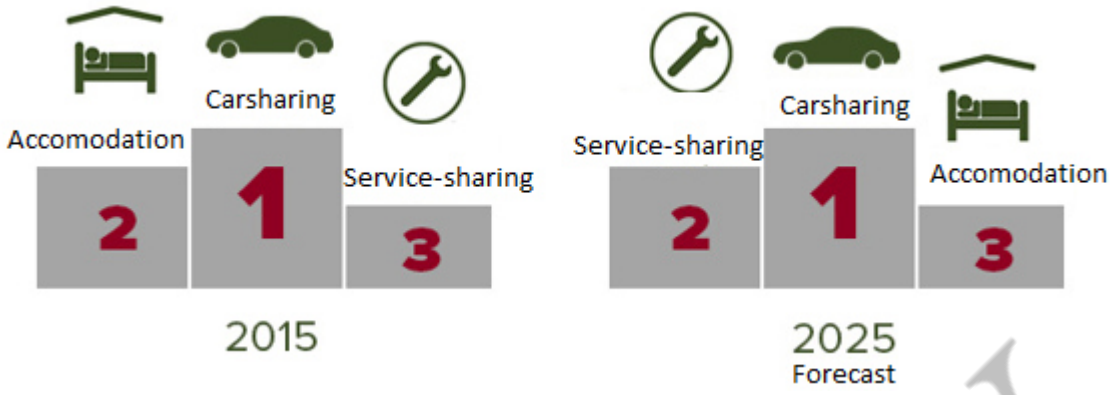

Fig. 2. Rating of European platforms of the sharing economy by revenue in 2015 and 2025 (forecast)

Digital aspects of its work are important in the innovative activity of the enterprise. The digital features of the sharing business include the company's information base, modularity, openness, capacity utilization. If a company creates added value mainly through information resources, it is easier for the company's ecosystem members to gain added value from interacting with each other on the basis of a digital platform, as information is scaled and disseminated at zero extra cost. The community that exchanges information within the digital platform is also valuable in itself, as it forms the basis of the network from which network effects arise. In this case, the information flows of the digital platform may have explicit forms (for example, user-generated content), and be covert (for example, digital platform algorithms). Thus, we can conclude that the greatest effect from the introduction of digital platforms will benefit companies in those sectors of the economy whose business model is based on information resources (services in general, banking, telecommunications, software development) (Mazzucato & Semieniuk, 2018). And companies in such sectors of the traditional economy as mining, metallurgy, construction, fuel and energy, where the share of capital assets is quite large, have difficulty in transforming their own business models in the development of digital platforms. whose business model is based on information resources (services in general, banking, telecommunications, software development). And companies in such sectors of the traditional economy as mining, metallurgy, construction, fuel and energy, where the share of capital assets is quite large, have difficulty in transforming their own business models in the development of digital platforms. whose business model is based on information resources (services in general, banking, telecommunications, software development). And companies in such sectors of the traditional economy as mining, metallurgy, construction, fuel and energy, where the share of capital assets is quite large, have difficulty in transforming their own business models in the development of digital platforms.

The impact of sharing on the future labor market is interesting. Although traditional jobs are unlikely to disappear completely soon, for some professions, sharing talent markets can be a much more attractive form of employment. They are more flexible than traditional hiring mechanisms, and employment platforms allow you to make money without leaving home or car.

Sharing reduces consumption, requires less valuable things, minimizes care for them, allows you to turn directly to people to solve household or one-time professional problems. In a broad sense, sharing is embedded in the general trend of abandoning hyperconsumption and returning to traditional communication between buyer and seller - without intermediaries in the form of resellers, agencies and consultants.

Thus, the development of new technologies moves the sharing industry forward. The digital features of the sharing business include the company's information base, modularity, openness, etc. The innovative aspect of the sharing economy involves not only a change in the paradigm of consumption, but also creates new trends in the labor market (Schmidt et al., 2016).

The sharing market is a complex phenomenon with close relationships between its subjects. Thus, in Fig. 3.1 shows the relationship between the main participants in the sharing market: asset owners, asset users and the online platform (which most often act as intermediaries).

It is important to analyse sharing market on a certain example. Carsharing is one of the leading sharing markets. Carsharing companies can be classified into four main types depending on their operational characteristics and features of business models: one-way with operational area, one-way with stationary parking, roundtrip (with return to the place) and P2P (Fig. 3).

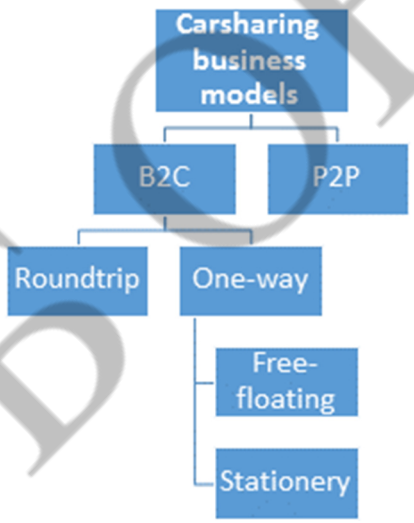

Fig. 3. Classification of car-sharing business models

In the one-way free-floating model, users rent a car and leave it in a convenient place for them. The presented model is the most flexible, as it allows freedom of movement and parking. However, the disadvantage is the limited operational area of service (in practice, limited to the city center).

The business model of a free-floating company with stationary parking spaces is much less common. Car-sharing users rent a car at the appropriate stationary sharing point and return it to the same or another parking space (Nelson et al, 2018). This business model is commonly used when sharing electric vehicles, so maintenance time is limited by charging the battery and the location of the point with the charger. In addition, potential users often have to wait until the electric car is sufficiently charged. Due to significant fixed costs and sometimes underdeveloped electric network, such a

business model is in most cases unprofitable, and only the rent from the tenant is not enough to make a profit (such companies often provide at least a minimum income from advertising).

The roundtrip business model requires the return of the car to the rental location (however, not necessarily to a stationary sharing point). Accordingly, this model is not convenient for one-way travel, but is used for short trips back and forth. Most existing business models of this type provide traditional cars instead of electric cars, which makes this model more flexible to use.

Recently, the P2P business model has become increasingly popular, with the company acting as an intermediary (renting cars from private owners and then renting them out to customers, winning the price difference).

Some classifications include business models not only for profit-making economic activities, but also for non-profit car-sharing, the essence of which is car-sharing on a charitable basis.

Thus, it was found that the sharing market is a complex phenomenon with close relationships between its subjects. It is determined that car sharing companies can be classified into four main types depending on their operational characteristics and features of business models.

V. CONCLUSIONS

In accordance with the purpose and objectives of the research work, the following conclusions can be drawn:

The most optimal definition of the definition of "sharing economy" given by the scientist S. Curtis is singled out. The basic principles of the sharing economy are clarified, namely: the principle of market self-regulation, the principle of openness, the principle of trust, the principle of using unused resources. The main drivers of the sharing economy development are identified, which include: technological, economic, social and environmental factors. It is considered that the COVID-19 pandemic had an ambiguous impact on the development of sharing entrepreneurship. Obstacles to the functioning of the common economy have been highlighted: the "grayness" of sharing companies and legislative irregularities.

The ecological effect of the functioning of the sharing economy is considered. It is determined that the positive aspects of the sharing economy (reduction of CO2 emissions, dematerialization of production) outweigh the negative ones. The development of new technologies is driving the sharing industry forward. The digital features of the sharing business include the company's information base, modularity, openness, etc. The innovative aspect of the sharing economy involves not only a change in the paradigm of consumption, but also the formation of new trends in the labor market.

It was found that the sharing market is a complex phenomenon with close relationships between its subjects. It is determined that car sharing companies can be classified into four main types depending on their operational characteristics and features of business models.

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Appendix 1

APPROVED

Deputy director of the enterprise
Center for Economic Research

I. Dehtyarova

№ 06/01 "06" January 2022

Act
on the implementation of the results of the study on the work
«**The Economic and Environmental Aspects of Sharing Economy Functioning** »

The results of the study, namely the economic substantiation of sharing economy functioning was used by PNP "Center for Economic Research" in developing a strategy for the development of Sumy region for 2023-2030.

The act was issued to submit a work for participation in the International competition of student research papers.

US-CHINA TRADE WAR

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Abstract: *In this paper, we consider the trade war between the United States and China, and its impact on the world economy. The United States and China are the largest countries in international trade: China is the world's largest exporter and the United States is its importer. The United States has maintained the status of the world's leading economy since the middle of the twentieth century, but in recent decades, China has shown particularly rapid development, strengthening its leadership in world markets. We analyzed the historical course of the trade war between the United States and China, as well as the current accounts of these countries. The paper considers the tariff policies of countries, and substantiates their impact on relations between the United States and China.*

Theoretical definition of trade war World trade wars are closely linked to international trade, which in turn is an integral part of international economic relations. But international trade can be used not only for exchange but also as a means of political and economic pressure. The trade war is the highest level of tension between countries, due to the use of various trade policy measures.

As for economic relations between the United States and China, after China's membership in the World Trade Organization, the situation went in a direction that is not the most favorable for the United States. Although for China it was one of the crucial stages in laying the groundwork for rapid economic development. The main reason for the full-scale US trade war against China was the trade gap between the two countries, as the trade balance between the US and China had a gap of 460 billion US dollars. The state of the WTO, initiated by the United States and China, indicates that the parties are trying to reach some compromises and will depend, inter alia, on progress in implementing the Economic and Trade Agreement between the United States and the Government of the People's Republic of China. In the process of regulating the trade war between the United States and China, the signing of trade agreements is being considered, which will help reduce tariffs between these countries. The signing of agreements is influenced by the following indicators: economic problems in China's economy caused by the COVID-19 pandemic, plane crashes, animal disease outbreaks, export controls, World Trade Organization decisions, the long-term impact of tariffs, and so on. High tariffs on Chinese imports affect American consumers and some American companies suffer losses because import duties are paid by US importers rather than Chinese exporters.

The establishment of China's trade barriers will increase US exports, and agreements to increase China's purchases of US products will help reduce imports, which should improve the US trade balance

Keywords: *USA, China, imports, export, trade war, World Trade Organization, world economy, foreign economic activity, international trade, trade balance.*

I. INTRODUCTION

In today's world, it is difficult to imagine world trade without various conflicts between its actors, and in times of globalization, competition is becoming more intense. In the struggle for the best conditions for trade in goods, countries are embarking on the path of trade wars and conflicts, and in the last ten years alone we can count about a dozen such examples. The most striking and large-scale example is, of course, the trade war between the United States and China. Since China's accession to the World Trade Organization, the country's economy has grown to the second largest in the world after the United States. And over the past twenty years, China's influence on the world economy has expanded markedly, and at the same time, China has gradually shifted the United States from its position as a major supplier of goods to most countries. As long as China operated as a cheap factory and was a commodity appendage, its economic growth was welcomed by the United States. However, later, the situation changed and China became difficult to call a cheap factory, as with rapid economic growth, the cost of production increased rapidly. The conflict that can now be observed between the two world giants is a particularly relevant topic for study, as in a globalized world, it cannot affect only the two countries that are directly involved in it. This trade war affects and affects all the world's economies, and affects them to a greater or lesser extent.

II. LITERATURE ANALYSIS

Theoretical definition of trade war are closely linked to international trade, which in turn is an integral part of international economic relations. But international trade can be used not only for exchange but also as a means of political and economic pressure. The trade war is the highest level of tension between countries, due to the use of various trade policy measures. Trade disputes and conflicts lead to trade war [1, p. 110]. As for the term itself, a trade war is a trade rivalry between two or more countries, countries or regions, which is conducted with the aim of capturing foreign markets, or with the aim of preventing trade occupation of the national economy. Accordingly, trade war can be divided into offensive and defensive. [2, p. 4] The main methods of offensive trade war include:

- increasing export quotas;
- reduction of export customs tariffs;
- use of dumping prices;
- embargo and economic blockade;
- recognition of competitors' products as harmful to consumers or the environment, as well as the promotion of international standards and norms that restrict and prohibit competitors' products.

The main methods of defense trade war include:

- increase in import duties;
- reduction of import quotas;
- introduction of non-tariff restrictions;
- recognition of competitors' products as harmful to consumers or the environment.

The history of trade since the Age of Great Discovery has always been associated with trade wars. Trade wars are not a new phenomenon in history, and even more, are quite common. Both China and the United States already have a history of trade disputes. The most famous of these are the First and Second Opium Wars, as a result of which China lost part of its territory. For the United States, these are trade conflicts with Canada and Japan. Regarding the latter, the trade dispute between the United States and Japan is one of the longest-running trade disputes in modern trade history. They have continued to this day since World War II. For further analysis, it is necessary to determine the clear causes and conditions of the conflict between China and the United States. Causes of the conflict Over the past 20-25 years, trade and diplomatic relations between the United States and China have grown significantly.

The normalization of trade relations began in 2000, when US President Bill Clinton signed the China-US Relations Act, which gave China the status of a permanent normal trade relationship and paved the way for membership in the World Trade Organization (WTO). The law also establishes a congressional executive committee to ensure China's compliance with international human rights law, labor standards, and religious freedom, and establishes a working group to ban the import of Chinese products made in forced labor camps or prisons. The law also includes so-called «anti-dumping» measures designed to prevent the influx of low-cost Chinese goods into the United States, which could harm the American industry from producing the same goods. For China, gaining WTO membership was an extremely important step [3]. China wanted to join the WTO, as it would provide access to new trading partners and improve relations with existing ones, raising the prospects for improving living standards in the country and giving China a place at the table in a globalizing world. The United States also had certain expectations [4]. For example, for China to join the US-led liberal-democratic order and move away from its communist model. Thus, Clinton and others advocated China's accession for several reasons:

- China would have to change its policy to comply with WTO rules, reducing tariffs and guaranteeing intellectual property rights, among other things, then countries like the United States should not do much in return.
- The United States has argued that membership in an international organization such as the WTO will act as a test of China's communist government, accelerating its transition to a market economy and encouraging it to become more involved in setting global rules. This was not a new idea, Clinton's predecessor acted on the same assumption that free trade leads to democracy: «No country on earth has found a way to import goods and services in the world, stopping foreign ideas at the border» said George H.W. Bush.
- It would also legitimize the World Trade Organization itself: China was the largest trading country outside the organization, and the WTO could not really claim the role of a global organization without China. In general, the United States has seen some advantages and disadvantages in economic terms.
- Consumers generally benefited from joining the WTO because they could buy goods from China at lower prices.
- Corporations have benefited from expanded access to China's mass market. For example, in 2017, China accounted for about 20 percent of Apple's sales, and since

2001, the value of US agricultural exports to China has increased by 1,000 percent. However, unions in manufacturing and factories opposed the WTO accession agreement, arguing that cheaper labor in China would cost jobs in the United States. And they were right: between 1999 and 2011, almost 6 million jobs were lost in the United States. Meanwhile, China's economic impact has been extremely positive. [5]

- China's economy has become eight times bigger than in 2001. Trade in goods between the United States and China has increased more than thirty times, from $ 8 billion in 1986 to more than $ 578 billion in 2016. In 2006, China became the second largest economic partner of the United States after Canada, jumping over Mexico-China surpassed Germany, becoming the world's largest exporter of goods in 2009. And the visualization of a successful export-oriented strategy and an overall impressive economic However, the political expectations set by the US Government have not materialized.

China has not come closer to democracy than the United States had hoped. In fact, huge economic successes have only legitimized the Chinese Communist Party, which President Xi Jinping believes is key to maintaining economic stability and enabling China to dominate technology-driven industries. China's tight state control extends to the Internet, which was to be the gateway to reform and innovation. China regulates the use of the Internet by restricting access to commerce and social media [7]. Over time, the current situation and supplemented by other political and economic factors formed the ground for a trade conflict. China's growth may serve as a chart below. However, the political expectations set by the US Government did not materialize. China has not come closer to democracy than the United States had hoped. In fact, huge economic successes have only legitimized the Chinese Communist Party, which President Xi Jinping believes is key to maintaining economic stability and enabling China to dominate technology-driven industries. China's tight state control extends to the Internet, which was to be the gateway to reform and innovation. China regulates the use of the Internet by restricting access to commerce and social media [7]. Over time, the current situation and supplemented by other political and economic factors formed the ground for a trade conflict.

February 7, 2020: China reduces tariffs on goods by $ 75 billion, according to the first phase of the agreement. China's Treasury Department has announced it will cut tariffs on 1,717 US goods, cutting tariffs on some goods from 10 percent to 5 percent and others from 5 percent to 2.5 percent to take effect on February 14, 2020.

The tariff reduction will be applied to the list of additional tariffs, which came into force on September 1, in the amount of $ 75 billion. The announcement corresponds to a reciprocal commitment by the United States under the first trade agreement to reduce tariffs from 15 to 7.5 percent on goods worth $ 120 billion on the same date. 19 Crude oil, meat products and soybeans are among the products that benefit from tariff reductions. The reduction will reduce oil tariffs from 5 percent to 2.5 percent, soybean tariffs from 30 percent to 27.5 percent, and pork, beef and chicken tariffs will fall from 35 percent to 30 percent. February 17, 2020: China provides tariff concessions on 696 US goods to support purchases According to the Chinese Tariff Commission, 696 US goods will be exempt from additional tariffs in China, as the Chinese government seeks to fulfill its commitments in a trade agreement with the

United States . 696 products include pork, beef, soybeans, wheat, corn, sorghum, ethanol, liquefied natural gas, crude oil, steel rails and some medical equipment. February 21, 2020: The Chinese Tariff Commission has released two new lists to exempt part of US imports from additional Chinese tariffs. Both lists will be valid for one year from February 28, 2020 to February 27, 2021. The lists will include 55 and 10 types of US goods, respectively, including timber, hydraulic motors, diaphragm pumps, aircraft parts, medical equipment and more.

Trade war is the highest degree of tension in trade relations between countries, trade war is conducted in order to capture the market of the opponent's state, or to prevent trade occupation of their own markets. As for economic relations between the United States and China, after China's membership in the World Trade Organization, the situation went in a direction that is not the most favorable for the United States. Although for China it was one of the crucial stages in laying the groundwork for rapid economic development. The main reason for the full-scale US trade war against China was the trade gap between the two countries, as the trade balance between the US and China had a gap of 460 billion US dollars. Another reason is the non-competitiveness of American companies. After all, they must reduce production costs to be able to match Chinese prices. The next formal reason is the insufficient level of protection of intellectual property rights in China, the lack of adequate practices and laws to protect foreign technology from illegal distribution in the country. And also, at the heart of the Sino-US trade war is actually a battle for global economic dominance. In total, there are five stages in the trade war since the beginning of 2018. During these stages, there have been endless changes in tariffs on various groups of goods and services, despite some lull now, tariffs remain high, and the results and consequences of the trade war can already be seen in different areas and in different regions.

The impact of the trade war on other countries developing countries will suffer the most from the confrontation between the United States and China. This will happen through:

• general slowdown in world economic activity;

• reduction of world trade and, consequently, exports, on which developing countries are overly dependent as small open economies;

• lower prices for basic customs goods, including metals, agricultural products, and other commodities amid concerns about the stability of demand; this, in turn, will negatively affect trade balances and exchange rates in developing countries;

• acceleration of inflation due to currency devaluation and related deterioration of inflation expectations due to a significant level of dollarization of economies;

• increasing volatility in world commodity and financial markets.

Deteriorating economic growth prospects in emerging markets will reduce investor demand for the assets of these countries, which will create conditions for capital outflows and, consequently, the devaluation of their national currencies.

Thus, according to the Institute of International Finance (IIF), only from the beginning of the trade war to September 2018, the volume of portfolio investment in developing countries decreased by 20.3 billion dollars. At the same time, the world's largest banks (Goldman Sachs, Citigroup, Morgan Stanley) have announced the sale of currencies of this group of countries, given the growing risks to the world economy.

However, the deterioration of financial conditions for emerging markets was not only due to the escalation of trade conflicts, but also due to tighter monetary policy of leading central banks.

Under such conditions, investors' interest in risky assets, including assets of developing countries, decreased, which increased the outflow of capital. Accordingly, the central banks of such countries have been forced to repeatedly raise key rates. Thus, the Bank of Indonesia even resorted to a precautionary increase in the period between regular meetings in order to stabilize the exchange rate against the background of tighter than expected monetary policy in the United States. In Russia and India, central banks were forced to break the cycle of lower key rates. In general, emerging market countries, with the exception of Argentina and Turkey, have been better prepared for deteriorating external conditions than in previous periods. This was facilitated by prudent macroeconomic policies, including monetary policies based on inflation targeting, which include flexible exchange rates, strengthening the institutional independence of the central bank, measures to ensure the strength of the financial system, and lack of fiscal dominance.

Since the beginning of 2019, external pressure on emerging markets has eased somewhat. This was facilitated, on the one hand, by a temporary truce in the trade dispute and, on the other hand, by softening the rhetoric of the leading central banks. However, a new wave of escalating trade disputes between the United States and China and harsher US rhetoric toward other countries, most notably Mexico, have negatively affected investor sentiment. Following the stabilization of US-China relations, financial conditions have eased, creating room for lower key rates in some emerging markets.

In countries where the contraction of external demand and the decline in trade will have a significant impact primarily on economic activity, central banks will be able to pursue softer monetary policies to stimulate domestic demand. This will be facilitated by a number of internal and external factors, namely:

• inflation within the target range;

• anchored inflation expectations at the central bank's target level and their low sensitivity to pro-inflation shocks, including exchange rate devaluations;

• low current account deficit (or surplus), sufficient reserves;

• investor confidence reflected in high credit ratings and low cost of external financing;

• low geopolitical risks.

This group includes the countries of Central and Eastern Europe and Chile. However, the scope for lowering nominal rates in these countries, especially in Poland and Hungary, is rather limited, as they currently do not exceed 2.5% per annum. Accordingly, active action by central banks is not expected.

III. OBJECT. SUBJECT. RESEARCH METHODS

The United States and China are the most involved in international trade: China is the world's largest exporter and the United States is its importer. The United States has held the status of the world's leading economy since the middle of the twentieth century, but in recent decades, China has shown particularly rapid development, gaining leadership in the markets of most countries. The loss of US export markets,

negative trade balances and dependence on imports from China continue to deepen, prompting US authorities to take protectionist measures and start a trade war. Undoubtedly, the trade war between the giant economic countries could have unexpected consequences for the entire world economy, which is why analyzing US trade flows with China and tracking their dynamics as protectionist measures deepen is very important.

The object of study is the trade war between the United States and China, and the subject, its impact on the world economy.

To study the impact of the trade war, we analyzed the current accounts of the United States and China, they can be seen a sharp decline in the surplus of this balance of payments in China by about 75% in 2018. This change is mainly the result of a significant increase in Chinese merchandise imports. The US deficit has also worsened significantly, indicating that Trump's tariff policy has only had negative consequences for the national economy, and one of the main goals of implementing tariff barriers - reducing the United States' trade deficit ─ has not been achieved.

Also for the study, we considered the dynamics of the trade balance between the United States and China.

China was the largest supplier of US goods in 2018, the main categories being electrical equipment, machinery, furniture and bedding, toys and sports equipment and plastics. China's total exports to other countries in the world had not decreased significantly in 2019, which means that China has opened new markets for its products, which were previously exported to the United States. China is also one of the largest exporters of agricultural products to the United States, leading supply categories include: processed fruits and vegetables, fruit and vegetable juices, snacks, spices and fresh vegetables. The United States estimated imports of services from China in 2018 at $ 18.4 billion. Imports of leading services from China to the United States have been in the transportation, tourism, and research sectors. Looking at US export flows to China, which became the 3rd largest export market for US goods in 2018, we can see a significant decline over the past two years. The main categories of US exports to China in 2018 were: aircraft, machinery, electrical machinery, optical and medical instruments and vehicles. The total volume of agricultural exports to China in 2018 amounted to 9.3 billion dollars, which is the fourth largest market for agricultural exports from the United States. Leading categories of Chinese imports from the United States include soybeans, cotton, hides, skins, pork and pork products, and cereals. Analyzing the data, we can assume that, in theory, the establishment of China's trade barriers will increase US exports, and agreements to increase China's purchases of American products will help reduce imports, which should lead to improved US trade balance.

IV. RESULTS

Analyzing the current accounts of the United States and China, revealed significant changes in their structures and dynamics. First of all, due to the large-scale growth of China's imports, there was a sharp decline in the current account surplus of this country. Equally important, the US deficit has also shown a marked deepening, which is evidence that Trump's tariff policy has only led to negative consequences for the national economy. An analysis of bilateral trade relations between China and the

United States has shown that close trade cooperation between the two countries began to decline in 2018, as a result of tight bilateral tariff regulation. Observations of trade flows and balances of payments have shown that the trade war has not yet led to the inevitable consequences in the economies of the United States and China, but signs of recession are already clearly visible on trade balances.

The introduction of reciprocal restrictions did not improve the US foreign trade position, because, firstly, part of Chinese purchases, which were abandoned by US importers, were replaced by more expensive imports from other countries, and secondly, rising Chinese import prices led to increased costs of already American exporters who use imported components in their production. Based on the simulation results, we can conclude that the signing of new trade agreements between the United States and China with agreements to increase Chinese purchases of American products, which took place in late 2019, should help the United States improve its trade balance, as opposed to increasing import tariffs led to negative results. These research results can also be used to establish trade relations not only with the United States and China, but also with other countries. The introduction of new trade agreements and the reduction of tariff restrictions will increase trade between countries and improve economic relations between countries.

CONCLUSIONS

1. The consequences of the confrontation between the United States and China in the trade sphere have a significant impact on both individual countries and the world trade system as a whole, as evidenced by the participation of a large number of interested countries in disputes between these countries in the WTO.

2. The state of the WTO, initiated by the United States and China, indicates that the parties are trying to reach some compromises and will depend, inter alia, on progress in implementing the Economic and Trade Agreement between the United States and the Government of the People's Republic of China.

3. Indicators of China’s purchase of American products under the first phase of the agreement were not reached. The state of trade between the United States and China has been affected by force majeure (COVID-19 pandemic, plane crashes, bird flu outbreaks in the United States) and export controls, World Trade Organization decisions, long-term effects of tariffs imposed by both sides.

4. China has offset the decline in supplies of American products by expanding imports from other countries, including Ukraine.

5. As a result of China’s tariff measures, American farmers have suffered serious losses, forcing the US government to make significant allocations to support them.

6. High tariffs on Chinese imports also affect American consumers and some American companies that import Chinese products have suffered losses, which have led them to sue the US International Trade Court.

7. China is projected to continue to reduce its dependence on the United States in trade and economic terms, including through enhanced cooperation with other countries under the One Belt, One Road initiative.

8. At this stage, the trade truce between the United States and China is quite volatile, given that most of the issues remain unresolved.

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MAIN TRENDS OF DIGITALIZATION DEVELOPMENT IN UKRAINE AND DIRECTIONS OF THEIR IMPROVEMENTS

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Abstract. *Today digitalization of Ukraine's economy is one of the most promising and relevant areas, which requires much attention, as well as new approaches to its implementation, research and reform. The whole world, including Ukraine, is undergoing a process of digital transformation and adaptation. It affects all areas of our lives, from education to the economy. Digitalization is a complex system that is interconnecting by interdependent factors that are vital to each other.*

At present, few studies have examined the state and level of digitalization of Ukraine's economy. Thus, there is a need to improve the mechanism and tools for the development of digitalization to achieve a high level, which led to the choice of research topic, its purpose, objectives and content.

The purpose of scientific work is to analyze the level of digital transformation of Ukraine and the world, development of methodological and scientific-practical recommendations for improving the mechanism of digitalization of the economy.

Keywords: *digital transformation, information technology, digitalization, digital economy, digital infrastructure, network effect, digital organization, blockchain technolodies.*

I. INTRODUCTION

The world economy has changed over the last ten years to such an extent and at a rate faster than ever before. Europe, North America, Asia are literally digitizing their economies, waiting for the global impact of advanced technologies to increase with increasing profits from e-commerce, data exchange and services. The realities of the global world dictate the following conditions for modernizing the economy and creating clear rules for a new era of innovation. The adaptation and transformation of business, education, health and public services through digital technologies is a major obstacle to solving global problems. Information technology allows any company to change its own business model to be competitive in the global market. Digital transformation itself is a catalyst for innovation and change in all spheres of life.

Given the urgency of this problem, the paper considers the main obstacles and drivers of digitalization transformation in Ukraine. External and internal preconditions and future challenges conditioned by digital transformation are analyzing.

II. LITERATURE ANALYSIS

2.1. Theoretical fundamentals of the process of transformation and digitalization of economic processes of the country

According to statistics, almost half of the world's population is an active user of the Internet. That is why now studying the world or doing business using new

technologies is not a trend, but a daily necessity. The digital transformation, or digitalization, has integrated into all aspects of society, including business, government, health care, the media, science, and so on. With the development of digital technologies, the term "digitalization" has become widely used.

Table 1. The main meanings of the term «digitalization»

№	Author	Meaning	Resource
1	Claude Shannon	Digitalization is the process of converting data, often tangible, into digital format that can read from a computer screen or smartphone. [1]	«Mathematical Theory of Communication», 1948
2		Digitalization is the use of digital technologies to change the business model and provide new opportunities for revenue and value creation; it is the process of transition to digital business. [2]	Gartner's Dictionary
3	Team «TruQC»	Conversion of data, documents and processes into digital analogues. [3]	Website «TruQC»
4	Margaret Rose	Margaret Rose Digitalization is the process of converting information into digital format. [4]	Website «WhatIs.com»
5		Digitalization is most often understood as the creation of opportunities, improvement and / or transformation of business operations and / or business functions / or business models / processes / or activities through the use of digital technologies and wider use and context of digitized data converted into intelligence and practical knowledge. [5]	Website i-SCOOP

So if we summarize the above meaning, we can say that digitalization is the conversion of data, documents and processes into digital format, through the use of digital technologies to provide new opportunities. Automation, optimization, process autonomy, as well as great flexibility and individuality of products and services - these are just some of the benefits and opportunities of digitalization.

Digital technologies are at the heart of an increasing number of transactions, and the digital economy is becoming increasingly integral to the functioning of the economy as a whole. Different technologies and economic aspects of the digital economy can divide into three main components (Figure 1).

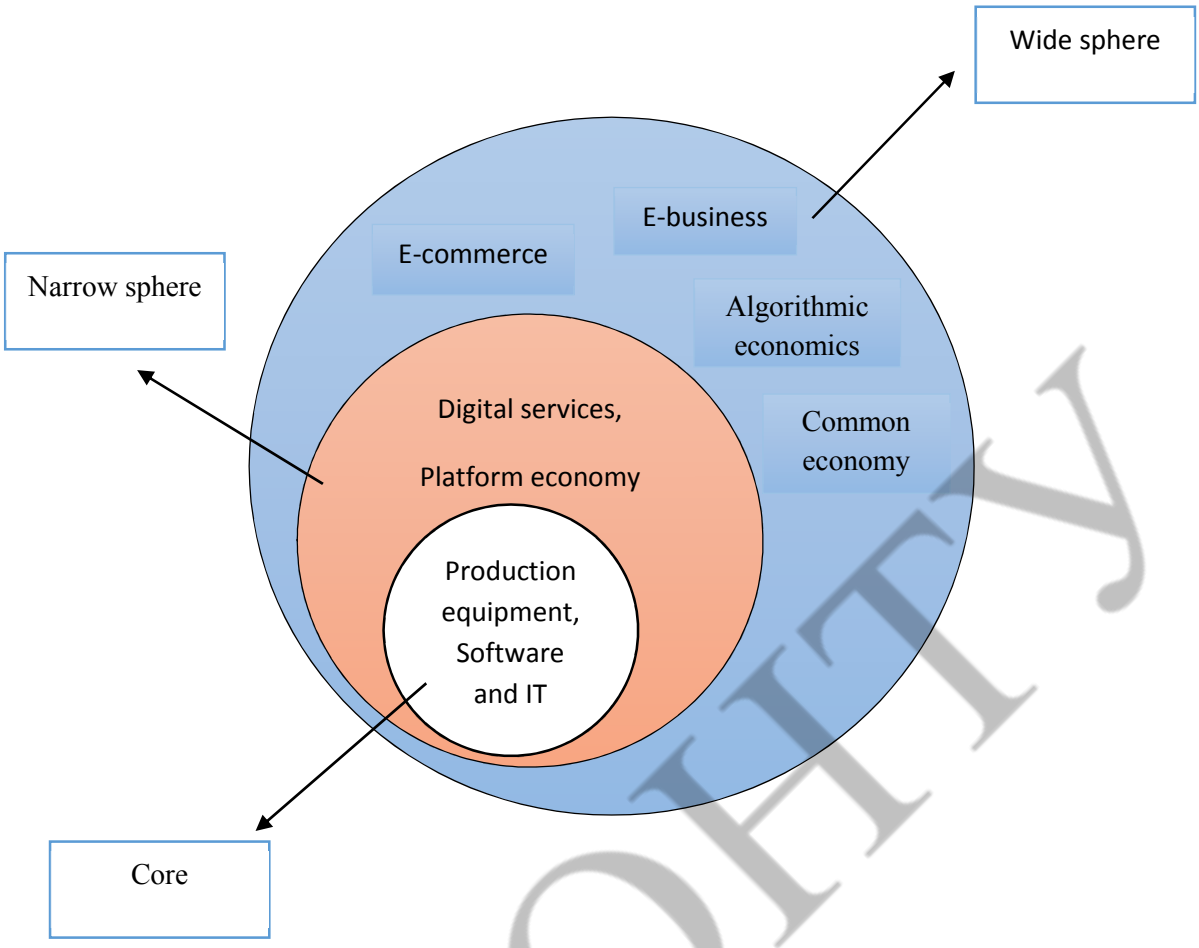

Figure 1. The main components of the digital economy

In order to make the digital transformation successful, the company must have the necessary prerequisites. There are three stages in the transition to digital organization (see table 2).

Table 2. Stages of the transition to digital organization

Evolution	Revolution	Digital part
The evolutionary change of the company to a digital organization. The phases of evolution are getting smaller, but the process is very slow.	Sharp restructuring of the organization. The process is faster than at the stage of evolution.	Separation of a digital division or its separation into a separate organizational unit, such as a subsidiary.

The main feature of the digital economy is that the key position is occupied by the process of increasing productivity: the more customers in the company, the more «productive» it is, and it follows that it is able to offer better services at the same price, which encourages new customers. This phenomenon is associated with network effects: the quality of service depends on the size of the network, ie the number of users. [6]

The increase in the number of enterprises with a network effect in the digital economy is due to lower transaction costs: digital technologies simplify the process of authenticating the other party and obtaining information about its reputation. In other

words, they facilitate communication and monitor the implementation of agreements and promote trust between parties who do not know each other. This has led to the emergence of huge platforms on which every entrepreneur, and not only, can find customers in optimal and safe conditions and provide them with services, the quality of which is sometimes higher than in traditional professions. [7]

When it comes to authentication of parties and transactions between them, you need to pay attention to Blockchain technologies. Blockchain technologies are a form of distributed registry technology that allows multiple parties to participate in secure, trusted transactions without an intermediary.

Digital markets are full of competition. In the digital economy, company monopolies are less stable than in traditional business networks. In the short time of the digital economy, temporarily dominant companies have been pushed out of their positions by subversive innovations or the emergence of more innovative competitors. The web browser market has been dominated by Netscape, Internet Explorer and Google Chrome. Although Google supplanted the first generation of search engines and became the second largest market capitalization in the world. The fragility of the positions won is due to particularly fierce competition. The cost of launching a product or service is very low: most digital markets require little physical capital to enter. Constant pressure from new entrants: the cost of starting startups has risen sharply over the last ten years, and their growth is increasingly financing by venture funds. Competitors of a dominant company can regain the initiative at any time and challenge its monopoly by rapidly expanding new processes or functions on a large scale. Finally, large digital companies are competing with each other, constantly diversifying into new markets to benefit from synergies and make it harder to combat their dominance. [8]

The instability of dominant positions can also explain by dependence on users. In traditional services, network effects arise due to infrastructure that requires high financial costs. In the digital economy, these effects are not relating to material infrastructures, but to the trust instilled in users: a single high-quality «experience» convinces them not to consider the proposals of other digital companies in the same direction. However, in the digital economy, where «competition is at arm's length», people are becoming more demanding. The Internet increases competition by reducing the cost of research and price comparisons. Consumers are constantly approaching by newcomers to the market. They communicate with each other, coordinate their actions and now form a huge mass, able to quickly compete with each other from the available proposals. With this situation, as in the past, digital companies can only gain a foothold in the material component and earned capital and regulatory barriers. They must constantly innovate and implement innovations to improve the product intended for the user. [9]

There are two types of network effect in the digital economy:

1. Direct network effect

Direct network effects occur when each user of the network benefits and enjoys connecting other users of the "same type" to the network. The example of the telephone shows that the benefits that the subscriber receives from the service increase with the number of other people who can connect. The dynamics of network effects depend on the fact that a permanent user base encourages potential users who are not yet

connected, and on the fact that each new user increases the satisfaction of users already present in the network.

2. Indirect network effect

Indirect network effects occur when multiple categories of users interact on platforms, linking multiple types of participants, such as multiple buyers and multiple vendors (as opposed to the traditional single vendor model and large number of buyers). In this structure, called the "bilateral" or "multilateral market", customer satisfaction on one side of the market increases with the number of users on the other side.

2.2. Analysis of the level of digitalization of the economy in the world

The business community and governments of the world, including Ukraine, are aware of the need to accelerate the process of digitalization and digital transformation of the economy in order to achieve competitive positions in the digital space of the new world economy. The digital economy sets the vector according to which the socio-economic systems of micro and macro levels will develop in the long term and calls for research and comprehensive analysis of digital transformation processes. Today, digital transformation has become a mass phenomenon, and relevant projects are vital to the success not only of individual companies, but also of individual regions and countries.

The analysis of Ukrainian and foreign practice, as well as theoretical research is carring out on several indicators (see Table 3.). [11]

Table 3. The main criteria for the level of digital transformation of the world economy

№	Criteria	Value of the criteria
1	Broadband	Fixed broadband transmission
2	Use of the Internet	Use of the Internet by citizens
3	Human capital	Internet Skills
4	E-commerce	The level of digitalization of business and digital commerce
5	Digitalization of public services and services	Level of e-government

In the period of globalization and development of new technologies, the Internet occupies an important place in public life. Most new technologies depend on the availability of Internet resources and related services. Connecting to the Internet allows you to develop the potential and competitiveness of the state in the digital world. Very fast connection to the Internet called broadband access. Therefore, most countries are working to provide their citizens with quality broadband. To date, there is no single approach to the definition of «broadband».

Over the past few years, e-commerce has become an integral part of the global retail and wholesale system. As in many other industries, the market has undergone significant changes since the advent of the Internet, and thanks to the long digitalization of modern life, consumers from almost all countries now benefit from online transactions.

The Asia-Pacific region and North America lead the regional e-commerce retailers. The Asian region accounts for 42% of worldwide retail sales, North America 22% and Europe 16%.

UNCTAD estimates that the global value of e-commerce (B2B and B2C) sales reached nearly $ 25 trillion in 2018, which is 30% of GDP and an increase of 8% compared to 2017 ($ 23.8 trillion) (see Table 4).

Today, the success of e-commerce can assess by several parameters:

- Level of logistics;
- Average income per buyer;
- Market income;
- Percentage of the population shopping online;
- Number of online buyers;
- Percentage of buyers from abroad;
- Number of buyers from abroad.

Table 4. Analysis of profits from e-commerce in the world

Rating	Country	Sales volume ($ billion)	Percentage of e-sales in the country's GDP (%)	B2B sales ($ billion)	B2C sales ($ billion)
1	USA	8,640	42%	7,542	1,098
2	Japan	3,280	66%	3,117	163
3	China	2,304	17%	943	1,361
4	Republic of Korea	1,364	84%	1,263	102
5	UK	918	32%	652	266
6	France	807	29%	687	121
7	Germany	722	18%	620	101
8	Italy	394	19%	362	32
9	Australia	348	24%	326	21
10	Spain	333	23%	261	72
	Sum	19,110	35%	15,772	3,338
	In the world	25,648	30%	21,258	4,390

Data from 2020 show that many more countries and municipalities are pursuing digital government strategies, some of which are radically different from those guided by previous e-government initiatives. Some of the new approaches used by Governments for digital transformation include e-government as a platform, integration of interactive and autonomous multichannel delivery, flexible development of digital services (supported by the whole government and society), expanding e-participation and partnerships, approaches, strengthening the digital capacity to provide people-oriented services, and the innovative use of new technologies such as artificial intelligence and blockchain (especially in the development of «smart city»).

Although there is usually a positive correlation between the ranking of e-government development and the level of income of the country, financial resources are not the only decisive factor in the development of e-government. Too often, strong political will, strategic leadership and a commitment to integrating digital services will allow a country to achieve a higher level of development than we might expect.

Significantly improved the provision of digital public services; today, more than 84% of countries offer at least one online transaction. The most common digital services offered worldwide are registering a new business, applying for a business license, obtaining a birth certificate, paying for utilities, and more.

All regions are making progress in e-government development, as evidenced by their higher e-government development averages (see Figure 2).

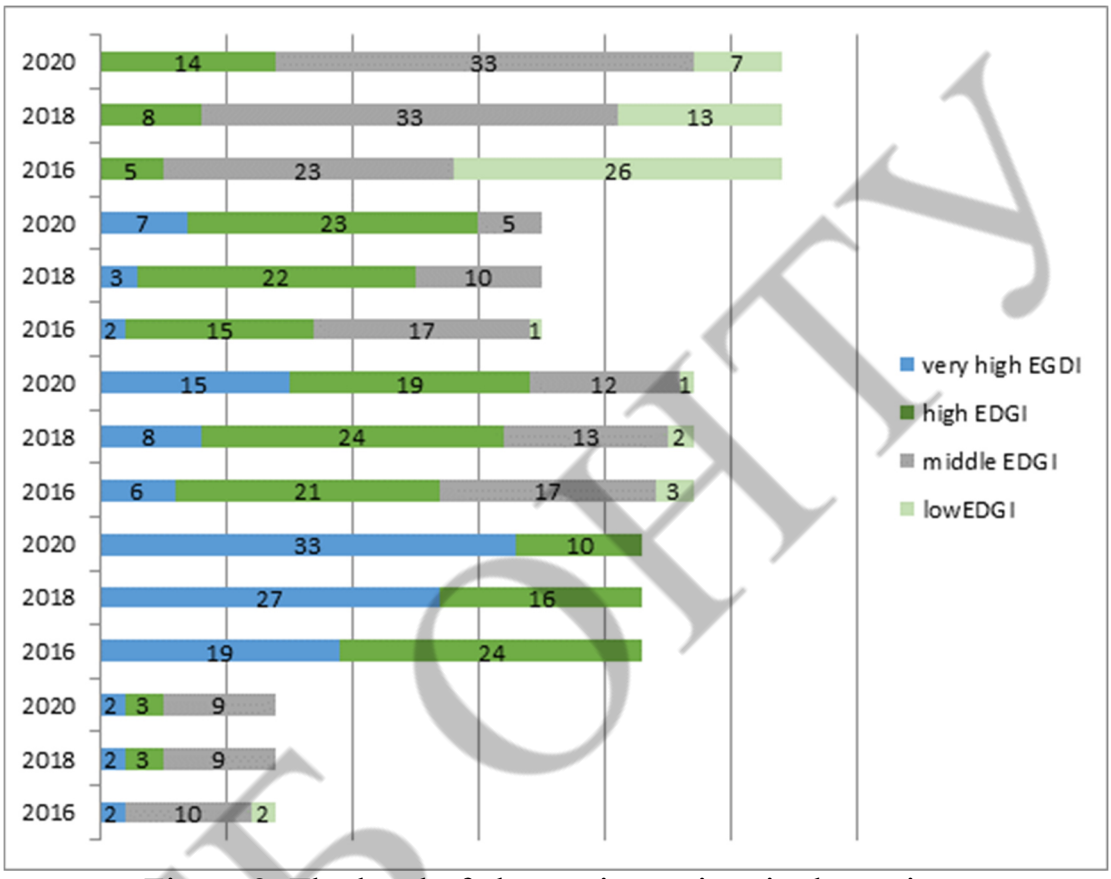

Figure 2. The level of electronic services in the regions

The leader remains Europe with the highest share of countries with a very high level of development (58%), followed by Asia (26%), America (12%) and Oceania (4%).

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of research is the digitalization of the economy of Ukraine and other countries in the world.

The subject of the research is the main trends in the development of digitalization in Ukraine and the directions of their development.

In the process of research, general scientific methods were used:

Methods of dialectical cognition (abstraction, historical and logical unity) revealed the essence of the process of digitalization, the main directions and problems;

Through the descriptive-inductive and analytical method, the main points of digitalization of Ukraine were considered and identified. Reforms were proposed to improve the management mechanism for the development of this process and scientific and methodological approach to the organization of its management.

IV. RESULTS

In recent years, mobile (mobile) operators have significantly expanded their coverage of 4G networks in Ukraine, which has increased to 78% of the population that can receive mobile broadband Internet access.

In turn, the expansion of 4G coverage and the widespread use of consumer end-to-end equipment operating on operating systems (smartphones, tablets) have led to an increase in the consumption of mobile Internet traffic.

In addition, there is a gradual increase in the number of consumers of machine-to-machine (M2M) and Internet of Things (IoT) services.

71% of Ukrainians (22.96 million) regularly use the Internet. This stated in the research of the Research Holding Factum Group Ukraine.

According to the dynamics of Internet penetration, in 2020 71% of Ukrainians used the Internet once a month or more often, which is 8% more than in the previous year (63% see Figure 2.2).

According to the study, in cities with a population of more than 100 thousand, Internet penetration - 42%, in areas with a population of less than 100 thousand - 29%, in rural areas the same figures - 29%.

The study shows that women are more likely to use the Internet - 52%, men - 47%.

The largest number of network users is in the Central-Northern regions of Ukraine (33%), in the East - 29%, in the Western regions - 27%. The south of the country reached 11%.

A large number of users among people aged 25-34 (25%).The second place to use the network is the population aged 35 to 44 years - 21%, 18% - people aged 45 to 54 years, adolescents and young people aged 15 to 24 years are only 15%, and 12% - people aged 55 up to 64 years and 8% of persons over 65 years.

In December 2020, the first results of the all-Ukrainian study of digital literacy of Ukrainians were obtained. It was based on the methodology used by the European Commission to calculate the Digital Economy and Society Index. This index consists of the following indicators: Internet connection, human capital, Internet use, digital integration, digital government services. The results showed that - 53% of the population of Ukraine (according to the methodology of digital skills assessment used by the European Commission) are below the "base level".

If you break down this figure in more detail, you can see the following:

- 37.9% of Ukrainians aged 18-70 have digital skills below the basic level;
- 15.1% do not own them at all.

If we analyze the growth rate of e-commerce in Ukraine, they have recently significantly exceeded the growth rate in Europe, which is primarily due to the sharp increase in Internet penetration in Ukraine. Unfortunately, this trend will not continue for more than 2 years, as the growth rate of Internet penetration decreases as its absolute value increases, which in turn significantly affects the dynamics of Internet trade (see Table 5).

Table 5. Dynamics of e-commerce development indicators in Ukraine

Indicator	2015	2016	2017	2018	2019	2020
Volumes of retail trade, UAH billion	901,9	1031,7	1159,3	1228,9	668,4	795,2
Volumes of Internet trade, UAH billion	12,3	25,5	38,4	48,0	65	76
Annual growth index of Internet commerce,%	75,2%	107,6%	50,4%	25,0%	31%	40%
Penetration of Internet trade in Ukraine,%	1,4%	2,5%	3,3%	3,9%	4,6%	5,5%

The research showed that OLX.ua (40.4% of users), Rozetka.com.ua (32.5%), Prom.ua (26.5%) were among the three most popular e-commerce sites in Ukraine in 2020. You can see that these resources relate to B2B, B2C and C2C relationships. The analysis of business models helped to identify the most successful Ukrainian e-commerce entities and determine which sites were most in demand:

- electronic bulletin boards - sites where individuals or companies place advertising offers of goods and services (OLX, ria.com, shafa.ua);
- e-shops, supermarkets - sale via the Internet of goods purchased from various manufacturers, on their own behalf at their own prices, mainly from their own stocks (Foxtrot; Comfy; Metro Ukraine, Rozetka, Modnakasta, Leboutique, LaModa);
- price Aggregators - comparison of offers from different companies (Hotline, Price);
- electronic ordering table - a platform for connecting buyers and service providers (Uber, BlaBlaCar). [15]

To improve the situation with the digitalization of Ukraine, it is necessary to develop a digital strategy that should cover all countries and segments of the population.

The strategy should focus on the structural separation of powers. It should be developed individually for each authority, ministry, region, city (taking into account the population), and village.

The problem of not very great achievements of digitalization is in the orientation of reforms carried out by the state. Most of the changes are comfortable for the urban population (100 thousand +), but a significant part of the population lives in cities less than 100 thousand and in villages.

Digital transformation can only fully realize if high-quality access to communication networks and services and the use of new technologies (described in the second section) and the benefits of their capabilities are available at affordable prices for all people and companies, regardless of who they are and where they live. This includes substantially upgrading infrastructure connections to meet the growing demand for data generated by billions of devices that will be connect to the network in the near future.

The main problems of development of broadband networks are:

- lack of 3G and 4G networks in rural areas and on Ukrainian highways;
- Uneven level of provision of information and reference services to the population by broadband and coverage operators. If we compare the coverage map of

the main operators of Ukraine, we can see their unevenness and rarity in some areas, which is one of the biggest problems;

- low level of broadband coverage.

This situation can change in several ways:

1) Encourage companies to distribute coverage in a larger area with tax holidays and a certain period of time with certain conditions;

2) Reduce the tax for a certain period of time with certain conditions;

3) Create a state operator (this is an idea for the future, at the moment it will be just a waste)

It should also be said about Internet providers, we do not have a national manufacturer, all private. Lack of competition is given in signs

Judging by the data on the social structure of Internet users in Ukraine, the most problematic segment is the elderly (retirees). Today, Ukraine has a population of 42 million, of which 8 million are elderly, which is 20% of the total population. Only 8% of 20% of retirees are Internet users, which is a very low figure. The main problem is the financial security of this segment of the population

The percentage of low-income families and large families who cannot provide children with everything they also need take into account.

In my opinion, the most adaptive solution will be to provide all favorable conditions, for example:

- Provide a counseling center in each town where every elderly person can consult and solve their online problems;
- Adapt social services in each village to help provide online services;
- With regard to low-income children, it is possible to provide all the necessary gadgets, children's centers and libraries.
- Unevenness

The unevenness is that we do not have uniform systems:

- Education: each state university has its own programs, websites, personal offices for students. If you compare the personal account of students from different universities, the functionality, the interface of the personal account is very different.
- Banks: if we compare the level of digitalization of state-owned banks, there is also a big gap between them. Privatbank is very digitalized, but Oschadbank lags behind it by 5 years. This difference felt in everything: from mobile applications to servicing in the bank itself.
- Transport system: when we buy a metro card in Kharkiv, we can't use it in Kyiv and Dnipro. It is much more convenient to make a single system for all cities, but this applies not only to the subway, but also to all transport.

V. CONCLUSIONS

It is established that today the economy of Ukraine has both applied and theoretical and legislative basis in order to strengthen its position among the countries of the world. However, its digitalization is still mostly innovative. Therefore, a combination of theoretical research with modern needs and opportunities is must for the national economy.

Ukraine is a country with great potential. And if we still assess the level of

digitalization, Ukraine is quite a digital country:

- Most government services are available online;
- Convenient sites and a nice interface;
- Sufficient number of companies that provide services online;
- Providing consultations, video lessons on adaptation to new programs;
- Stimulating the development of innovations;
- Grants;
- Encouraging startups.

But for the full digitalization of the country it is necessary to ensure the availability of citizens to these technologies. Digital transformation can only fully realize if high-quality access to communication networks and services and the use of new technologies and the benefits of their capabilities are available at affordable prices for all people and companies, regardless of who they are or where they live.

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RESEARCH OF THE MODEL OF RELATIONS BY METHODS OF GAME THEORY

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Abstract. *We considered a two-player signal game: the sender and the receiver. This game was solved for the mixed strategy Nash equilibrium. It gives us game theoretic predictions. We found the optimal strategy of both participants for the optimal solution of the conflict model.*

Keywords: *The Market for «Apples», game theory, economics.*

INTRODUCTION

To date, any questions related to the economy are important for follow – up. In the minds of the complicated situation in the world economy, it is important to understand the basic principles and laws that govern the economy.

The current world cannot be seen without markets, and the markets, in their own right, cannot be imagined without competition. However, markets and, obviously, competition are not the same. When solving economic problems, it is often necessary to analyze situations in which the interests of two or more competing parties collide, which are followed by different numbers – which is especially characteristic in the minds of the market economy.

We will say that the situation is a conflict one, that it is the subject of the conflict, the sides are stubborn, for some reason, the subject of the conflict could have been designated as the subject of the conflict, it could be possible to reach its goal.

LITERATURE ANALYSIS

So what is a game? The game is a system of rules that determines the possible actions of participants, their number, the rules of distribution of winnings, which depend on the behavior of each participant, as well as the outcome of the game as the winnings of each player. To solve the game means to give recommendations to the players on the optimal choice of strategy and to indicate the winnings of the player who corresponds to the chosen strategy of behavior.

The subject of the study is the model of the conflict situation of the economic market between buyer and seller. The object of the study is the strategy of both participants to optimally resolve the conflict model. Solution methods are game theory methods.

Let us turn to a brief historical overview of the emergence and development of game theory. Already in the XVIII century, some formalized the strategic approach in the behavior of market participants, including the work of J. Bertrand and A. Cournot. Later, E. Lasker, E. Cermelo, E. Borel offered the world the idea of a mathematical approach to conflict resolution. But the lack of relevant methodology for taking any steps by market participants in the XX century gave impetus to the creation of game theory. In their research, John von Neumann and Oscar Morgenstern concluded that the specific

behavior of a market participant is influenced not only by his personal intentions and condition, but also by similar indicators of his competitors.

In their work "Game Theory and Economic Behavior" Neumann and Morgenstern formulated the concept of "game" as the activity of two or more people, which has the conditions of the so – called. "Win". It is important to note that participants in such a "game" can use certain "resources" and interact with each other. Therefore, make any decisions based on the behavior of other participants. The authors mathematically describe the means of finding optimal strategies – those that lead to gain [1].

To further study conflict situations, we turn to theoretical materials.

The nature of player relationships affects the ability to form coalitions. Non-coalition games are games in which players are unable to form coalitions.

By the nature of winnings, games are classified as zero – sum games and non – zero – sum games. In the first case, it is a game in which the total capital of all players does not change, but is redistributed between players depending on the results of the game, ie the sum of players winnings is zero. Otherwise, the game will be with a non – zero amount. An example of a game with a non – zero amount can be trade relations between countries. As a result of applying their strategies, all countries can benefit [1].

Bimatrix game is a non-coalition game in which each player has a finite number of strategies. Let the first player have m, $i = 1,\dots,m$. The second player has n strategies, $j = 1,\dots,n$. The winnings of the first and second players are determined by the matrices, respectively: $\begin{pmatrix} a_{11} & \dots & a_{1j} & \dots & a_{1n} \\ a_{i1} & & a_{ij} & & a_{in} \\ a_{m1} & \dots & a_{mj} & \dots & a_{mn} \end{pmatrix}$ $\begin{pmatrix} b_{11} & \dots & b_{1j} & \dots & b_{1n} \\ b_{i1} & & b_{ij} & & b_{in} \\ b_{m1} & \dots & b_{mj} & \dots & b_{mn} \end{pmatrix}$.

In the context of the study of the coalition-free game, it is important to mention the concept of "equilibrium" as defined by John Nash. Equilibrium according to John Nash is characterized by the fact that deviating from the balance of one player can not increase his winnings, and thus the rational strategy of each player should be to achieve balance.

Nash equilibrium is a set of strategies (i^*, j^*), that for any player, deviating from their strategy can only worsen their situation:

$$\begin{cases} a_{ij^*} \le a_{i^*j^*} \\ b_{i^*j} \le b_{i^*j^*} \end{cases}, \text{ to all}(i,j).$$

So, to solve a bimatric game means to find all the balance situations and winnings of the players that correspond to them.

The number of moves of the game is divided into: single-step and multi – step. In the first case, the game ends after one move by each player. Multi – step games, in turn, are divided into: positional – games in which there may be several players, each of which can make moves. Winnings are determined depending on the results of the game. If the moves in the game lead to the choice of certain positions, and it is possible to return to the previous position, the game is stochastic. For the game Γ_1 we have:

$$\begin{pmatrix} a_{11} & \dots & a_{1j} & \dots & a_{1n} \\ a_{i1} & & \Gamma_1 & & a_{in} \\ a_{m1} & \dots & a_{mj} & \dots & a_{mn} \end{pmatrix} \begin{pmatrix} b_{11} & \dots & b_{1j} & \dots & b_{1n} \\ b_{i1} & & \Gamma_1 & & b_{in} \\ b_{m1} & \dots & b_{mj} & \dots & b_{mn} \end{pmatrix}$$

In this situation (i, j), there is a draw of the game Γ_1 in which the number of strategies for players is finite, but may be different. In turn, a new game Γ_1 can be drawn in the game: $\begin{pmatrix} a_{11} & \dots & a_{1l} & \dots & a_{1n} \\ a_{k1} & & \Gamma_2 & & a_{kn} \\ a_{m1} & \dots & a_{ml} & \dots & a_{mn} \end{pmatrix} \begin{pmatrix} b_{11} & \dots & b_{1l} & \dots & b_{1n} \\ b_{k1} & & \Gamma_2 & & b_{kn} \\ b_{m1} & \dots & b_{ml} & \dots & b_{mn} \end{pmatrix}$.

Depending on the state of information, there are games with complete and incomplete information. If at each stage each player knows which choices were made by the players before, such a game is called with full information. Otherwise, the game with incomplete information. An example of a game with complete information is a game of checkers [1].

By repeating the bimatrix game repeatedly, players will choose their pure strategies with a certain frequency. Therefore, we can move on to a new production - bimatric game in mixed strategies (Bayesian game). We will consider a complete set of probabilities $x = (x_1, ..., x_m)$ the first player's application of his pure strategies to the mixed strategy of the first player, and the full set of probabilities $y = (y_1, ..., y_n)$ the second player's use of his pure strategies – the mixed strategy of the second player.

There are other types of games, other principles of game classification are also possible.

Nash equilibrium (or decision of the game) is a set of strategies (i^*, j^*) and player gains, which for any player deviating from their strategy can only worsen their situation $\begin{cases} a_{ij^*} \le a_{i^*j^*} \\ b_{i^*j} \le b_{i^*j^*} \end{cases}$, to all (i, j).

By repeating the bimatrix game repeatedly, players will choose their pure strategies with a certain frequency. So you can move on to a new setting of the game, the solution of which will provide a full set of probabilities and $\begin{matrix} x^* = (x_1, ..., x_n) \\ y^* = (y_1, ..., y_n) \end{matrix}$. This new production is a matrix game in mixed strategies or a Bayesian game. Incomplete game or Bayesian game in game theory is characterized by incomplete information about opponents, but players have some confidence in the distribution of probability. The Bayesian game can be turned into a game with complete but imperfect information, assuming the assumption of a general a priori distribution. Unlike incomplete information, imperfect information includes knowledge of opponents strategies and winnings, but the game history (previous actions of opponents) is not available to all participants. Bayesian equilibrium is a generalization of Nash equilibrium in mixed strategies in the case of Bayesian games. The winning function is a mathematical expectation of winning [2].

A pair of numbers (x^*, y^*) forms Nash equilibrium in a mixed expansion of the coalition – free matrix game $\begin{cases} \sum_{i,j} a_{ij} x_i y_i^* \le \sum_{i,j} a_{ij} x_i^* y_j^* \\ \sum_{i,j} b_{ij} x_i^* y_i \le \sum_{i,j} b_{ij} x_i^* y_j^* \end{cases}$, when $x = (x_1, ..., x_n) -$ mixed strategy of the first player, $y = (y_1, ..., y_n) -$ mixed strategy of the second player [2].

The paper will also use a decision tree – a mathematical model consisting of arcs, decision nodes, event nodes and end nodes (outputs), which defines the decision – making process so that it reflects every possible decision that precedes, subsequent events or other decisions and the consequences of each final decision [3].

OBJECT, SUBJECT, AND METHODS OF RESEARCH

It is known from game theory that it is impossible to find the "perfect" solution for all players, but to use the optimal solution is a very real task. This aspect is especially relevant for the economy. Consider a market model with incomplete and asymmetric information on the example of the game "buyer – seller".

Assume that the seller sells only two types of used computers: good (let's call them plates), which are worth $330(\$)$, the cost of this product is $200(\$)$, and bad (let's call them apples), which are worth $220(\$)$ the cost of this product is $150(\$)$. This is not an auction where only one product is selected, and the gain depends on the mathematical expectation of the price of the product. In this case, there are several products - bad and good gadgets. Therefore, it is worth mentioning the strategies of the game. The number of good and bad computers is the same. The buyer has no additional information about the condition of the goods, so the probability that he will choose a plate or an apple is $\frac{1}{2}$. The buyer can offer an average price for the product: $\frac{330+220}{2} = 275(\$)$. If the selected product is a plate, the seller will refuse the transaction, because then his profit will be $200 - 275 = -75(\$)$. But it doesn't make sense for the buyer to offer an average price for an "apple", as he can buy this computer for a lower price: $275 > 220(\$)$. That's why he always has to offer $220(\$)$. In such a coincidence, the seller for one stage of the sale can earn: $\frac{1}{2}(220-150) + \frac{1}{2}(0) = 35(\$)$. Expected income is: $\frac{1}{2}(220-150) + \frac{1}{2}(330-200) = 100(\$)$, with full awareness of buyers and the same demand for both types of gadgets.

This situation has the following consequences: the seller will be forced to reduce the share or stop selling quality computers altogether. Customers who need a quality computer are forced to move to another market.

Now consider the signal game "The market for Apples". This theory was based on the article by Nobel laureate George Ackerloff "The market for Lemon"[4].

Suppose a reseller of used computers again has the same number of bad (apples) and good (plates) machines. The buyer does not distinguish apples from plates. Therefore, the seller decides to give some of the computers sold a one – year warranty,

which fully covers the cost of repairs. It is known that during the year the expected cost of repairing apples is 10($) and plates – 50($).

The rules of the game are as follows. First, the buyer makes the move – he chooses the computer. This is a random move. The seller then says whether he gives a guarantee for the selected product. The next move of the buyer – offers its price: 200($) or 300($). Transactions will take place unless a price is offered for a plate 200($).

The signal game has:

1. many types of seller: *T={T, N}* where it means *T* – a good computer (plate), *N* – a bad computer (apple);
2. many messages from the seller *M= {W, J}*: where *W* – a computer with a warranty, *J* – a computer without a warranty;
3. set of actions of the buyer *R ={220;330}: 220* – the buyer offers 220 ($), *330* – the buyer offers 330 ($).
4. the set cost of computers *Q = {S, Z},* where *S* – is the cost of an apple 150($), Z – is the cost of a plate 200($);

The imagination that the buyer chooses an apple or a plate, ie the imagination of the buyer about the signals of the seller is $\mu(N) = \mu(T) = 0{,}5$.

The signal game tree has the following form (Fig. 1). The strategic form of the game is as follows: (Table 1). Find the mathematical expectation of players winnings. Whereas the payment matrix acquires the following values $\begin{pmatrix} (10;25) & (125;-25) \\ (35;0) & (95;5) \end{pmatrix}$.

Note that this bimatrix game has no balance in pure strategies (Table 2). We will find balance in mixed strategies. Let's use the method of dominant strategies – reduce the size matrix 4×4 to 2×2. Strategy [220;220] dominates [220;330] and [330;330]. After that we see that the strategy JW dominates the strategy JJ, and the strategy WW dominates WJ (Table 3). We have the following payment matrix.

We will look for solutions to the bimatrix game by solving systems for the first and second players, respectively:

$$\begin{cases} (p-1)(-55q+30) \geq 0, \\ p(-55q+30) \geq 0. \end{cases}$$

$$\begin{cases} (q-1)(55p-5) \geq 0, \\ q(55p-5) \geq 0. \end{cases}$$

The equilibrium point will be $(p^*;q^*) = \left(\frac{1}{11};\frac{6}{11}\right)$, where mixed strategies $p^* = (p;1-p) = \left(\frac{1}{11};\frac{10}{11}\right)$, $q^* = (q;1-q) = \left(\frac{6}{11};\frac{5}{11}\right)$.

The probability distributions will be as follows:

$$p^*_{WW} = \frac{1}{11}, p^*_{WJ} = 0, p^*_{JW} = \frac{10}{11}, p^*_{JJ} = 0, q^*_{[220;220]} = \frac{6}{11}, q^*_{[220;330]} = 0, q^*_{[330;220]} = \frac{5}{11}, q^*_{[330;330]} = 0.$$

Then the price of the game for the first player is:

$$H_S\left(\frac{1}{11};\frac{1}{6}\right) = 10\cdot\frac{1}{11}\cdot\frac{6}{11} + 125\cdot\frac{1}{11}\cdot\frac{5}{11} + 35\cdot\frac{10}{11}\cdot\frac{6}{11} + 95\cdot\frac{10}{11}\cdot\frac{5}{11} = \frac{685}{11} \approx 62.$$

For the second player:

$$H_R\left(\frac{1}{11};\frac{6}{11}\right)=25\cdot\frac{1}{11}\cdot\frac{6}{11}-25\cdot\frac{1}{11}\cdot\frac{5}{11}+0\cdot\frac{10}{11}\cdot\frac{6}{11}+5\cdot\frac{10}{11}\cdot\frac{5}{11}=\frac{25}{11}\approx 2.$$

The use of signals allows the seller (player *S*) to increase their winnings 35($) without signals from before winning 62($) with signals. Then the signal game tree will acquire the following values (Fig. 2).

Bayesian balance of the game looks like. In an equilibrium situation, the seller always gives a guarantee for a quality computer: $\tilde{p}^*(T)=\begin{pmatrix}\tilde{p}_W^*(T)\\ \tilde{p}_J^*(T)\end{pmatrix}=\begin{pmatrix}1\\0\end{pmatrix}$, and on a bad computer gives a guarantee at random: on average, one guarantee for 11 computers:

$$\tilde{p}^*(N)=\begin{pmatrix}\tilde{p}_W^*(N)\\ \tilde{p}_J^*(N)\end{pmatrix}=\begin{pmatrix}\frac{1}{11}\\ \frac{10}{11}\end{pmatrix}.$$

Instead, the buyer always offers a price for the computer without a guarantee: $\tilde{q}^*(J)=\begin{pmatrix}\tilde{q}_{220}^*(J)\\ \tilde{q}_{330}^*(J)\end{pmatrix}=\begin{pmatrix}1\\0\end{pmatrix}$, and assigns a random price to a gadget with a guarantee:

$\tilde{q}^*(W)=\begin{pmatrix}\tilde{q}_{220}^*(W)\\ \tilde{q}_{330}^*(W)\end{pmatrix}=\begin{pmatrix}\frac{6}{11}\\ \frac{5}{11}\end{pmatrix}$, $220(\$)$ with probability $\frac{6}{11}$ and $330(\$)$ with probability $\frac{5}{11}$.

In turn, after the signals of the seller, the buyer has the following opinion. If the seller offered a guarantee, the buyer considers: with the possibility that he chose a bad computer: with probability $\frac{1}{12}$, that he chose a bad computer: $\mu(N|W)=\mu(D)=\frac{1}{12}$; with the probability $\frac{11}{12}$, that he chose a good one: $\mu(T|W)=\mu(G)=\frac{11}{12}$.

If the seller did not offer a guarantee, the buyer believes that he chose a bad product: $\mu(N|J)=\mu(E)=1$, $\mu(T|J)=\mu(F)=0$.

RESULTS

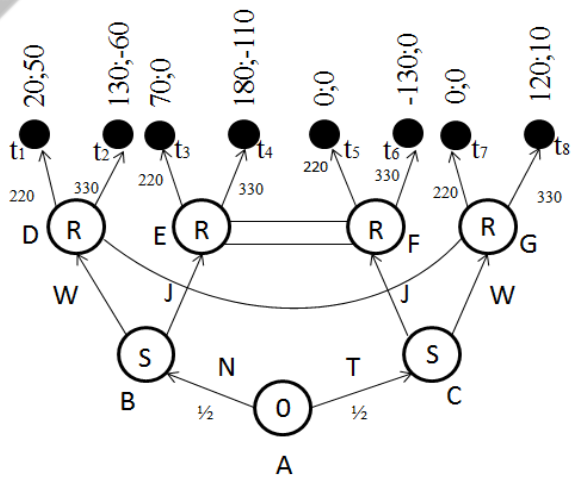

Fig.1. The signal game tree

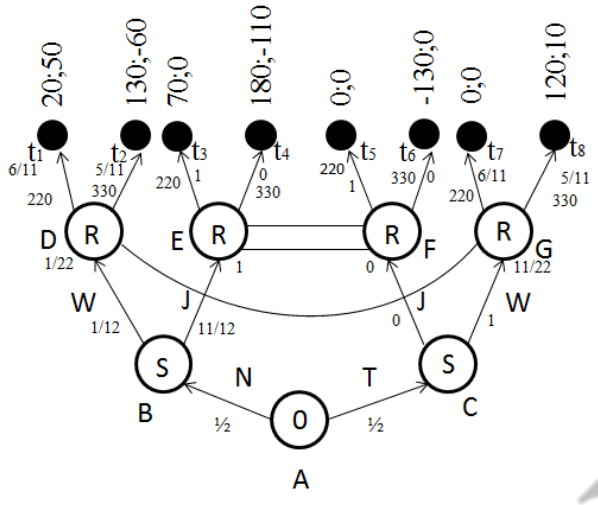

Fig.2. The signal game tree

Table 1. The strategic form of the game

Event	Run	Player	Win
D	t_1	S	$220 - S - W = 20$
		R	$220 + W - N = 50$
	t_2	S	$330 - S - W = 130$
		R	$N + W - 330 = -60$
G	t_7	S, R	The agreement was not made
	t_8	S	$330 - Z - J = 120$
		R	$330 + W - T = 10$
E	t_3	S	$220 - S = 70$
		R	$N - 220 = 0$
	t_4	S	$330 - S = 180$
		R	$N - 330 = -110$
F	t_5	S, R	The agreement was not made
	t_6	S	$330 - Z = 130$
		R	$330 - T = 0$

Table 2. Bimatrix game of dimension 4×4

	$[\mathbf{220}; \mathbf{220}]$	$[\mathbf{220}; \mathbf{330}]$	$[\mathbf{330}; \mathbf{220}]$	$[\mathbf{330}; \mathbf{330}]$
WW	$10; 25$	$10; 25$	$125; -25$	$125; -25$
WJ	$10; 25$	$-55; 25$	$65; -30$	$0; -30$
JW	$35; 0$	$90; -55$	$95; 5$	$150; -50$
JJ	$35; 0$	$25; -55$	$35; 0$	$25; -55$

Table 3. Bimatrix game of dimension 2×2

	$[\mathbf{220}; \mathbf{220}]$	$[\mathbf{330}; \mathbf{220}]$
WW	$10; 25$	$125; -25$
JW	$35; 0$	$95; 5$

CONCLUSIONS

In this paper, we came to the conclusion that the use of strategy is an important aspect of the functioning of the economic market, for which, of course, the concept of "game" is relevant. The strategy was studied as a means of creating an optimal model for all participants in the "conflict". It has been shown that in the absence of information from buyers, low-quality cheap goods displace expensive quality goods from the range. Based on the analysis, the following conclusions can be drawn about the prospects for the use of game theory and formal models in the study of modern conflicts. An important but insufficiently studied area is the analysis of the actions of opponents in several periods, the strategic behavior of participants in the presence of incomplete information. Another area that is practically not taken into account in both classical and modern research and games is the moral norms, values of society, the moral side of each strategy. The main feature of the studied theory will be the aspect of "uncertainty". Game theory allows you to structure the process of making optimal strategic decisions in a situation of uncertainty, when it is not known how opponents will behave in the game, which, of course, is one of the properties of the economic market.

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MARKETING COMPLEX DEVELOPMENT FOR THE PROJECT "WINE ROUTES OF UKRAINIAN BLACK SEA REGION" ON THE BASIS OF MARKETING RESEARCH

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Abstract. *The scientific paper reviews theoretical approaches to wine tourism marketing, identifies management and marketing problems of wine tourism development in Ukraine. The results of processing interviews with stakeholders are presented, macro- and microenvironment factors are analyzed, consumers of wine tours are segmented, and the motivation of visiting wineries is studied. Basic, competitive and functional (commodity, price, distribution, communication) strategies of the project of wine routes of the Black Sea region of Ukraine are proposed.*

Keywords: *wine tourism, wine routes, marketing complex, marketing research, stakeholders, structured interviews, hypotheses, target segment, consumer portrait, communication channels.*

I. INTRODUCTION

The relevance of the topic is due to the fact that today the wine tourism market in Ukraine is characterized by stable development and positive forecasts. Recently, local wines and wineries that produce them have become increasingly popular. People demand something special, limited, unusual and, necessarily, natural. Today, both the leaders of the wine industry and little-known wineries have begun to organize excursions to their own vineyards or production facilities. The first Routes of Wine and Taste have already been created in Bessarabia and Transcarpathia, and Kherson and Mykolaiv regions intend to create similar roads.

In 2020, the international project Sea of Wine was launched. This project involves the development and launch of a wine route that will pass through four countries: Ukraine, Georgia, Armenia and Greece. From the Ukrainian side, winemakers of the Black Sea region, namely Odessa, Mykolaiv, and Kherson regions, can take part in the project.

The purpose of the research is to substantiate management decisions on the formation of a marketing complex for the development of wine tourism in the Black Sea region based on marketing research.

II. LITERATURE ANALYSIS

One of the promising areas of development of the tourist services market is wine tourism – a thematic type of tourism associated with getting acquainted with the history, production technology and culture of consumption of wines in a particular region and tasting them directly from the manufacturer. [1; 4; 5]

Wine tourism is an important element of two branches of wine-making and tourism, a tool for reviving economic activity due to the influx of domestic and foreign tourists to wine-producing regions. For the tourism industry, wine and related attractions are an essential factor in the competitiveness of a tourist product, a motive

for special travel, an element of food, treatment and entertainment services. For wineries, wine tourism is one of the ways to promote a brand to ensure long-term consumer commitment. [1; 4]

Some aspects of the development of wine tourism in Ukraine are covered in the works of D. Basyuk [1], K. Badeshchenkova [2], T. Bozhuk [3], S. Ivanov [4], L. Gorshkova [5], O. Lyubitseva [6], V. Matveeva [7], S. Nezdoiminova [8], A. Pergat [9]. Among foreign authors, the peculiarities of marketing in wine tourism are studied in the works of M. Hall, G. Johnson, James E. Wilson, K. Storchmann, [10-12] et al.

However, a systematic scientific study of the peculiarities of the influence of environmental factors on the development of wine tourism, as well as the behaviour of consumers of wine tours, has not been conducted in Ukraine today.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of research is the processes of forming a marketing complex for the project of wine roads of the Black Sea region and its justification by the results of Marketing Research.

The subject of the research is a set of theoretical, methodological and applied aspects of conducting marketing research in order to form functional strategies (commodity, price, distribution, communication) of the Wine Road project.

Research methods: PEST analysis, analysis of microenvironment factors, methods of qualitative and quantitative Marketing Research (survey, structured interview, text content analysis), 4P marketing package (Product, Price, Place, Promotion).

IV. RESULTS

The driver of the development of European wine tourism is the creation of regional wine roads. Almost all wine countries have such "wine roads" leading from Castle to Castle, from winery to winery. In Italy, there are special routes with the names “Strada del Chianti”, “Strada del Vino”, pleasant for wine lovers. [13] a total of 173 "wine routes" and 3,900 wineries are located in Italy. [14] Georgia's most famous wine route starts from Tbilisi and passes through Msheta in Borjomi. In Tbilisi, tourists visit the sparkling wine factory "Bagrationi 1882", where they get acquainted with the history of the factory, a tasting room that serves 12 types of sparkling wine, enjoy pita bread, fruit and cheese. The German wine route is one of the most popular tourist routes in the Palatinate region. It consists of several long rural roads with a total length of 85 kilometres, winding along forests and grape Hills, ruins of castles and cozy German villages. [15] Alsace wine Road is the most famous Wine Road in France, founded in 1953. When traveling along it, it is worth visiting the towns of Colmar, Riquir, Riboville and Egisheim – they are considered the most authentic and beautiful, and Riquir and Egisheim are generally included in the lists of the most beautiful villages in France (Les Plus Beaux Villages de France).

Compared to Europe, wine tourism in Ukraine has appeared relatively recently. The conditions and results of its development are the creation in 2019 of the project and public organization "Road of wine and taste of Ukrainian Bessarabia" and in 2020-2021 of the "Road of wine and taste" of Transcarpathia, Kherson region, Mykolaiv region, Carpathian region and Kryvyi Rih region. The main goal of these organizations is to ensure the preservation of the historical, cultural, ethnographic and

enogastronomic environment of certain regions of Ukraine, their popularization, support for local producers, introduction of European quality standards for craft products, as well as increase the tourist and investment attractiveness of the region.

The management problem of wine tourism in Ukraine is insufficiently high rates of development in comparison with European countries.

Based on the management problem marketing problems were identified:

- insufficient certainty of macro-environmental factors affecting the development of wine tourism in Ukraine, including in the Black Sea region;
- insufficient certainty of the behaviour of consumers of wine tours;
- insufficient certainty of motivation of Ukrainian wineries to become participants in wine roads.

4.1 Marketing research

Marketing research is the systematic collection, recording and analysis of data on problems related to the marketing of goods and services.

Table 1. Types of development research of wine tourism

Types of research	Secondary research	Primary research
Macro- and micro-environment factors	Reviews of the wine tourism market in Ukraine	Interviews with stakeholders at Odessa Wine Week
Wineries	Monitoring of wineries websites	Survey of TOP managers of wineries on Odessa Wine Week
Consumers	Monitoring of research on segmentation and motivation of wine tourists in Europe	Online survey (Google form of the questionnaire) of tourists of the Black Sea region on Facebook

Qualitative and quantitative marketing research was conducted to solve the identified problems (Table 1):

1) qualitative research - interviewing industry stakeholders (stakeholders are those who are actively involved in a project or business, those whose interests may be affected by the success or failure of the project, as well as those who, by virtue of their position or authority, can influence the project themselves);

2) quantitative research:

- based on the processing of the answers to the first question of the interview, environmental factors and opportunities for market participants were identified; factors were grouped into groups: political, legal, economic, socio-cultural and technological; an expert assessment of the influence of factors on the development of wine tourism was carried out (PEST analysis);
- based on the processing of the answers to the following three interview questions, hypotheses of segmentation of wine tour consumers were formed in accordance with the characteristics of behavior; an online questionnaire was conducted to confirm the hypotheses for the first two segments
- a survey (questionnaire) of TOP-managers of wineries who took part in the round-robin tasting at ODESSA WINE WEEK was conducted (19.05.2021).

The list of stakeholders of Ukrainian wine tourism, interviews with whom were conducted during Odessa Wine Week, namely on May 21, 2021, during the conference "Enogastronomical tourism - a driver for the development of tourist destinations":

1. Kirill Dombrovsky, First Deputy Chairman of the government agency for tourism development of Ukraine
2. Irina Dyachenkova, director of the publishing house «Drinks+»
3. Alexander Grabovsky, president of the Odessa Association of tour operators and agencies
4. Maria Yukhnovets, president of the Association of entry tour operators of Ukraine, and Marina Antonyuk, member of the board of the Association of entry tour operators of Ukraine
5. Yevgenia Nikolaichuk, co-founder of «Like a Local's Wine Bar», teacher of the Sommelier School, WSET4
6. Sergey Morenets, founder of the club of wine connoisseurs «Vintage» (Odessa)
7. Albina Manzul, technologist at the family winery Manzul Winehouse
8. Kristina Beshleul, communications specialist of The Sea Of Wine Project, PR Manager of the wine company «Tairovo» LLC (TM «Виноробна Станція» («Wine Station»))
9. Tatiana Dymnich, travel agency «Я вам розкажу за всю Одесу» («I will tell you for the whole of Odessa»)
10. Roman Kozlovsky, travel agency «Давай поїдемо» («Let's go») [16]

The experts were asked to answer a number of questions:

1) From your point of view, in the next few years, which 3-5 factors will most strongly influence the development of wine tourism in Ukraine?
2) How can you describe the portrait of a Ukrainian wine tourist: who is he, what does he do, what interests him?
3) Where can I find him to communicate with him?
4) How can he be lured to the Black Sea region?

The results of grouping macro factors based on processing stakeholders ' responses to the first question are presented in Appendix A. The results of processing the portrait response and communication with wine tourists are presented in Appendix B.

4.2 PEST analysis of wine tourism development in Ukraine.

Environmental factors and opportunities for wine tourism market participants were grouped according to the classification of PEST analysis factors (Table.2).

The analysis showed that political, legal and economic factors will have the strongest impact on the development of wine tourism in the coming years.

Among the political factors, most experts highlighted the need for state support for the development of wineries and wine roads, and also emphasized the risks associated with quarantine restrictions at the legislative level of social contacts, which affects the decline in demand for tourist services in general, including a decrease in income from wine tours, tastings, etc.

Table 2. Macro-environment factors determined on the basis of the conducted interviewing of experts in the field of wine tourism and wine.

Factor	Opportunities
Political and legal factors	
Government support for the development of wineries and wine routes	Lobbying for bills to reduce tax pressure on participants in wine routes
	Positioning of Ukraine at the government level as a tourist and wine country, promoting its regions as attractive tourist destinations
Legal restriction of social contacts, movement of tourists due to COVID-19	Domestic tourism development due to lockdown
Economic factors	
Stagnation of the country's economy as a result of the pandemic effect	WT as an important source of sales of its products for small wineries
	Development of thematic ("niche") tourism, including business, medical, and wine tourism
Growing popularity of various types of local gastro and enotourism	Cooperation (collaboration) with craft producers of various products
	Maintaining interest in everything local, including local wines that can only be tasted at this winery
Development of regional infrastructure, comfort of movement, and service	Creating a set of additional services at wineries for the relevant consumer segments (hotel, restaurant, etc)
Development of craft winemaking	The emergence of new craft wineries with an good attractive location, reasonable price of tasting and wines
Attracting international investment in the development of wine tourism	Participation in international wine tourism development projects
	Promoting the development of new forms of community in enogastronomy tourism (International Wine travel awards)
Sociocultural factors	
Popularization of Ukrainian wine	Changing preferences of Ukrainian consumers in the direction of domestic honest, high-quality wine
Development of wine consumption culture	Attitude to wine as a food product (recognition at the legislative level)
	Informing about the usefulness of dry wines
Development and support of Ukrainian cuisine and its combination with local wines	When developing wine tastings, take into account the combination with local gastronomy, specialties
Technological factors	
Introduction of technological innovations in craft winemaking	Growth of the quality level and expansion of the range of wine from craft producers
Introduction of online methods in training, communication, tourism, etc.	Growing popularity of online wine tastings accompanied by professional sommeliers

The results of the assessment of political, legal, economic, socio-cultural, technological factors are summarized in Table 3.

Table 3. Assessment of the impact of macro-environment factors on the development of wine tourism.

Factors	Weighted Average
1. Political and legal factors	**1,215**
Government support for the development of wineries and wine routes	0,675
Legal restriction of social contacts, movement of tourists due to COVID-19	0,360
Unstable political situation in the country	0,180
2. Economic factors	**1,180**
Stagnation of the country's economy as a result of the pandemic effect	0,400
Growing popularity of various types of local gastro and enotourism	0,210
Development of regional infrastructure, comfort of movement, and service	0,240
Development of craft winemaking	0,270
Attracting international investment in the development of wine tourism	0,060
3. Sociocultural factors	**0,860**
Popularization of Ukrainian wine	0,315
Development of wine consumption culture	0,320
Development and support of Ukrainian cuisine and its combination with local wines	0,225
4. Technological factors	**0,760**
Introduction of technological innovations in craft winemaking	0,320
Introduction of online methods in training, communication, tourism, etc.	0,320
Development of online communications	0,120
Total	**4,015**

Almost all experts paid attention to economic factors, but at the same time everyone spoke about the sore point. Therefore, this group of factors turned out to be the most numerous. Thus, Kirill Dombrovsky, First Deputy Chairman of the State Agency for Tourism Development of Ukraine, highlighted the impact of the stagnation of the country's economy due to the pandemic effect, and representatives of tour operators paid more attention to the development of infrastructure, service, comfort of movement.

Among the socio-cultural factors, the development of a culture of wine consumption and the popularization of Ukrainian wine were singled out. In addition, many talked about the importance of combining wine and local specialties, and at the enogastronomical conference one of the panels was devoted to Odessa cuisine as a tourist magnet of the region.

Among the technological factors, the introduction of technological innovations in viticulture and winemaking to improve the quality of wine and the development of IT technologies (web applications, websites) are highlighted.

Hence, the total weighted estimate showing the degree of readiness to respond to environmental factors was 4,015. In this case, the assessment indicates that the response to macro-environment factors is at an average level.

4.3 Analysis of wineries

In total, a survey was conducted with representatives of 16 wineries, including by geographical location by region:

Bessarabia (4): LLC «PTC Shabo», NSC “Institute of Viticulture and Winemaking named after V.E. Tairov” , Frumushika-Nova, “V. Petrov” winery

Black Sea (8): LLC "Tairovo" (TM « Vinorobna Stanzia»), JSC Koblevo», The winery of Prince P. N. Trubetskoy, TM « Shustov»,
«Beykush winery», 46 Parallele Wine Group, FALCON CRAFT WINE, «WINECRAFT» winery

Transcarpathia (2): «Chateau Chizay» wine company, «STAKHOVSKY WINES» craft winery

Podolia (1): PE "GIGINEISHVILI WINE HOUSE"

Center Of Ukraine (1): Biologist craft winery

The response received was displayed as diagrams in Fig. 1-4.

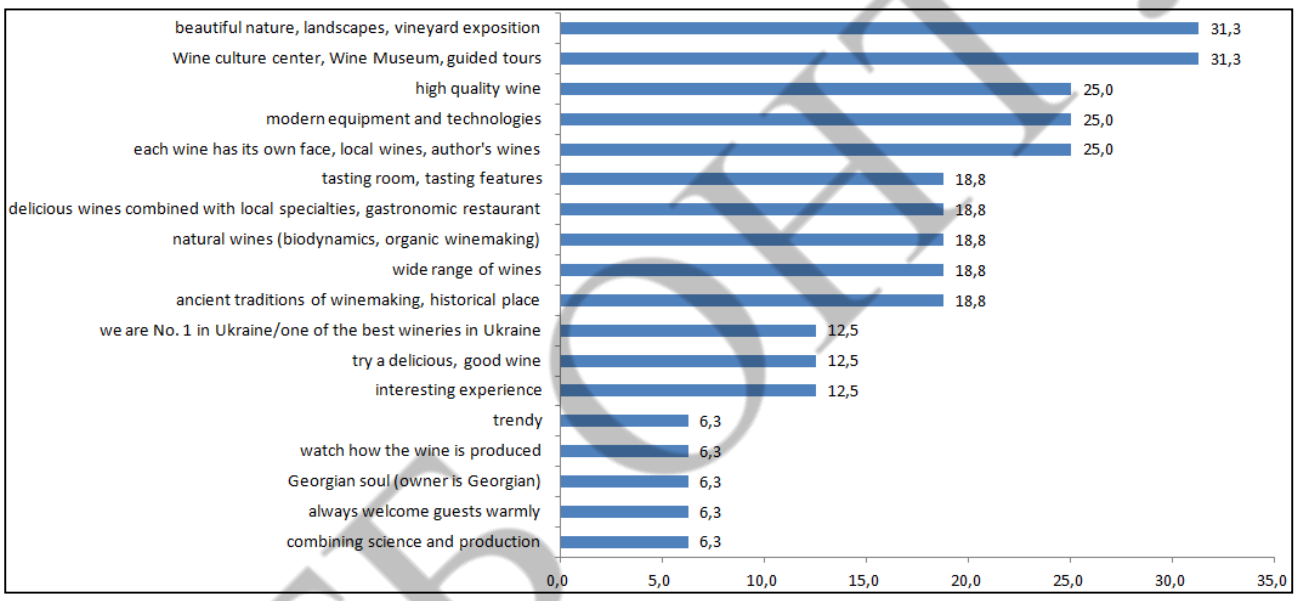

Fig. 1. Reasons to visit a winery.

From the point of view of wineries, the main two reasons for wine tourists to visit them are specially created museums, cultural centers with excursions and magnificent landscapes and picturesque vineyards around (31% of respondents chose both answers). Also, in the top 5 reasons to visit the winery were: the opportunity to taste unique local or author's wines; high quality wine and the use of modern equipment (each of the answers was chosen by 25% of wineries).

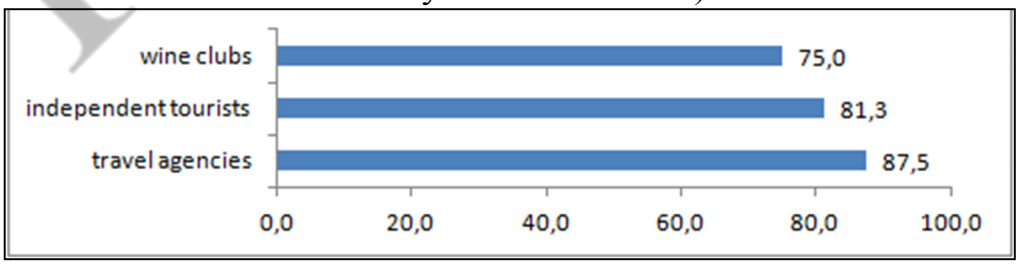

Fig. 2. Who organizes a trip to the winery? (% of respondents)

Most often, trips to wineries are organized by travel agencies.

Fig. 3. Information Resources of existing wineries.

Facebook- Instagram (100%), and almost all of them have their own website and page (86%). Ordering via the Internet is a promising area for selling wine products, which is why 81.3% of wineries sell wine on their own website; 62.5% of wineries offer their products on the Rozetka.

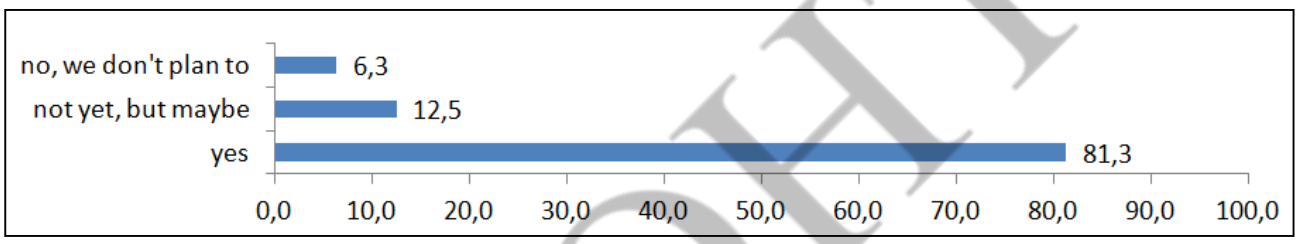

Fig. 4. Does the winery plan to become part of the wine roads of Ukraine?

Most wineries see prospects for development in the field of enogastronomical tourism, that is why 81.3% of the respondents plan to join the wine roads.

To the question "how can the income for the participants of the wine routes grow?" most of the surveyed wineries believe that the profit can increase in the range of 25-30% for the participants of the wine roads.

4.4 Analysis of consumers of wine tourism services in the Black Sea region

Analysis of the stakeholders' answers (second-fourth questions) allowed us to identify the following four groups of wine tourists:

1) Advanced wine connoisseurs, who are mostly united in wine clubs. They have experience in tasting both domestic and foreign wine. They have experience in tasting at wineries.

2) Ukrainian tourists who are interested in everything new. They have travel experience, primarily domestic tourism.

3) People whose professional activities and the purpose of their trip to wineries are directly related to wine and tourism.

4) Foreign tourists

Hypotheses about the segment №1:

- Mainly women aged 40-60 years, employees engaged mainly in intellectual work
- A consumer with an income level of "average" and "above average", has free time to travel.

- Have an interest in wine consumption, are interested in new knowledge about wine, in new impressions.
- Traveling with friends, close acquaintances or with family.
- They attend wine festivals. Most often, they are members of wine clubs.

Hypotheses about the segment №2:

- A consumer with an above-average income, aged 25-45 years.
- A person who learns about the world and himself through travel has quite a lot of experience in traveling.
- A working person who is interested in new experiences, emotions and knowledge.
- Young audience, leads a healthy lifestyle; prefers wine rather than stronger alcohol.
- They can travel with a loved one, family, friends, employees.
- Their interests are complex: new places, beautiful landscapes, historical sights, local cuisine combined with wine.
- They can attend national and local festivals on any topic of interest: music, hand-made, enogastronomy, etc.

To clarify the motivation of tourists traveling in our region, an online survey was conducted among representatives of the segments №№1 и 2.

Overall, out of 58 respondents, 72.4% are women and 27.6% are men, mostly between the ages of 36 and 45 (41%).

The results of the responses are presented below.

Travel organizer:

- independent - 75.9%
- travel agency - 24.1%
- wine club - 10.3%
- travel club - 6.9%

How often do people come to the Black Sea region of Ukraine:

- 1-2 times a year - 58.6%
- 3-4 trips per year - 27.6%

Sources of information about tourist destinations of the Black Sea region of Ukraine:

- friend's offers - 41.4%
- advertising in FB, Instagram - 31.0%
- sites about trips and tourism - 20.7%
- announcements on the pages of the tourist/wine club - 20.7%

Motivation for a weekend trip to the Black Sea region (maximum 5 points)

- Avoid everyday life, new experiences - 4.41
- Discover a new city and culture - 4.17
- Relax by the sea - 3.66

Reasons for choosing a destination (maximum 5 points)

- Beautiful nature, landscapes - 4.59
- Tour price (travel expenses) - 3.90
- Local food and wine - 3.86

Wine: habits (maximum 5 points)

– I am interested in wine and related activities - 3.28
– Wine-related activities are reason enough to travel - 2.97
– I often attend wine tastings - 2.93

Results of answers to the question "Acceptable expenses for 1 day of travel that are interesting to you in this program": the majority of potential tourists (27.6%) are guided by average expenses from 700-1400 UAH, another 24% consider pleasant expenses for a day up to 700 UAH. 10.3% are ready to spend more, namely 1401-2000. Also, 6.9% of consumers expect an elite level of services, more than 3000 UAH.

4.5 Analysis of microenvironment factors is given in Table 4.

Among the factors of the microenvironment, the most influential are contact audiences and consumers.

Table 4. Risk assessment of the microenvironment of the Black Sea Wine Roads Project of Ukraine

Factors	Weighted Average
1. Intermediaries	**0,88**
• Development of rural tourism	0,52
• Pricing of tourist services	0,36
2. Contact audiences	**1,17**
• Informing about local wines of a certain area	0,48
• Development of wine clusters	0,30
• Attitude of local authorities and the population to the project	0,39
3. Substitute goods	**0,36**
• Increasing domestic imports of European wine products in supermarkets and wine boutiques	0,36
4. Competitors	**0,44**
• The popularity of wine roads in Transcarpathia and European countries	0,44
5. Consumers	**0,91**
• Growing demand for domestic tourism	0,55
• Consumer interest in products with a geographical indication	0,36
In general	**3,76**

4.6 SWOT analysis

The main strengths of the project are the presence of well-known wineries with quality products and the success of the pilot project "Roads of wine and Taste of Bessarabia".

Among the weaknesses are the low level of awareness of some project participants and the limited financial resources of project participants.

The main opportunity is the growing interest in the national local flavor on the part of Ukrainians and foreigners, the support of the project participants from the state.

The main threats of the project are the introduction of quarantine and the prohibition of tourist activities, as well as low consumer awareness.

Table 5. SWOT analysis of the wine roads project

Internal factors (strengths and weaknesses) **External factors** (opportunities and threats)	**Strengths (S)** 1. The presence of well-known wineries with quality products and interesting storytelling 2. Success of the pilot project "Wine and Taste Roads of Bessarabia" 3. Complexity of acquaintance with local sights 4. The beauty of the area, the photogenic nature of the objects visited	**Weaknesses (W)** 1. Inaccessibility of the region for foreign tourists. 2. Seasonality of the attractiveness of visiting wineries 3. Low level of service quality of certain objects of the tourist sphere 4. Heterogeneity in the level of development of wineries 5. Low level of awareness about some project participants 6. Limited financial resources of project participants
Opportunities (O) 1. The growing popularity of rural (green) tourism 2. Growing interest in the national local color of Ukrainians and foreigners 3. The trend of awareness of wine products in the media 4. Awareness of the importance of partnership activities within the wine cluster as a condition for accelerating development. 5. Increasing the role of local self-government in attracting investment in the development of small settlements 6. Support from the EU in Ukraine, attracting the attention of foreign tourists.	**SxO** 1. Formation of tours to wine and other trendy agricultural locations 2. Development of PR-programs to acquaint the target audience with the project 3. Complexity of media support 4. Organization of open-air tasting meetings in the traditional style for the South of Ukraine.	**WxO** 1. Participation in EU grants 2. Development of an event program for project participants during the year 3. Organization of seminars and conferences 4. Improving cooperation between individual producers with government officials.
Threats (T) 1. Introduction of quarantine restrictions, as well as a ban on tourism 2. Decrease in demand due to rising prices 3. Negative feedback from social and media people 4. The growing popularity of relatively cheap European wines. 5. Low consumer awareness of wineries.	**SxT** 1. Development of advertising campaigns on social networks 2. Development of a program for working with bloggers 3. Involvement of photographers to demonstrate the beauty of the area 4. Formation of value proposals for certain segments of tourists	**WxT** 1. Development of marketing legends for little-known project participants 2.Development of online tours, teasers for the formation of interest among consumers (tourists) 3. Conducting marketing research to identify promising target segments

4.7 Complex marketing of the wine roads project

General strategy

The project development strategy was chosen as the general strategy for this project.

Development strategy is a long-term qualitatively defined direction of development of the company concerning the sphere of activity of firm, means and forms of its activity, system of relations within the organization, and also its position in environment leading the organization to the purposes.

Competitive strategy

The strategy of differentiation was chosen as a competitive strategy. The essence of the differentiation strategy is to improve and personalize the product, which aims to improve its attractiveness to the consumer. The main task of the chosen competitive strategy is to provide each segment of consumers with personalized services.

Table 6. Strategy 4P of the wine roads project

4P	Type of strategy	A set of measures
1. Product	Differentiation strategy The strategy of "market novelty"	It is necessary to develop quality wine tourism products for each consumer segment; Develop a Development Program / Wine Tourism Development Roadmap; Develop a list of wine tourism entities; Develop marketing of wine tourism products. In perspective: Create a wine tourism infrastructure (construction along the routes of a network of guest houses at wineries, restaurants, cafes) Create a museum of Ukrainian wine with a wine shop.
2. Price	Flexible pricing strategy	Wine tourism is an additional promotion for winemaking. According to experts, sales with the active development of wine tourism will increase the turnover of winemakers by 30%.
3. Place	Intensive distribution strategy	Establishing links and partnerships with various tour agencies and operators. Interaction with contact audiences. Website development.
4. Promotion	Pull Strategy	Develop your own website in several languages. Development and publication of printed products (booklets, guides, tourist maps, catalogs, etc .; Active participation in international tourism exhibitions and fairs; Advertising in the media of Ukraine and CIS and foreign countries; Organization and holding of info-tours for representatives of mass media and tourist organizations; Contextual advertising; Targeted advertising on Instagram, Facebook.

V. CONCLUSIONS

Wine tourism is a specialized type of tourism that aims to taste, consume, and buy wine directly from the producer. The study showed that among modern tourists, the share of those who are looking for an opportunity to add more celebration and pleasure to their holiday in terms of culture and discover new gastronomic sensations combined with Fine Wines is growing.

The management problem of wine tourism in Ukraine is the insufficiently high rate of its development. The driver of the development of wine tourism in the region can be the creation of a map of tourist routes between wineries, historical monuments, interesting places, hotels and restaurants - the so-called "Wine routes" or "Wine and taste routes".

To solve certain management and marketing problems, primary and secondary research of the market, wineries, and wine tourists was conducted.

PEST analysis has shown that political and economic factors have the greatest impact on the development of wine tourism. State support for the development of wineries and wine roads should help reduce tax pressure on participants of wine roads, and most importantly, promote the positioning of Ukraine at the state level as a tourist and wine-producing country, promote its regions (including the Black Sea region) as attractive tourist destinations. It is also more important to overcome the stagnation of the country's economy due to the impact of the pandemic.

The success of spreading wine roads depends on the activity of their participants, especially wineries. Most wineries see prospects for development in the field of enogastronomy tourism, which is why 81.3% of respondents plan to become part of wine roads. The projected percentage of revenue growth from participating in the Wine Road project is approximately 25-30%. Their representatives named specially created museums, cultural centers with excursions, as well as beautiful landscapes and picturesque vineyards around them as the main motives for wine tourists to visit wineries. Among consumers of wine tours, you should pay attention to communication with such promising segments:

1) advanced "wine connoisseurs", which are mostly united in wine clubs. They have experience in tasting both domestic and foreign wines. They have experience in tasting at wineries. Active users of social networks. They can become a source of "word of mouth", positive reviews and recommendations. Communication channels: offline and online route presentations in wine clubs, local wine tastings accompanied by sommeliers in City wine boutiques, regional wine and gastronomy festivals.

2) "travellers" – Ukrainian tourists who are interested in everything new. They have travel experience primarily in domestic tourism. Communication channels: recommendations of friends, reviews in social networks, offers of travel agencies, information about wine routes on specialized sites of wine roads; presentations of wine routes at city festivals.

Based on the conducted research and SWOT analysis, ***the 4P marketing mix complex*** was developed, and a different strategy was chosen for each of the elements.

Product - a strategy of market novelty. For this strategy, you must:

- develop high-quality wine travel products for each consumer segment;
- develop a development program/roadmap for wine routes;

- develop a list of wine tourism entities;
- develop value propositions of wine products based on the needs of certain segments of consumers.

Pricing strategy – a flexible pricing strategy. The site with a map of wine roads should have a calculator for calculating the total cost of a wine tour, depending on the chosen route and the complex of basic and additional services.

An intensive ***distribution strategy*** has been selected for distribution channels. It is necessary to establish contacts and partnerships with various travel agencies and operators. Creating a wine roads website that can be not only informative, but also a means of online tour sales in the future.

The ***promotion strategy*** in this project is a Pull Strategy. The strategy assumes that the manufacturer uses communication tools to directly influence the consumer through mass distribution channels.

The website may contain information not only from winemakers and restaurants, but also from liquor stores, other tourist activities in the region related or unrelated to wine, such as local cheese factories; nature reserves or historical sites. In general, all tourist information about the region should be provided, including local hotels or rural lodges for the night (proven, with good service).

You need to create a section of the website: activities (experiences), where you can collect all travel offers. For example, red wine tasting in an old mansion; picnic in the vineyards; blind wine tasting; wine and local gastronomy. In general, everything that you can experience, live and get impressions there! And remember that wine roads aren't just about wine!

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Appendix A

Table A. 1 - Macroenvironment factors determined on the basis of an interview conducted by experts in the field of wine tourism and wine.

Political and legal factors			
Factor		Opportunities	
State support for the development of wineries and wine roads	Kirill Dombrovsky Irina Dyachenkova Sergey Morinets Tatiana Dymnich	Lobbying for draft laws to reduce preferential pressure on participants of guilty roads	
		Positioning Ukraine at the state level as a tourist and wine-growing country, promoting its regions as attractive tourist destinations	Kirill Dombrovsky Irina Dyachenkova Maria Yukhnovets and Marina Antonyuk
Legal restriction of social contacts, movement of tourists due to COVID-19 (closed borders, vaccination additional documents for entry to another country)	Kirill Dombrovsky Sergey Morinets Tatiana Dymnich	Domestic tourism development due to lockdown	Yevgenia Nikolaichuk
Economic factors			
Factor		Opportunities	
Stagnation of the country's economy as a result of the pandemic effect	Kirill Dombrovsky	Wine tourism as an important source of sales of its products for small wineries	Albina Manzul
		Development of thematic ("niche") tourism, including business, medical, and wine tourism	Yevgenia Nikolaichuk
Growing popularity of various types of local gastro and enotourism	Odessa Wine Week	Cooperation (collaboration) with craft producers of various products	Albina Manzul
		Maintaining interest in everything local, including local wines that can only be tasted at this winery	Albina Manzul
Development of regional infrastructure, comfort of movement, and service	Alexander Grabovsky Maria Yukhnovets and Marina Antonyuk Sergey Morinets Kristina Beshleul	Creating a set of additional services at wineries for the relevant consumer segments (hotel, restaurant, etc.)	

Continuation of the table. A. 1

Development of craft winemaking	Alexander Grabovsky	The emergence of new craft wineries with an attractive location, good location, reasonable price of tasting and wines	Roman Kozlovsky
Attracting international investment in the development of wine tourism	Kristina Beshleul	Participation in international wine tourism development projects, such as “Sea of Wine”	Kristina Beshleul
		Promotion of new forms of community in gastronomic tourism (International Wine travel awards)	Irina Dianchenkova
Sociocultural factors			
Factors		Opportunities	
Popularization of Ukrainian wine	Maria Yukhnovets and Marina Antonyuk	Changing preferences of Ukrainian consumers in the direction of domestic honest, high-quality wine	Alexander Grabovsky
Development of wine consumption culture	Yevgenia Nikolaichuk Tatiana Dymnich	Attitude to wine as a food product (recognition at the legislative level)	Odessa Wine Week
		Informing about the usefulness of dry wines	Yevgenia Nikolaichuk
Development and support of Ukrainian cuisine and its combination with local wines	Odessa Wine Week	When developing wine tastings, take into account the combination with local gastronomy, specialties	Tatiana Dymnich
Technological factors			
Factors		Opportunities	
Introduction of technological innovations in craft winemaking	Sergey Morinets	Growth of the quality level and expansion of the range of wine from craft producers	Sergey Morinets Kristina Beshleul
Introduction of online methods in training, communication, tourism, etc.	Odessa Wine Week	Growing popularity of online wine tastings accompanied by professional sommeliers	Odessa Wine Week

Appendix B

Table B.1 – Results of a survey of experts on the portrait of a wine tourist

1	**Characteristics of a wine tourist**	**Full name of the expert**
1.1	This is any person who gets to know this world and gets to know himself in this world, reveals new facets, learns something new, travels, acquires experience, impressions	Kirill Dombrovsky
1.2	These are people who at least has a job. And people who are basically interested in life, new directions, maybe new attractions, new knowledge, strive to get them directly from the sources of this knowledge and like to form their own opinion about a particular subject.	Irina Dianchenkova
1.3	Oddly enough, women respond to such trips with great enthusiasm. Men prefer to drink in men's companies and without formalizing the situation. And as a woman, she would always like to receive, in addition to the product itself, also information. To get in the mood for new knowledge and pleasure, it is more pronounced in the female audience. Although it can not be said that men are somehow indifferent, but women are more emotionally perceived and naturally in the group they prevail today.	Alexander Grabovsky
1.4	Age from 35 years, on average. They are a kind of hedonists who appreciate the pleasure of wine and food. By middle age, such a certain selectivity is already being formed. These are people with an above-average budget. These are definitely not budget tourists. Because it doesn't make much sense to go on a food tour and save on everything and not try anything. You can then go to Silpo, buy a bottle there and finish your gastronomic tours. Interests can be diverse in terms of professions. These are mostly people of creative professions, rather than people of some engineering professions. Plus, these are people who need to popularize Ukrainian.	Marina Antonyuk
1.5	If we talk in general about the portrait of such a wine tourist, you can call it foody. I would not separate those who love wine tours from gastronomic ones, because wine is a whole culture and is also closely related to food. These are definitely aesthetes who enjoy absolutely every component. Wine tour, gastronomic tour in general it is always very beautiful, it is always very aesthetically pleasing it is always very full. Second, yes, absolutely, these are people with a fairly high income, because they basically belong to the category of significantly average +. These people are not banal. That is, if a person wants to see Chile or Ukraine… or any other country where there is winemaking, that is, he consciously wants to fly there only because there is winemaking, that is, this indicates a non-banal view of travel and his high interest in wine topics. And these are definitely people who you know such people in life as, do you speak English? "No rush" is people who live by the principle of "no rush" to enjoy absolutely every moment during their lifetime	Maria Yukhnovets
1.6	I would distinguish two categories. The first category is professionals or people related to this topic in one way or another. They go to wineries purposeful the second category of people is looking for something interesting, but they are not quite in the wine topic. They go because one of their friends organized it, or it's some kind of big corporate trip. Now it is also popular among corporate trips.	Yevgenia Nikolaichuk

	Therefore, the average age is in any case 25-40. Maybe 45. This is definitely the average plus segment in terms of money. This person is so quite open. And in the past, most often, he already has a good experience of traveling as such. Well, he is also interested in gastronomy, of course.	
1.7	These are mostly women aged 40-50 years. Because if men go, it's only for the company. Basically interested in tourism, not only wine, has time to travel. In other words, these are most likely people who are freer in time. Some may be freelancers who are not burdened with worries. They are also interested in wines. This is how the connection is: interest - wine, interest - tourism, interest in gastronomy	Sergey Morenets
1.8	Even 5-7 years ago, probably there were people starting from the age of 30+, but now it is still changing, because I see from my personal experience that of course the majority, probably 70% of people are 30+, but still there is already a younger generation, which ... what attracts, first of all, it is basically an interest in life, that's all interesting to learn. It's not interesting, it's boring to live here, as if it's just monotonous to do your work there, and so on. This is the first point. The second is that wine is still inextricably linked with a healthy lifestyle and basically this whole story, if, for example, earlier they really consumed more strong alcohol, now everything is getting closer to drinking more wine and therefore the younger generation, it also strives to drink this particular drink. Well, in general, let's say I can say that about myself, I have mostly families who lead, try to lead a healthy lifestyle, who like to travel, who basically likes to live interestingly, as a rule, these are people with well, what with higher education is self-evident, but basically, they are quite educated and have seen a lot in life, here.	Albina Manzul
1.9	Women 40-60 years old, employees, with higher education, intellectual work (teachers, doctors…)	Roman Kozlovsky
2	**Where to find a wine tourist**	**Full name of the expert**
2.1	Through mass media, digital, and communication. It is necessary to form a Ukrainian culture of traveling in their own country, this stitches Ukraine together. Because when a person from one region goes to another region, learns traditions, through cuisine, through wine, through communication, through culture, through conversation, through literature, whatever, then returns to the place of his permanent residence and extrapolates this experience to his friends, acquaintances, relatives – this unites us, it stitches the country together, and this is the main thing.	Kirill Dombrovsky
2.2	International expohabs are enogastronomical, primarily wine. These are global exhibitions about wine, such as in Germany Prowine, in London LondonVineFest, in France VineParis or VineexpoParis, in Spain Alimentaria and in Moldova and Georgia these are Wine Days and in Ukraine these are WineISpirits Ukraine - exhibitions that take place in Kiev. The audience of visitors and exhibitors is 100% the same as the audience of wine tourists. Because people who are very active, they are interested in wine, they already understand something about wine and they like to travel.	Irina Dianchenkova

2.3	You need people to know what you do, to trust you, but these are not simple things at all. This is a matter of time, a matter of constant work, a matter of correctly set information flows. The organization of wine festivals, such as in Bolgrad, Tarutino, will inform tourists	Alexander Grabovsky
2.4	We need to hold as many local festivals as possible. This has always been a very good mechanism to attract attention, basically, some seasonal wine-making moments: grape harvesting and so on.	Maria Yukhnovets
2.5	People who go to restaurants, people who go to tastings. Or today, corporate tourism is also looking for interesting locations.	Yevgenia Nikolaichuk
2.6	Promotion through travel agencies, through international travel agencies	Sergey Morenets
2.7	Themed wine communities (clubs). Tasting sites (festivals…)	Roman Kozlovsky
3	**What is interesting about the Black Sea region for a wine tourist**	**Full name of the expert**
3.1	Sea, air, sun, cuisine, wine – that's why it's interesting. Culture, good people...	Kirill Dombrovsky
3.2	For international wine tourists, Ukrainian local wine is exotic.	Irina Dianchenkova
3.3	The quality of the product and harmoniously selected tasting pairs - with aged cheeses with high-quality brynza, with meat specialties. If I were still interested, I would think that Odessa is always distinguished by high-quality fish. It is not yet so densely present in wine tastings.	Alexander Grabovsky
3.4	In order for a person to come to a tourist site, they were offered not only a set of wines of some interesting nature, but also a gastronomic combination. Yes, some kind of lunch can be local cuisine Offer a 3-4-day tour, which would be more profitable to go to than to Turkey	Sergey Morenets
3.5	The theme of a healthy lifestyle combined with gastronomic tourism. Just wine is quite difficult to lure a person, that is, you need to create a complex for him: there is food, and wine, and some beautiful locations When a family arrives who also needs to lure a child, many wineries produce grape juice, that is, to make it interesting and good not only for adults	Albina Manzul

FEATURES OF THE IMPLEMENTATION OF REENGINEERING OF ADMINISTRATIVE SERVICES IN THE DEPARTMENT OF ADMINISTRATIVE SERVICES OF THE ODESSA CITY COUNCIL

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Abstract. The relevance of the topic *is due to the increasing importance of creating an innovative model of the development of high-tech management as a significant factor in ensuring the effectiveness of the implementation by citizens, given their potential, the development of personal and social quality life, in particular, precisely by obtaining high-quality administrative services in a decentralized environment.*

A significant tool of interaction between the state and society today is electronic services, which in the future will have the largest share and therefore require a more detailed review of the procedure of reengineering of the administrative services system into an electronic format.

The purpose of the *work is the activity analysis of the Department of administrative services for the past 4 years and consider the process of reengineering as a major factor in improving the efficiency of the Department.*

Task of the work:

• reveal the content of the concept of administrative service;

• to analyze the performance indicators of the Department of administrative services of the Odessa City Council;

• reveal the process of reengineering as a tool to improve the work of the Department of administrative services of the Odessa City Council.

The work considers the activity of the Department of administrative services of the Odessa City Council and the relations arising in the process of implementation of administrative services between the Department of administrative services of the Odessa City Council and the subjects of appeals.

The work contains 21 pages, 2 tables, 9 figures. The list of references includes 10 titles.

Keywords: *administrative services, center of administrative services, subjects of appeals, subjects of administrative services, Department of administrative services.*

I. INTRODUCTION

It is difficult to imagine in the modern world a developed country with an outdated system of administrative services, where citizens are forced to visit several government agencies in order to receive one service and spend at least a day to collect the necessary documentation. The development of a quality and efficient system of administrative services contributes to the reform of decentralization and the development of democracy by using citizens' own potential to create a developed society.

The usual methods of improving productivity - streamlining and automating processes - may not always lead to the serious improvements that are needed. Improving the efficiency of the Department requires not framing existing processes

with software. Only their complete destruction and the development of these procedures anew through reengineering will allow reaching a new level of efficiency.

II. LITERATURE ANALYSIS

In the service state model, the provision of services by the state is the most important function of state structures. The concept of "services" expresses a certain category, indicating the interaction between the subject that offers and provides services to the object that needs them. Any service is understood as an activity aimed at meeting certain human needs, that is, a service is an action, the result of which is consumed in the process of its provision.

Together with the creation of centers of administrative services, the country began a long and thorny path from a large bureaucratic system, which cannot be understood by an ordinary citizen, to a transparent system of interaction with the state. By delegating the authority to provide services to the local level, the state provides local self-government with an appropriate resource: either through inter-budgetary relations by directing transfers (subventions, subsidies) from state local budgets, or through transferring to the localities a share of the relevant national taxes and fees [1].

The system of administrative services is represented by the interaction of the subject of the application and the subject of administrative services, the subject of which is the administrative service.

According to the definition given in the Law of Ukraine "About administrative services" of 6.09.2012, "administrative service" is the result of the exercise of power by the subject of administrative services at the request of an individual or legal person, aimed at the acquisition, change or termination of the rights and/or obligations of such a person in accordance with the law [2]. One of the characteristics of an administrative service is a certain typicality of the case, since the issuance of permits, passports, licenses, etc. has standardized procedures for the actions of subjects of application and the provision of administrative services [1].

The price of the provision of a particular administrative service should be uniform, regardless of whether this service is provided by state authorities, local self-government bodies or businesses. However, in Ukraine the level of readiness to apply such an approach is still low and this issue requires additional discussion at different levels [1].

It should be noted that at present the possibility of providing and receiving administrative services in electronic format has been introduced. The list of services that can be obtained in electronic form differs significantly from the general list of services, but this direction is developing rapidly. Therefore, it becomes necessary to define this segment of administrative services.

The result of the providing administrative services by the executive authorities through the introduction of digital technologies is now an electronic service [3].

It should be noted that electronic services exclude the corruption component from the system of citizen-state relations. The transformation of an administrative service into an electronic services is accompanied by a reorganization and restructuring of this process in order to ensure transparency and maximum efficiency.

Along with the introduction of electronic services in the sphere of permits, it became possible to implement the principle of "blind" distribution. This means that the

decision to approve a project can now automatically be randomly sent in contrast to the place of application of the region [4].

There are two types of electronic services:

- fully automated, the process of providing the service takes place completely in the electronic plane, when human participation is minimized (this category includes automatic services that exclude contacts with the employee);
- partially automated, when a part of the processes is automated, and the other part is in "manual mode" [5].

The "democratic" component (e-democracy) is dominated by "bottom-up" communications, i.e. citizens influence the functioning of public authorities in a certain way, receive information from civil servants, control the compliance of public policy priorities with their own priorities and on this basis take part in political decision-making. In contrast, the "administrative" component (e-government) is based on "top-down" relations, focusing on providing administrative services and the implementation of managerial activities [1].

Among the tasks carried out by the Department, it is customary to highlight three main ones: optimization of the process of providing services so that the number of calls to the Center and their duration for one service (or related ones) are reduced; combination of quality and simplicity in administrative services; increasing the percentage of public awareness on the procedure of receiving administrative services, a list of requirements and deadlines for results.

An important aspect of the further deregulation of administrative services is to conduct a thorough analysis of the optimality of the processes of their provision, elimination unnecessary links, study and apply the best foreign practices, their quality regulation for further automation, as well as, as an element of competition, involving businesses in the circle of providers of these services, but at a single price [1].

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of the research is the activity of the Department of administrative services of the Odessa City Council.

The subject of the research is the relations that arises in the process of implementing administrative services between the Department of administrative services of the Odessa City Council and the subjects of appeals.

The methodological basis of the work is the method of logical analysis, a combination of quantitative and qualitative analysis in a systematic approach.

IV. RESULTS

4.1. Analysis of the activities of the department of administrative services of the Odessa City Council

It is possible to visualize the course of the Department's workflow by considering quantitative indicators of activity, namely the number of applications, services rendered, field receptions, etc.

The department is in the development stage, the positive dynamics is observed in almost all types of activities, as well as in the total number of provided administrative services, in Fig. 1.

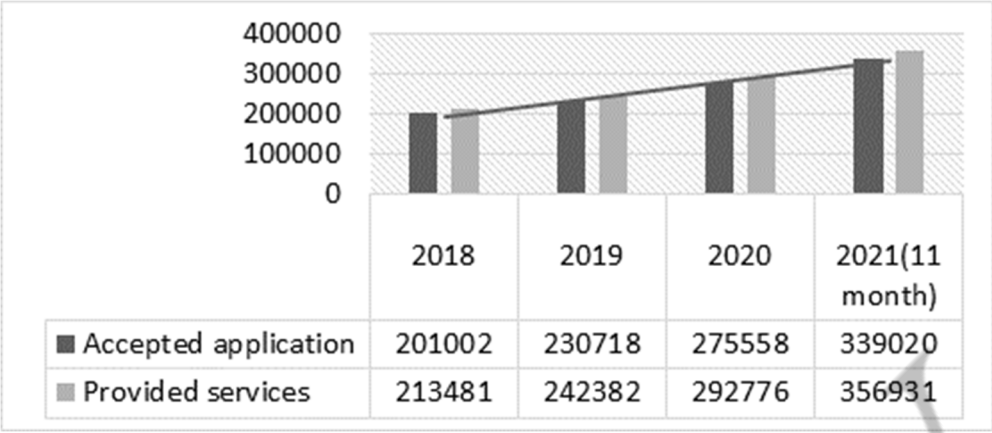

Fig. 1. Dynamic of provided administrative services for 2018-2021, units
Built on the basis: [4]

The Department does not always act as a service providing body, it is also an intermediary in this process.

It is possible to distinguish the leaders among the bodies providing services, besides the Department of administrative services, the large specific weight among all the ready results is occupied by the Main Department of the State Migration Service of Ukraine in the Odessa region. This factor is due to the provision of services for the issuance of biometric passports, including for travelling abroad in different circumstances and pasting the photo in the old passports. The Main Department of the State Geo-cadastre in the Odessa region is in the third place, in Table 1 below.

Table 1 shows that the rapid growth of indicators is due to the increase in the number of services provided by the Department of administrative services, as the subject of service provision. The DAS of the Odessa City Council is the undisputed leader in the number of issued services as a subject of service provision.

Table 1. **The number of issued ready-made results by subjects of provision for 2020, units**

The ready-made results have been issued	DAS of the Odessa city council	MD of the SMS of Ukraine in Odessa region	MD of the State Geo-Cadastre in Odessa region	Other administrative services (local, ORSA, territorial divisions of CEB)	Total
January	11324	2842	2588	3103	19 857
February	11 437	3009	2793	3 256	20 495
March	12774	2554	1743	3 275	20346
April	16491	2019	1148	1 132	20790
May	12682	1673	1276	2 971	18602
June	15991	2840	1485	4 080	24396
July	19065	3857	1795	4 250	28967
August	15744	3390	1804	6 927	24475
September	18396	4243	2068	5 496	30203
October	18755	4005	2024	4 120	28904
November	18 540	3 509	1 965	3 136	27 150
December	18 777	4 320	2 091	3 403	28 591

Built on the basis: [6]

Today it is possible to estimate the dynamics of administrative services during 11 months of work of the DAS of the Odessa City Council in 2021, which is presented in Fig. 2.

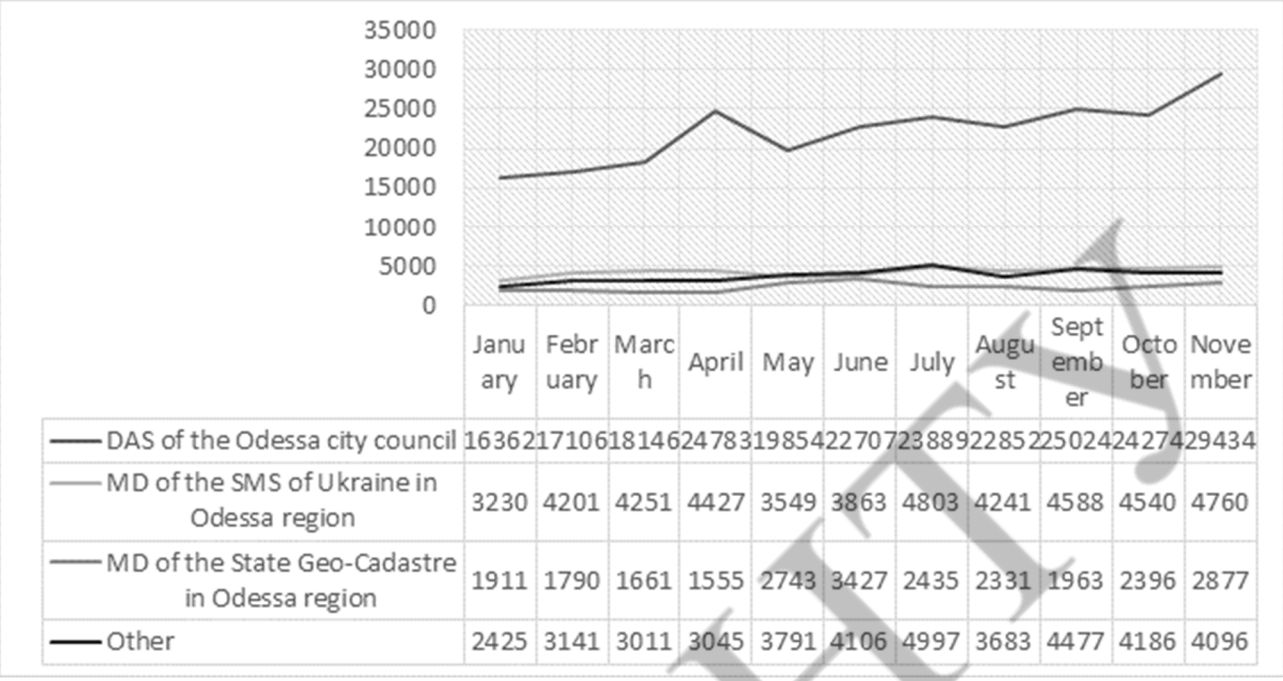

Fig. 2. The number of issued ready-made results of services by the subjects of their provision in 2021, units
Built on the basis of: [6]

The result of DAS's work in 2020 was the provision of 302 types of administrative services, and starting from May 11, 2021, their number increased by as many as 50 administrative services. This rapid growth is due to the beginning of cooperation between the Department and the Southern Interregional Department of the Ministry of Justice (Odessa) of the registration of civic groups through the CPAS [7].

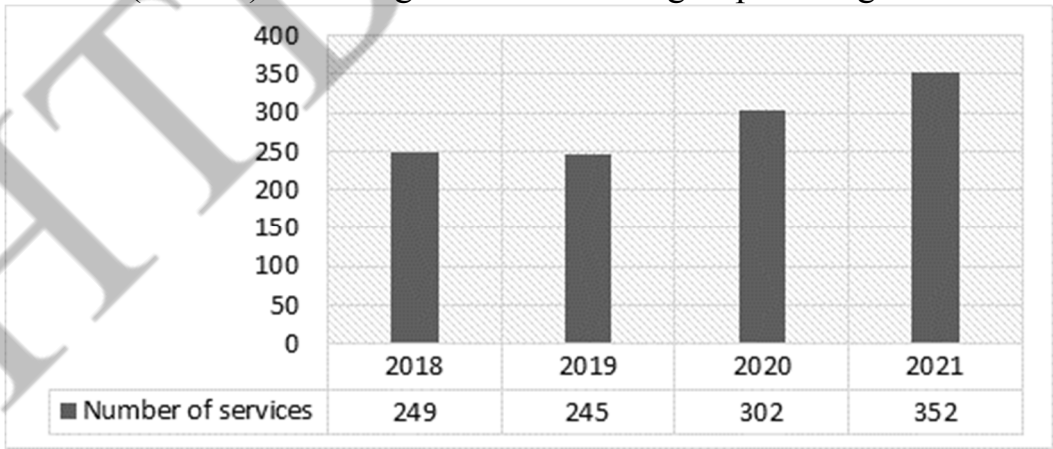

Fig. 3. Dynamics of the number of names of administrative services provided by CPAS for 2018-2021, units
Built on the basis of: [4]

Each administrative service provided by the Department has its own unique digital format cipher (XXX-X), or (XXX-XX), in which the first three numbers indicate the organization acting as the body providing the service, the last two - the

number in the order of service provided by this body. The table of executors of administrative services with ciphers is presented in Exhibit A.

The full list of administrative services is very difficult to comprehend for the average citizen who needs cohesion on certain grounds. In general, the services of the Department can be divided into five categories, ie to classify activities by common characteristics, then it becomes possible to estimate the share of these services in the overall activities of the Department, as shown in Figure 4. It is possible to a conclude about the popularity of the state administrative services.

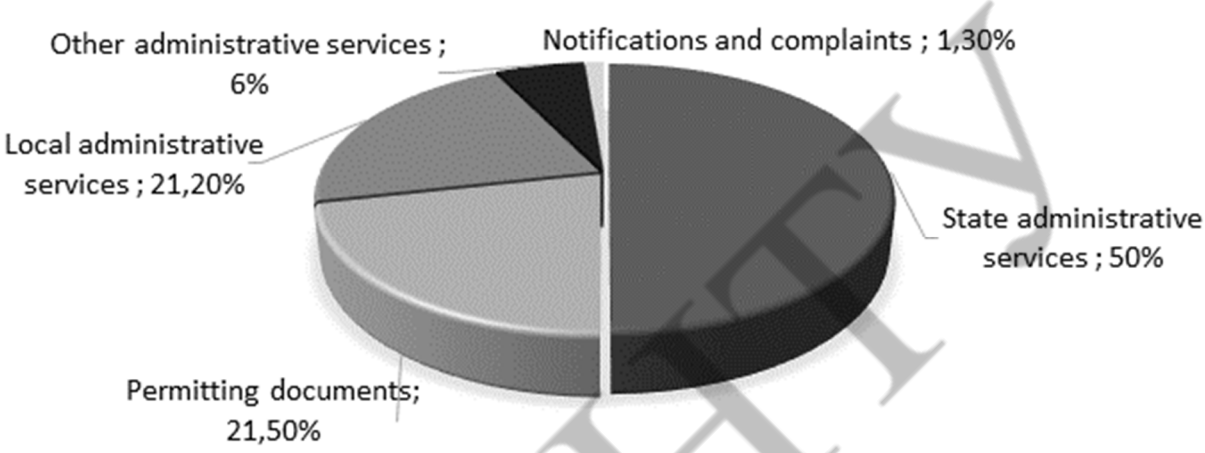

Fig. 4. The share of administrative services provided through the CPAS in 2020,%
Built on the basis of: [4]

A key feature of the service state is the creation of the most favorable conditions for citizens. The Center of administrative services provides free trips to residents of Odesa who are not able to get personally to the CPAS, as shown in Figure 5.

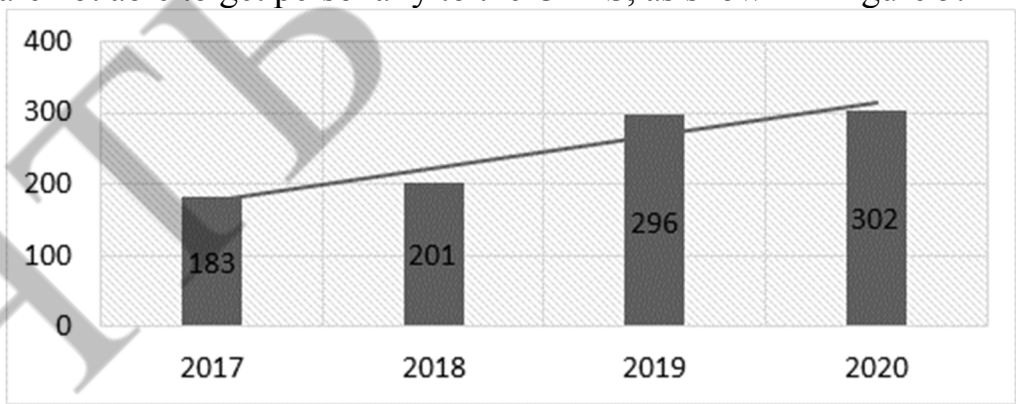

Fig.5. Dynamics of the number of outreach receptions for 2017-2020, units
Built on the basis of: [4]

The Government of Ukraine, heading for EU accession, should improve its activities in the field of administrative services by using best practices and new ICTs.

The digitalization of the Department started in 2020, when the administration decided to launch a web portal in a test mode at cnap.odessa.ua. The site is responsible for informing citizens, namely: the list of services, the procedure, cost and timing of their implementation.

The leading activity of the Department is the activation of work in the sphere of providing electronic services. It is planned to increase a quantity of free time for civil servants to resolve complex, non-standard or controversial issues, to reduce their work on the usual typical procedures for interacting with the subjects of appeals.

The Department has introduced 11 services provided in electronic form, free of charge, among which the DAS of the Odessa City Council acts as an intermediary. There is also a system of certification documents by QR-code, instead of the previously used stamp and signature. This practice is used in the provision of a small number of services, when the subject of the appeal receives a finished service in the form of a document certified by QR-code and completely identical to the documents issued by the Department, to his e-mail without re-applying to the administrator.

Digitalization will allow citizens with disabilities to obtain the necessary documents at home on their own, without the departure of the CPAS administrator to their place of residence. Since the on-site reception includes a visit of the administrator to the citizen's home, collection of documents, execution of the service and another visit to deliver the finished administrative service, the procedure is very time-consuming, approximately 1 on-site reception per day is realized.

At the same time, it is usually possible to register in an electronic queue for the most popular services, such as registration or de-registration of residence, no earlier than a month in advance. The long waiting time creates obstacles in the social activities of citizens. At that time the deadline for these administrative services is 1 day. When this situation arises, two types of measures are possible:

- operative: give him someone to help, transfer some of the work to other administrators.
- strategic: review and optimize CPAS processes [8].

4.2. The concept of reengineering of administrative services

The usual methods of improving productivity - streamlining and automating processes - may not always lead to major improvements. In particular, major investment in the information technology can be frustrating because technology is used only to mechanize the old work processes, leaving existing procedures untouched.

The workflows, management mechanisms and organizational structures of most administrative services were developed in an era when today's computers and technology did not exist. They are built with efficiency and control in mind, where the core concept of the present is innovation and speed, service and quality.

Reengineering is characterized as an all-or-nothing phenomenon and does not include a definite result, a detailed plan and careful steps. For a large number of administrative services, re-engineering is the only way to end an outdated process

It is necessary to subject the existing outdated procedures for the provision of administrative services to "reengineering": a radical restructuring of existing processes with the help of modern ICT. Reengineering involves identifying outdated procedures and discarding some of them in favor of new ways of doing work. In the developed new procedures, there will also create new rules that correspond to the spirit of the times.

Reengineering is characterized as an "all or nothing" phenomenon and does not

include a definite result, a detailed plan and careful steps. For a large number of administrative services, reengineering is the only way to end an outdated process that is exerting downward [9]. The reengineering process has certain features that characterize it meaningfully, which are shown below in Fig. 6.

Reengineering is based on the concept of jumpiness, which can be called the concept of discontinuous thinking - identifying outdated procedures and fundamental assumptions on which the work is based, and a decisive break with them [9].

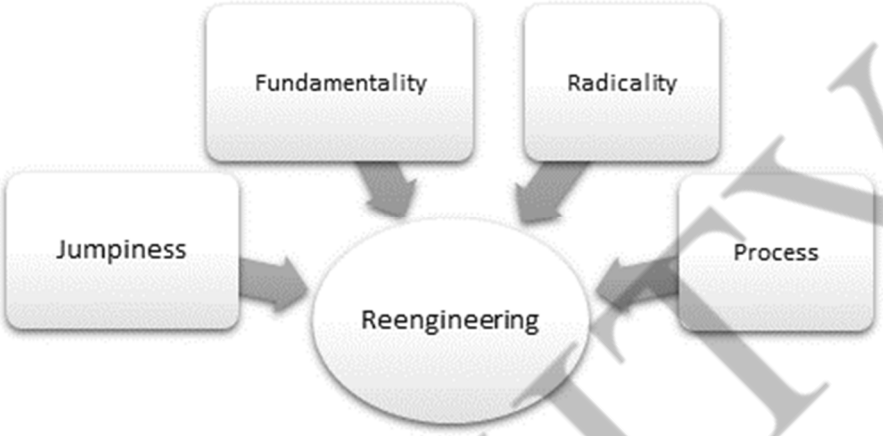

Fig.6. Reengineering signs
Built on the basis of: [10]

In general, the goal of reengineering is to significantly improve the efficiency of the public service delivery, which should become free from triviality and boundaries between departments, to be broad and cross-functional [9].

Like most performance improvement processes, reengineering includes certain implementation principles that distinguish it from other processes, such as performance improvement and quality management systems. These principles are defined in the figure below.

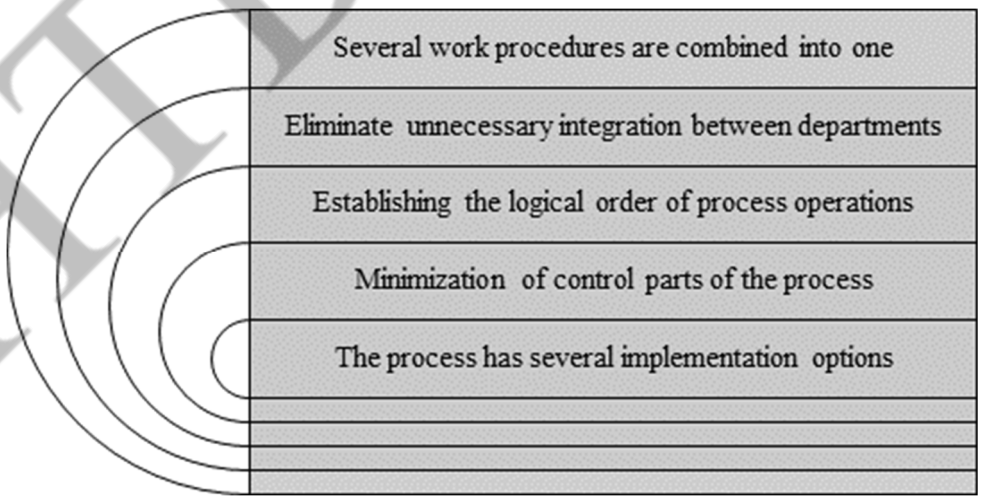

Fig. 7. Principles of reengineering of business processes
Built on the basis of: [10]

The structure of the usual adminservice process is fragmented, lacking the integration necessary to maintain quality and service organization. As a result, people

begin to replace the process task for the narrowly defined goals of their departments. When the work is passed from person to person and from one department to another, errors and delays are inevitable. The limits of responsibility are blurred and the most important issues are lost.

It is necessary to distinguish such processes as reengineering and improvement, the first is more radical and occurs through a complete reorganization of processes. Table 2 comparison of these tools to improve performance is listed below.

Table 2. Comparative characteristics of process improvement and reengineering

Comparison criteria	Improvements	Reengineering
The level of change	scaleable	radical
The frequency of changes	permanent	disposable
The duration of changes	short-term	long-term
The direction of changes	bottom-up	top-down

Built on the basis of: [10]

In the process of reengineering, the Group must ask the same questions in order to fully reengineer: "Why?" and "What if?" Why do we need an administrator's signature on the application form? Is it a control mechanism or a decision point? What if he or she doesn't review them at all? The process of raising and resolving heretical questions can truly separate the necessary parts of the process from the superficial details.

Reengineering brings many configurations to life, not just in the administrative services process. Responsibilities of administrators, organizational structures, management systems - everything related to the process - must be reengineered in an interconnected way [9].

In general, the reengineering process involves:

– analysis of the current business process;

– development of business process reengineering by means of a flowchart;

– definition of information exchange with the state registries, if necessary (within the flowchart);

– nomination of an updated application form (list of steps and fields).

4.3. Reengineering of the administrative service for the provision of housing subsidy

As an example, it was chosen an administrative service of providing the housing subsidy, which contains two documents to be filled out: Application and Declaration (sample documents are given in Exhibit B).

First of all, given that these two documents deal with the same issue, it is advisable to combine them into one Application, as the available information is somewhat duplicated.

Further, reviewing the Application, it is necessary to automate the process of filling in the name of the local department of social protection based on the place of residence to which the application for a subsidy is attached, since the corresponding state body is associated with each place of residence. This information is even

contained in the 2GIS service in the information about the house, so there is no need to ask the subject of the appeal about this. Such data as full name, registered place of residence, phone number, passport data, RNTRC, vehicle data are also filled in automatically from the information available in the Action application database. In case that a person lives in a place other than the registered one and wants to apply for a subsidy - the actual place of residence is filled in manually.

Regarding the choice of the type of service, namely the direction of assignment of the housing subsidy (to pay for housing and communal services, liquefied gas, etc.), it should be made from a "drop-down" list.

Today most utility payments are made through official websites of service providers, where users have their own personal accounts with information about meters and payments. It is reasonable to carry out some integration with these sites and their registries to obtain information about the subject of appeal, which will be more reliable, relevant and will not complicate for the subjects of appeals the process of obtaining an administrative service.

The item "give consent..." should be moved to the end of the application and put a box next to it for a "tick", this is a standard scheme of filling out applications and similar documents.

Reviewing the Declaration it was found that obtaining data on the place of residence should also be made automatic, without the participation of the subject of appeal, as this information is contained in state registries.

Data about relatives are typical data, which are available in the Action, so it would be appropriate to indicate which relatives live "daughter, wife..." and share a QR-code via a link in Telegram to confirm their provision of data. Filling in manually in the absence of the application is also left as a possible feature, since not every citizen has this application yet.

Data on staying abroad are recorded in the database of the state border service, so it is advisable to check this information in the register.

It is not yet possible to bypass the indication of income that is not in the database of the tax service, therefore it is necessary to mark the full name of the employee, make a “drop-down” list of these four types of income, in the case of marking the presence will appear a field about the amount and organization.

It is still difficult to reliably find out expensive purchases without the participation of the subject of appeal, so you should ask a citizen about this. If a citizen chooses “yes” to the question of purchasing goods for more than 50 thousand UAH a field for entering the full name, a “drop-down” list of types of goods, a field for the cost and a date selection appear. Consent to all conditions, data processing, etc. is carried out at the end of the application by putting a “tick”, this should include agreement with the terms of service provision from the part of the Application.

Schematically, the administrative service after the reengineering process is shown in Figure 8.

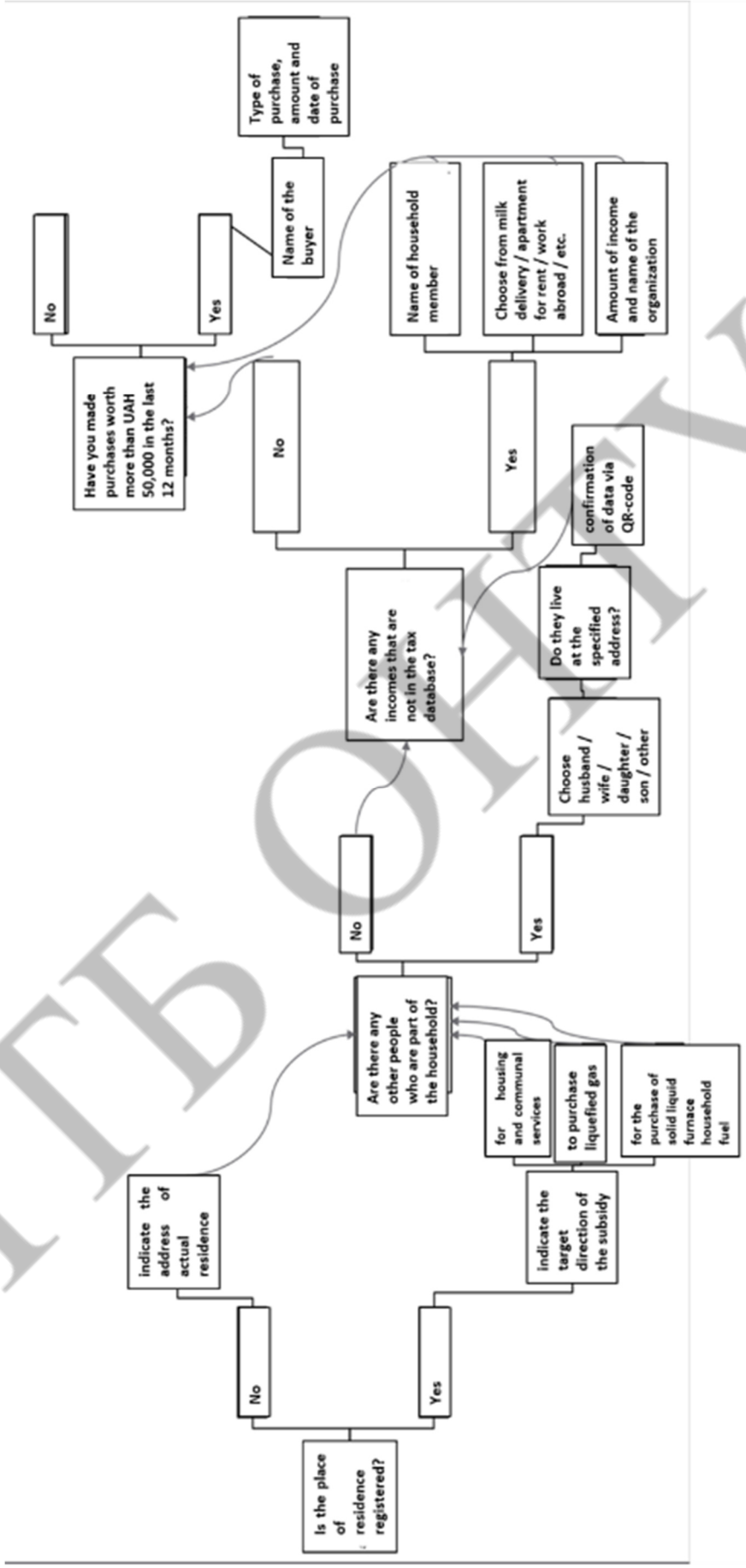

Fig. 8. The process of reengineering the administrative service for the appointment of housing subsidies

Administrative service cannot look like a scheme; need to develop its final form for the subject of appeal. For example, using the smartphone interface, can depict the interface after the reengineering process, in Figure 9.

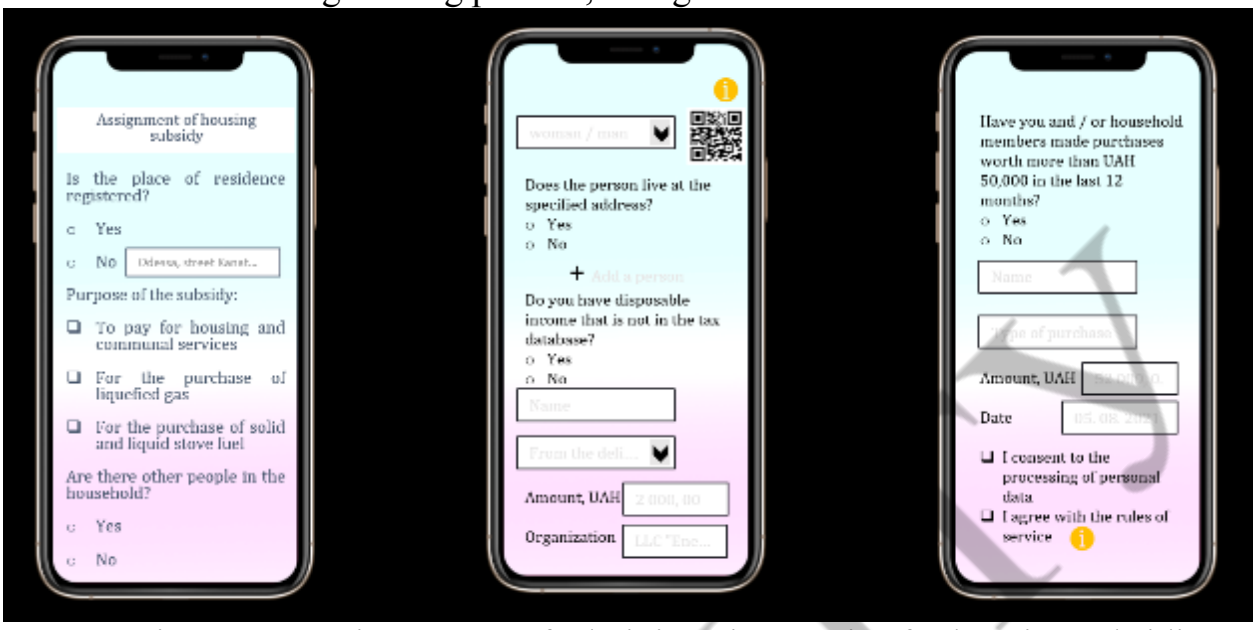

Fig. 9. Approximate type of administrative service for housing subsidies

It is important to organize the process of providing the service as clear and simple as possible. It is desirable at this stage to provide a test design service focus group conducted development and improve if necessary.

V. CONCLUSIONS

For many years, government services were mostly associated negatively: long lines, lack of understanding of what to do, endless offices, sometimes unfriendly employees, and bribes. Unfortunately, this trail of distrust continues to this day. Today the state is working on creating a new face of the service state.

Today, one of the priority areas of activity of the authorities in the framework of the development of the information society is customer focus and accessibility in physical and electronic form. A high-quality system of administrative services that meets all the challenges of our time is being created through the integration of electronic services into the activities of the Department.

1. Revealing the concept of administrative services, it is defined that the system of providing administrative services is represented by the interaction between the subject of appeal and the subject of providing administrative services, the subject of which is an administrative service. Delegating to the local level the authority to provide services, the state provides local government with an appropriate resource: either through inter-budgetary relations by sending transfers (subventions, subsidies) from state local budgets, or through transferring to the localities a share of the relevant national taxes and fees, helping to implement the decentralization reform.

2. Analysis of the Department's activity made it possible to see that today there is an active development, despite the quarantine and other possible restrictions. Every year the number of the services provided and the specific weight among them provided

by the Department of administrative services of the Odessa City Council as the body of the service providing is increasing.

3. Revealed the process of reengineering of administrative services as one of the ways to improve the work of the Department, it can be seen that it is a highly effective method of improving the quality of services in the Department of Administrative Services of the Odessa City Council. These measures will speed up the process of their provision, reduce queues and make it easier for citizens to register.

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THE ROLE OF INTELLECTUAL PROPERTY RIGHTS AND INTERNATIONAL TRANSFER OF TECHNOLOGY IN FOSTERING THE ECONOMIC DEVELOPMENT: THE CASE OF CHINA

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Abstract: *The significance and role of the intellectual property rights (IPR) evolves each year in dependence of the country economy. By striking the right balance between the interests of innovators and the wider public interest, the IP system aims to foster an environment in which creativity and innovation can flourish. Companies are attentive when it comes to identifying and protecting intellectual property because it holds such high value in today's increasingly knowledge-based economy and stimulates domestic economic growth. Also, producing value intellectual property requires heavy investments in brainpower and time of skilled labour, which means that increasing the inbound of foreign direct investment could determine the rise in the R&D expenditure from the GDP. This translates into heavy investments by organizations and individuals that should not be accessed with no rights by others.*

Keywords: *intellectual property rights, developing countries, transfer of technology, IPR Index, Foreign Direct Investment, patents, trademarks, industrial designs, innovation, economic growth.*

I. INTRODUCTION

Over the years, the role of intellectual property has grown considerably in all areas of activity, and especially in those countries which register continuous economic growth by recording a high tendency in displaying intellectual property protection systems in which the public has a basic degree of confidence [23].

Legal protection of innovation has been one of the determinant factors of economic development in many countries. Habits of mind and patterns of activity which release human creativity and generate new technology have been fostered by innovation protection. Protection of industrial and commercial secrets through the "trade secret," protection of creative expressions through copyright, protection of inventions by patents, and protection of commercial names through trademarks, has played a beneficial role in boosting economic growth in those states [23]. In this context, the intellectual property rights do represent an encouragement to stimulate the increase of economic growth of a nation, which consequently it does strengthen the motivation and possibilities of population in producing and developing new things, as well as encouraging investment in R&D and innovation, which will, eventually, create job opportunities and faster development of the world technologies. Moreover, being recognized as an asset to trade, it leads to the increase of competitiveness through industries worldwide [25, p.6]. When realising new invention, it is important to patent it, with the purpose to give the creator all the credits, to guarantee the industrial property rights, make possible for the inventions to be transferrable between inventors and thereby stimulate international trade and economic, technical and scientific

cooperation and, fulfil the function of trading products manufactured with the aid of inventions to its foreign partners, otherwise it will be considered as a "know-how".

In these regards, in 1984, the United States designated inadequate protection of patents, trademarks and copyrights as an unfair practice that could invoke retaliation under section 301 of the Trade Act of 1974, which was adopted with the purpose to eliminate unfair foreign trade practices that adversely affect U.S. trade and investment in both goods and services. As result, during the Uruguay Rounds, in the period of 1986-1994 there was negotiated the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), which establishes minimum standards for the regulation by national governments of different forms of intellectual property (IP) as applied to nationals of other WTO member nations and introduced intellectual property law into the multilateral trading system for the first time by remaining the most comprehensive multilateral agreement on intellectual property [13, p.1].

Another substantial role and importance in developing, increasing and expanding the economic growth is played by the international transfer of technology (ITT), which represents a multilateral flow of information and technical knowledge. It integrates various scientific fields, institutions, and business entities. Knowledge thus obtained contributes to the creation of a certain, more or less advanced, technological base [23]. The process presented above is not a new thing. It existed from the beginning of the humanity. Each simple gesture, word or even concept was created by someone, was transmitted through generations, and evolved over the years, and it did represent a simple explicit transfer of technological knowledge in a friendly environment. During the course of the years the complex requirements of the human being increased, being determined by their daily life needs. The elementary creation of various agricultural instruments, the formation and transfer of the knowledge how to realise it, represents an involuntary deliver of technology. Back then, there were no IPRs and law that permitted to the creator to take advantage from the invention, but, over the years, the continuous rapid evolution of different sectors and industries introduced the necessity of an elaborated management transfer of technology.

The actuality of the researched topic is determined by the increase of the importance of innovations, the purpose of which is the sustainable economic growth both at national and global level in a prosperous digital era, through various types of investments and applicable laws for the protection of intellectual property rights.

Therefore, this article is divided into two main sections: the first represents a general overview of the intellectual property rights in China after the sign of the TRIPS Agreement, while the second one focuses on the analyses of the China technology transfer, mainly with its "direct" competitor U.S.A.

II. LITERATURE ANALYSIS

The article is conducted based on several centric ideas about the intellectual property rights and technological transfer in the context of continuous prosperous economic development, especially in the developing countries.

Romer (1990), and Grossman and Helpman, (1991) recognized that Intellectual property rights are seen as part of the infrastructure supporting investments in Research and Development (R&D) leading to innovation and subsequent economic growth [22,

6 Ch. 11]. However, Kanwar (2006), analysed the IPR and its role in the economic development deeper, by claiming that strengthening IPRs could lead to greater innovation in developed countries, which in turn, could be helpful for developing countries [12]. Similarly, Taylor (1994) also argued that strengthening IPRs affect innovation and economic growth indirectly through the flow of FDI and transfer of technology from the North to South [26]. The model "South-North" mentioned, was developed by David Ricardo [17], which provides a growth-sustaining escape mechanism by enabling two regions two specialise. On the same prospective, the economics professor Ronald Findlay from the Columbia University developed largely the theory and explaining the growth of a less developed "South" or "periphery" economy that interacts through trade with a more developed "North" or "core" economy. Likewise, Grossman and Helpman (1991), based on the model presented above, analysed the consequences of imperfect IPRs protection on technical progress and economic growth by assuming that innovation takes place only in the North, which are considered to be dominated by developed economies, and imitation takes place only in the South, represented by developing ones. According to these authors, imperfect IPRs protection encourages imitation activity in the South. As result, the increase in number of replicated goods, there is registered a rise in the "stock of knowledge" in the south countries. However, from this model can be drawn the conclusion that a strong protection of the Intellectual Property Rights may reduce the rate imitations, which means that the north countries will maintain its monopoly over a long period of time in terms of innovation and technological progress, while the south countries, the productivity decrease, determine by the rapid innovation evolution, and the stock of knowledge is limited for a specific period of time. Nevertheless, taking into account the expansion of imitation process, appears two contradictory factors. The first one, acts positively on behalf of the north countries, being a stimulator for innovation and technical progress, with the purpose to maintain its dominant position on the market, while the second one, affects negatively the innovators themselves by the disappearance of the rent that they receive at the moment of the introduction of their innovation and its successful spreading, because of the variety of the specific innovation is imitated [6, Ch. 11].

On the contrary, Falvey et al., (2006) argued theoretically that strong IPRs may have a negative effect on developing countries that undertake little or no R&D, by asserting that because of the low level of innovative capabilities in the developing countries, imitation can be a significant source of technological development [5].

Comparably to the Taylor's (1994) idea, Park and Lippoldt (2008) showed that stronger IPRs in developing countries are associated with an increase of technology-intensive FDI [19], while Awokuse and Yin (2008), provided a concrete example concerning the relationship of IPR protection in China to FDI inflows, concluding that IPR reforms in China have had a positive and significant effect on inbound FDI [27].

Diwan and Rodrik demonstrated that stronger patent rights in developing countries give enterprises from developed countries a greater incentive to research and introduce technologies appropriate to developing countries. Similarly, Taylor (1994) showed that weak patent rights in developing countries lead enterprises from developed

countries to introduce less-than-best-practice technologies to developing countries. Interestingly, the relationship goes in both directions.

In relation to several academic research, which present a strong correlation between IPR and technology transfer, Lippoldt (2008) showed that IPR strengthening in countries—particularly with respect to patents—is associated with increased technology transfer via trade and investment [19]. Research has revealed that a country's level of intellectual property protection considerably affects whether foreign firms will transfer technology into it. That matters because the welfare gains from the importation of technology via innovative products, while differing across countries, can be substantial. For instance, foreign sources of technology account for over 90 percent of domestic productivity growth in all but a handful of countries.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of this study is to determine the impact and importance of intellectual property rights and technology transfer in the developing countries and how they affect the economic growth. To have a more elaborated and concrete picture of the analysed theme, it was presented in depth the case study of China, and the China-U.S. relationship in terms of technology transfer.

In order to comprehend the impact of the intellectual property rights and the international transfer technology upon the economic development in the developed countries, and what are the key factors that influence directly the development and competitiveness of new inventions within a developed market, there are some objectives that are set within the framework of this study:

-to make an analysis of the intellectual property rights impact upon the economic development of the developing countries, especially China;

-to analyse the relationship between U.S.-China within the Intellectual Property rights and technology transfer framework;

-analysis of the Chinese domestic and foreign patentees.

The subject of this research is the intellectual property rights and technology transfer in China.

The methods of research consist of the qualitative and quantitative research, such as theoretical and statistical analysis, deduction and data synthesis in accordance with the consulted sources for approaching the relevance of IPR within and integrated and continuously growing economy. At the same time, there was analysed the evolution of the intellectual property rights from the TRIPS Agreement, the China IPR and its position in different world rankings. Therefore, to outline the effects of technology transfer in the developing countries was take the China-U.S. trade relationship in accordance to the Ricardo's examined method. For the overall research, we have looked up to such indicators: Human Development Index (HDI), Global Innovation Index (GII), Intellectual Property Rights Index (IPRI). Based on these indicators, the research analyse: the correlation between GII, the number of IPR applications, and the expenditure on the R&D from the GDP and the relationship between FDI inflows and R&D expenditure and their impact on the IPR applications and index. Simultaneously was consulted several reports from the World International Property Organization (WIPO), China National Intellectual Property Administration (CNIPA) 2020 Annual

Report and used data from the World Bank Data, Chinese National Bureau of Statistic, WIPO Statistics and IPRI Database.

IV. RESULTS

4.1 The evolution of intellectual property from the establishment of the TRIPS Agreement.

Nowadays the relevance of intellectual property is crucial when developing a new product, technology or method of development. Being into an era where already everything exists, the tendency and risks of copying it is substantially high. In this context, the applicable law is useful in helping the countries, companies or inventors to overcome conflicts regarding the IPR.

From the implementation of the TRIPS Agreement in 1994, the global protection for creative innovation and expression markedly increased, as the gradual harmonization of national IPRs policies. A similar and comparable period to that before signing the TRIPS Agreement came at the end of the 19th century during the negotiations of the Paris Convention (1886). The Paris Convention was adopted in a period of intensive and extensive industrialization, where the high demand for patents represented a public support for appropriating the returns to inventions in the manufacturing era. Today's even greater advance in protection, determined by the relevance of IPRs in supporting the new high-technology, information-based economy of the new century. In the 21st, we are not talking about the invention of a simple pen, which back then was considered a turning point, but new software programs, advanced technology, pharmaceutical formulas, etc., which are more exposed, if not protected according to the intellectual property law.

Over the years the world countries showed a high potential of innovation in introducing new innovative products on the market. The term of innovation fits perfectly into the context, due to the fact that itself represents the intellectual property, which accordingly to the World Intellectual Property Organization (WIPO) is defined as "creations of the mind, such as inventions; literary and artistic works; designs; and symbols, names and images used in commerce"- to sum up, invent "something innovative".

Following, the Global Innovation Index (GII) 2021 only a few economies have consistently delivered peak innovation performance. Only Switzerland and Sweden have remained in the top three of the innovation ranking for more than a decade. Switzerland, Sweden, the United States of America and the United Kingdom have ranked in the top five for the past three years, as shown in figure 1, and registering a GII score between 65.5 and 59.8 points. These countries registering also top positions according to the HDI. However, it also can be seen that beginning with 2019, China become part of this top, as being the only developing country that manage to enter in a 5 years' time period, by registering an increase in its position, and becoming the twelfth innovative country. At the same time, China remains the only developing country in the top 30 most innovative economies [3, p.3-20].

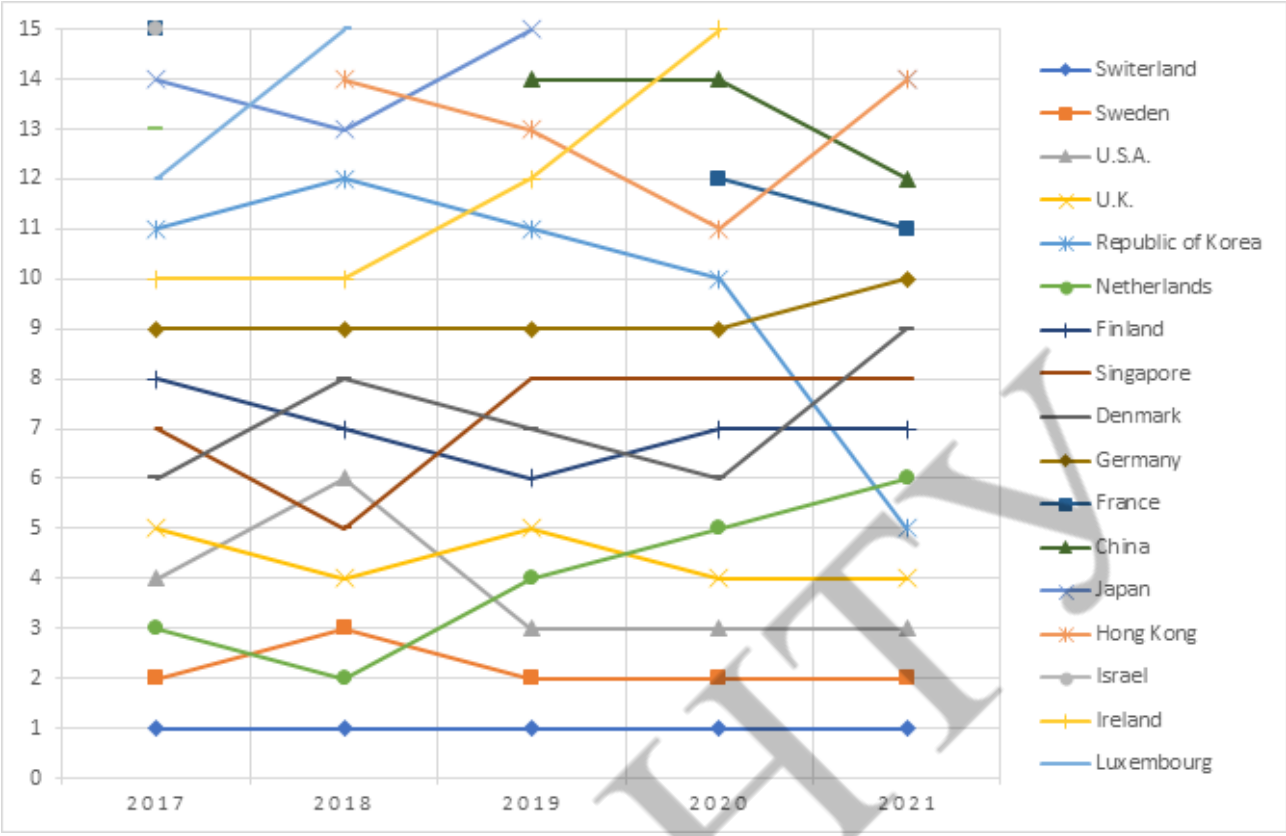


Figure 1. Movement in the GII top 15 positions, 2017–2021

Source: Elaborated by the author in accordance with the GII Database, WIPO 2021[3, p.22]

Even though the developed countries register a high GII over the years, they do not account for the highest number of IPRs applications. According to the statistical data provided by WIPO, the high-income countries in line with the World Bank Data (or developed countries according to HDI), is the second largest group in terms of applications for IPRs (see table 1).

Table 1. Total Applications by type of IPR at the world, high-income countries, upper-middle income countries level and China for years 2011, 2020.
Source: elaborate by the author in accordance to the World Bank Data and WIPO Statistics. [31] https://data.worldbank.org

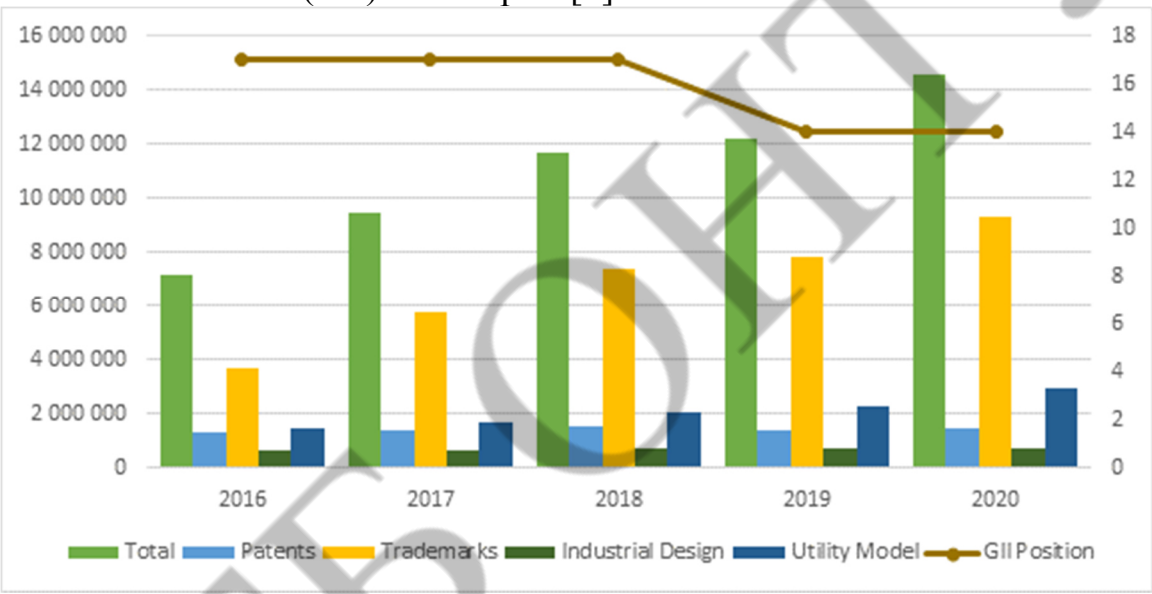
	2011				2020			
Type of IPR	**World**	**High-Income countries**	**Upper-middle income countries**	**China**	**World**	**High-Income countries**	**Upper-middle income countries**	**China**
Industrial design	1,089,600	441,300	609,600	521,468	1,387,800	465,100	861,400	770,362
Patent	2,158,200	1,410,800	655,800	526,412	3,276,700	1,552,800	1,617,100	1,497,159
Trademark	6,319,000	2,878,400	2,618,400	1,414,576	17,198,300	4,238,100	11,198,200	9,345,757
Utility Model	671,220	49,410	609,530	585,467	3,000,110	39,590	2,949,590	2,926,633

The highest number of applicants come from the group of upper-middle income countries, especially from China, being also the highest applicant for year 2020, and the one that determined the significantly evolution in a ten years' time period (e.g.,

China increased its patent applications by 184,4%, or utility models applications by 380,14%), (45.7% from the World Patent and Utility Models applications, 54.3% from the World Trademarks applications and 55.5% from the World Industrial Designs applications). As result, we can deduct that even though developed economies represent the group that dominate the knowledge-intensive flows, developing countries' share is growing rapidly, being represented by China, which knowledge-intensive flows are the world's second largest. [10] To correlate with the GII, beginning with year 2019, China registers a high raid growth in the number of application (see graph 1), (e.g., trademarks applications increased by 19,31% from 2019 to 2020, while from 2018 to 2019 increased only by 6.3%).

Graph 1. Correlation between GII and the number of IPR applications of China, 2016-2020

Source: elaborate by the author in accordance to the WIPO Database and the Global Innovation Index (GII) 2021 report [3].



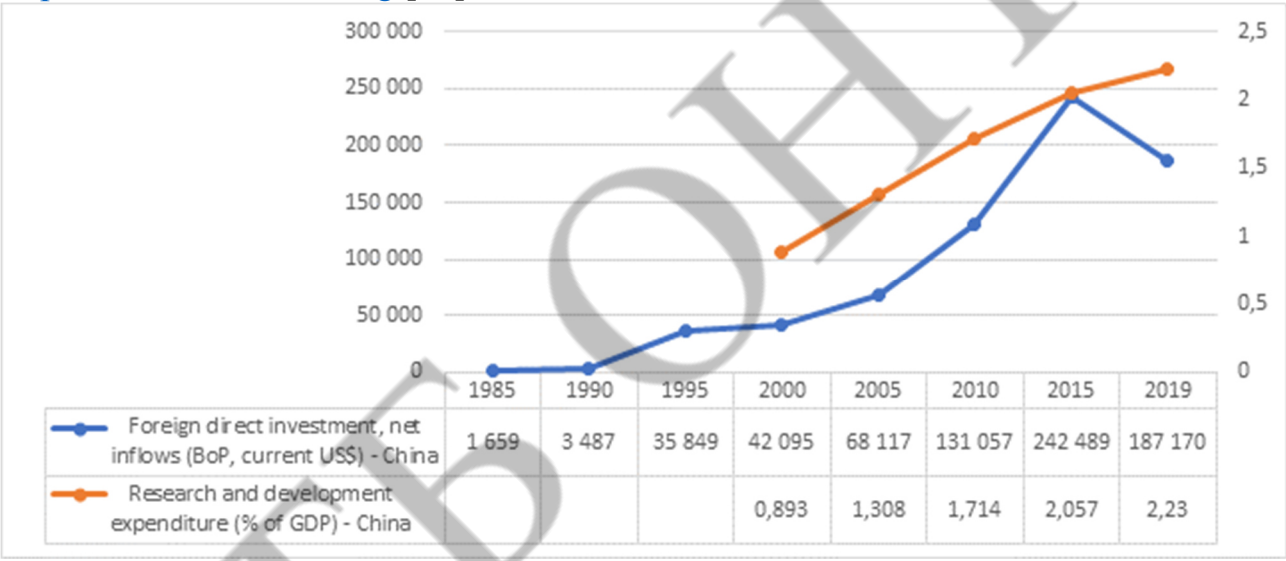
In order to gain the access to WTO, China enhanced the protection of IPRs by designing a number of strategies in 1996 APEC Individual Action Plan, including improve the enforcement of administration, enhance the public awareness of IPRs protection and strengthen judicial tools. [29] Finally, China has obtained the entry into the WTO in 2001, complying with the minimum standards of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs). The TRIPs require a number of countries to strengthen their patent and other intellectual property rights (IPR) systems. Even though policy makers have committed to significant reforms, the implementation of this agreement remains contentious.

The main benefit claimed for strong IPR protection is that by allowing innovators to appropriate a share of the benefits of their creative activities, R&D is encouraged, which leads to innovation and higher long-run growth. R&D expenditure is a measure of the input into innovative activity. Patent applications are a measure of the output, and patents are recognized as the most important form in which industrial innovation is protected [21]. As more and more Chinese firms develop their R&D capacity and obtain their own intellectual property, the general public's perception of intellectual property is likely to change and a greater domestically-driven push for

stronger intellectual property protection is expected increase. In this case, the ability to produce different and more high-tech products which obtained by R&D and innovation, are provided by Foreign Direct Investments (FDI), which have become more important. FDI, provides substantial financial capital, technological know-how and managerial expertise to the recipient economies (see Graph 2). According to the National Bureau of Statistics from China, the total public and private science and technology expenditures in 2019 rose 12.5% over the previous year to 2.21 trillion Chinese yuan ($322 billion). Spending on basic research accounted for 6% of the total; applied research, 11.3%; and development, 82.7%. The spending amounted to 2.23% of GDP, an increase of 0.09 percentage points from the previous year. And following the OECD's purchasing power parity comparison, in terms of absolute expenditures, China represents the world's second biggest spender on R&D [14].

Graph 2. Foreign direct investment, net inflows (BoP, current US$) and R&D expenditure (% of GDP) - China

Source: elaborated by the author based on the World Bank Data. https://data.worldbank.org [31]



In 2005 China only accounted for 0.8% of triadic patents (defined as a set of patents registered in various countries (i.e., patent offices) to protect the same invention) (i.e. triadic patent families are a set of patents filed at three of these major patent offices: the European Patent Office (EPO), the Japan Patent Office (JPO) and the United States Patent and Trademark Office (USPTO)), China set the goal to increase R&D spending to 2.5% of GDP and join the top five countries receiving triadic patents by 2015 [14]. However, beginning with year 2014, China aimed to strive the fourth position within the triadic patents, and maintaining it through a 5 years period until 2019, according to according to the 2021 Mapping Technology Structure report issued by the Institutes of Science and Development of the Chinese Academy of Sciences. In order to increase its position, China should focus on creating high-quality patents, representing one of the key challenges in striving the science and technology development, and simultaneously increase its number of triadic patents in chemistry and materials science, scientific fields in which China is traditionally strong.

To get ready for global competition, Chinese companies are also consciously building up their intellectual property portfolios. For example, in the automotive sector,

access to technology, brand names and other intellectual property assets appears to have been a main motivation for Chinese efforts to acquire foreign producers. This increased stakes in intellectual property are already contributing to a shift in the balance of domestic business perspectives on intellectual property.

The multi-dimensional nature of China's intellectual property environment has important policy implications. First, while the legal side of intellectual property protection has been increasingly formalized and centralized, regional variation – in particular local weakness in enforcement – remains to be addressed. Second, achieving an effective IPR regime will require reform extending beyond legal structures to include other complementary policies such as those needed to assure appropriate access to capital and talent. There are also risks of distortion or discrimination in the Government's strategic approach to innovation. Finally, redoubled education and awareness-building may be required to challenge social misperceptions with respect to the abuse of intellectual property. According to the Intellectual Property Rights Index, in 2021, China reported a score of 6.088 on a scale from 1 to 7 (see table 2). The index is analysed based on three variables:

$$IPRI = (LP+PPR+IPR)/3$$

IPRI- Intellectual Property Rights Index;
LP- Legal and Political environment;
PPR- Physical Property Rights;
IPR- Intellectual Property Rights.

Table 2. Intellectual Property Rights Index of China in 2011, 2015, 2021

Source: elaborated by the author based on data provided by the IPRI. https://www.internationalpropertyrightsindex.org

	2011	**2015**	**2021**
IPRI SCORES	5.500	5.389	6.088
LP SCORES	4.500	4.316	4.856
PPR SCORES	6.800	6.539	7.131
PPR SCORES	5.200	5.313	6.275

This evolution of China's IPR is due of two major turning point events. Firstly, the transition from a centrally planned economy to a market economy provided the strong impetus for the development and improvement of China's IPR system. Second, the openness of China's market for FDI and the increased success of Chinese products in the overseas market generated pressure for China's IPR system to accelerate its development to be in line with international standards [15].

China's drive to modernization through improving intellectual property protection has been pushed forward by constant efforts to improve formal intellectual property laws and institutions for acquiring, maintaining, and enforcing intellectual property rights. Chinese policymakers and government officials have worked diligently for over forty-five years in a consistent, unwavering drive to create and improve the country's public intellectual property institutions (the time period is taken into-consideration from 1973, when Premier Minister Zhou visited WIPO for the first time, also being considered the first time that the Chinese government allowed an officer to visit an international intellectual property institution [15]). It's for sure that both the management and enforcement of IPR in China will make a progress over time.

4.2 Technology transfer and Protection of Intellectual Property Rights in China

Technology transfer (TT) represents the process of transferring (disseminating) technology from the person or organization that owns or holds it to another person or organization, in an attempt to transform inventions and scientific outcomes into new products and services that benefit society. [2] It is thought as a channel of spreading in the norms of law, the technical progress and the evolution of innovative products, seen as factors which stimulate the economic growth for the high-income and countries, considered to be more technological advanced. From this type of countries, the developing ones acquire such advanced technology, with the intent to increase the economy and register in a long-term technological progress.

China and U.S. represent an adequate example to describe the model presented in the literature, "South-North". Chinese companies—in many cases with the backing of the Chinese government—use a variety of methods (see table 3) to acquire valuable technology, intellectual property (IP), and knowhow from U.S. firms. Generally, China invests in the critical future technologies that will be foundational for future innovations both for commercial and military applications: artificial intelligence, robotics, autonomous vehicles, augmented and virtual reality, financial technology and gene editing. [16]

Table 3. Methods of facilitating Technology Transfer by the Chinese companies from the United States

Source: U.S.- China Economic and Security Review Commission, May 2019. [1, p.3]

	Description
Foreign Direct Investment (FDI)	The Chinese government directs Chinese firms to invest in and acquire U.S. companies and assets in order to obtain cutting-edge technologies and IP, fostering technology transfer in strategic industries.
Venture Capital (VC) Investment	Chinese VC investments in the United States have increased in recent years, in particular targeting U.S. technology start-ups. Although the trends and implications of Chinese VC investment in the United States are new and still underexamined, they may allow Chinese firms to access valuable U.S. technology and IP, including technologies with potential dual-use applications.
Joint Ventures (JVs)	In many industries, foreign firms must enter into JVs to invest or operate in China. JVs are often the source of Chinese companies' most technologically advanced and innovative procedures and products, acquired through technology transfer from their foreign JV partner.
Licensing Agreements	Licensing approval processes in China are often unclear and arduous, requiring companies to disclose sensitive information typically not required in other markets. Chinese government agencies often do not have to agree to destroy company information submitted in the licensing process, so companies' IP can be shared or exposed even after the license is adjudicated.
Cyber Espionage	Through covert cyber intrusions, Chinese actors gain unauthorized access to a wide range of commercially valuable U.S. business information—including IP, trade secrets, technical data, negotiating positions, and sensitive and proprietary internal communications—which are then provided to and utilized by select Chinese firms.
Talent Acquisitions	The Chinese government maintains government programs aimed at recruiting overseas Chinese and foreign experts and entrepreneurs in

	strategic sectors to teach and work in China. Moreover, Beijing utilizes intergovernmental and academic partnerships and collaborations in the United States, establishes Chinese research facilities in the United States, and sends experts abroad to gain access to cutting-edge research and equipment without disclosing the organizations or individual's connections to the Chinese government.

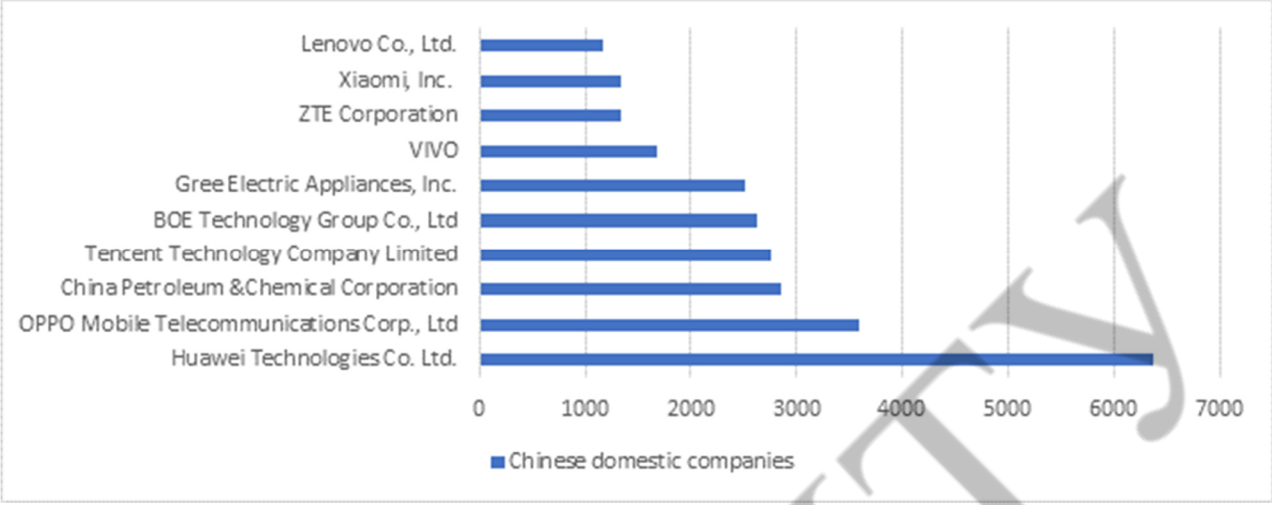
Licensing is the best-known approach in transferring patented technologies. Because of the dominant positions of multinationals in controlling core technologies, domestic Chinese companies are price takers in patent licensing negotiations. According to the American Chamber of Commerce in China's 2019 business survey, 35 percent of survey respondents cited licensing requirements as a top challenge of operating in China [7]. Similarly, the U.S.-China Business Council has found that more than half of U.S. companies experience licensing challenges even during renewal processes in China, and report facing challenges obtaining licenses that their domestic competitors do not [28]. Chinese data protection and security laws also allow the e Chinese Communist Party (CCP) to acquire U.S. IP and technology through localization requirements for foreign technology firms. For instance, China's new Cybersecurity Law, which entered into force in June 2017, requires data to be stored locally in China, forcing foreign companies to either invest in new China based data servers subject to government spot checks, or hire a local server provider such as Huawei, Tencent, or Alibaba [8]. The Chinese government has utilized coordinated, government-backed cyber espionage campaigns to steal information from a variety of U.S.-based commercial firms, including those in the oil and energy, steel, and aviation industries [18]. According to James Lewis, a senior vice president at the Center for U.S.-China Economic and Security Review Commission 9 Strategic and International Studies, over the past two decades Chinese cyber espionage has likely cost the U.S. economy between $20 billion and $30 billion annually [9]. The Chinese government maintains official programs aimed at recruiting overseas Chinese and foreign experts and entrepreneurs in strategic sectors to come teach and work in China. These programs seek to acquire U.S. technology by blurring the line between informal technology transfer and IP theft, using methods such as utilizing open-source intelligence, recruiting leading U.S. experts in high-tech fields, and promoting academic exchanges [11].

Corresponding to the China National Intellectual Property Administration (CNIPA) 2020 Annual Report the number of invention patent applications filed in China in 2020 year increased by 6.9%. Among them, there were 1.345 million domestic invention patent applications filed (see graph 3), accounting for 89.8% of the total, a year-on-year increase of 8.1%; there were 152,000 foreign invention patent applications filed (see graph 4) in China, accounting for 10.2% of the total, a year-on-year decrease of 3.0%.

The Chinese IP law enforcement authorities have been taking aggressive actions against IP infringements. All of these efforts have resulted in enhancing IP protection in China, helping the IPR right holders to build a stronger IP-based moat for their businesses and creating a competition environment friendly to the IP right holders.

Graph 3. The top 10 Chinese invention patentees in 2020 and the number of invention patent grants

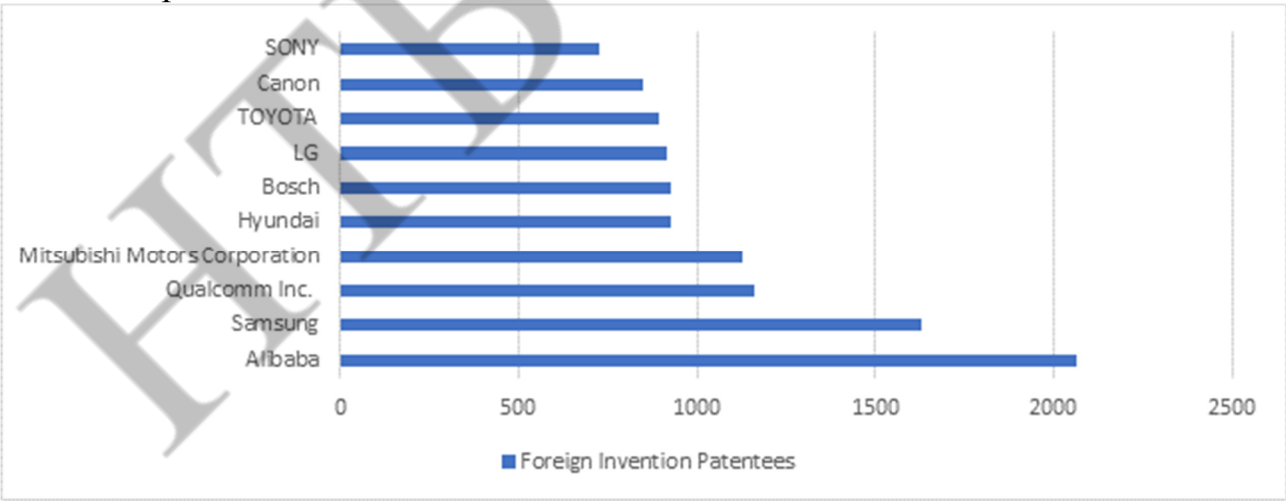
Source: China National Intellectual Property Administration (CNIPA) 2020 Annual Report



In 2020, a total of 3,470 civil IP litigations were docketed and 3,260 lawsuits were concluded by the Supreme People's Court, respectively 38.58% and 64.98% higher than the cases in 2019. In 2020, the local courts across China docketed 443,326 civil IP litigations of first instance and concluded 442,722 lawsuits, respectively 11,1% and 12.22 higher than the previous year. Through strengthening the IP laws, China increased its IP litigations (e.g., patent litigation increased from 2019 by 28.09% registering 28,528 Patents litigations). [4]

Graph 4. Top 10 Foreign Invention Patentees in 2020 and the number of invention patent grants.

Source: China National Intellectual Property Administration (CNIPA) 2020 Annual Report



Despite all the litigation that registers China, the country still registers foreign patentees, as can be seen from the graph 4. The main foreign applicants are Japan and USA, with a total application of IPRs of 53.368 and respectively 43.589 applications in 2020. China tends to emphasize the importance of promoting the domestic inventions by maintaining strong IPR protection within the borders, by registering less foreign patentees than domestic ones. From the top 10 foreign invention patentee in

2020, only one American company (Qualcomm Inc.) has managed to gain a position, the others being taken by South Korean, Japanese and German companies.

The recent developments of IPR protection are bound to drive innovation and create a pro-business environment and help the IPR holders to rely on IPR to protect their economic castles and ensure competitive advantages and continued growth in the market. Looking at the general market overview, technology transfer had a direct impact in 2021 on contributing to global public health issues, by enabling global access to COVID-19 vaccines. [32] During 2021, vaccine developers concluded over 200 technology transfer agreements. One example was AstraZeneca concluding the licensing and technology transfer agreements on AstraZeneca with the Serum Institute of India and with Daiichi Sankyo of Japan to supply vaccines for COVID-19, which were developed in collaboration with the University of Oxford. [30] Within this process Intellectual Property was part of the solution and an important tool for facilitation of affordable global access to COVID 19 treatments – as it was the case in two licensing agreements between Medicines Patent Pool (MPP) and pharmaceutical companies Merck and Pfizer.

V. CONCLUSION

Being creative and innovative in the 21st century is the biggest challenge, but putting your product on the market can be considered a competition. In this context, intellectual property is the safest way to present and sell ideas and products on the national and international market, giving the opportunity to hold a copyright without the possibility of being plagiarized. Through intellectual property rights and the law that promotes them, the economic development of countries is ensured.

According to Ricardo's model, developed countries are a primary and innovative source for developing ones. However, according to the analysis, developing countries get the most applications for all kinds of intellectual property rights over the years, and China represents the main applicant. Following to the research, China is a fairly competitive developing economy in the international market with regard to the IPR and technology transfer. It registered an impressive growth in the GII, determined by the high number of IPRs application within one year period, by achieving an increase of 19,03% of the total application in 2020. Even though it does not represent the highest increasing, there should be taken into consideration the other factors that influenced the GII position changing, such FDI inflows and R&D expenditure in the year 2020, representing real mechanism in fostering the innovation development and improvement.

The relation of China and U.S. in terms of IPR and technology transfer are very specific, in the case it is take into consideration the conflict that started in 2016, resulted in the expression of mutual dissatisfaction of the parties involved, where the Trump administration alleges that China practices unfair trade with the U.S, pointing to the growing trade deficit in China's favour, the theft of intellectual property, and the forced transfer of technology to China. However, they still represent for each other one the major trading partners in terms of technology transfer of IPRs. In the case of China, U.S. representing the second larger applicant as a foreign country after Japan.

In the context of techology transfer, China is still promotig the domestic inovation, by registering a higher number of applicants than foreign ones.The main

characteristic of the Chinese IPRs, is that they strive to focus on critical future innovation, those that are innovative and essential for the future population, despite that for the presents seems to look ambiguous.

To sum up, the research presented the impact and importance of intellectual property rights and technology transfer in the developing countries and how they affect the economic growth, based on the China case study.

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DIGITAL MODEL OF BLOCKCHAIN ECONOMY AND ITS IMPACT ON VARIOUS AREAS

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Abstract. *The constant development of competition in the market and the sharp differentiation of the needs of the population pushes global and domestic companies to find solutions to meet the desires of customers, make a profit and protect their own interests. It is these conditions that have led to the development of cryptocurrencies and the growing share of e-business algorithms that were used only in narrow areas, have become widely used and now perform the functions necessary for the stable development of enterprises. This is the most well-known and most profitable blockchain technology, which in recent years has proven its effectiveness by increasing the profits of companies that use it. This technology can significantly reduce the costs of companies, especially those that are participants in the stock market, and provides high stability and consolidation of market positions. It can reduce data processing resources and increase information flows. The article analyzes the advantages and disadvantages of this technology, its prospects and ways of development. With the help of clustering methods, global companies were distributed according to the amount of profit in terms of blockchain use, based on which it is possible to make initial conclusions about the effectiveness of technology for implementation not only by global companies but also domestic ones. . As a result, the introduction of this technology will allow companies to assess the risks of information loss, minimize them and develop algorithms that will be most effective in each case. This will lead to the construction of a high-quality customer-oriented approach, which can significantly increase revenue, affect the number of users and their level of satisfaction. Thus, blockchain technology can be recommended for use by Ukrainian companies to increase their productivity and innovate with minimal losses.*

Keywords: *blockchain, clustering, stock market, profit, profitability of companies.*

I. INTRODUCTION

Globalization of the economy, intellectualization of labor, development and dissemination of information and telecommunications technologies have led to the virtualization of economic relations and the emergence of virtual economy, a new concept of economic relations based on information technology and network systems aimed at producing intangible goods, information and knowledge in public administration is significantly transformed. The relevance of research on the use of blockchain technology in public administration is due to the institutional problems faced by society in the development of the information economy. These are, first of all, problems of trust, high costs of maintaining state registers and managing large amounts of information, risks of information attacks and the possibility of damage or loss of data due to various circumstances, including fraud, theft or unauthorized use of

registers. Issues of introduction of blockchain technologies in the field of public administration, business structures are widely discussed among politicians, lawyers, specialists in the field of information and telecommunications technologies, public administration.

Blockchain technology allows to solve the above problems in an optimal way, minimize the costs of participants in electronic interaction, opens new opportunities in the creation and management of electronic registers and their promotion in a network economy. Blockchain technology can be implemented to solve the problems of information management, in particular for maintaining public registers, in such areas as: banking, finance, office work, medicine and more.

In 2017, the World Economic Forum recognized blockchain technology as one of the most promising. In our opinion, blockchain technology is the most important modern technology that will ensure an innovative breakthrough and great progress of society in the coming decades in the field of Big Data, innovative technologies and public administration.

II. LITERATURE ANALYSIS

1. What is blockchain technology

A blockchain is a distributed database that contains information about all transactions made by system members. The information is stored in the form of a chain of blocks. Each of them records a certain number of transactions.

The blockchain analogy is a necklace. Each bead is a "block" or action record. This necklace - or "chain" - cannot be destroyed or destroyed. Thus, the blockchain is an indestructible digital record of actions. The reliability of this system has made it possible to use it to increase the efficiency of monetary transactions and the exchange of information among individuals, corporations and even the public sector.[1]

Consider in more detail.

Blockchain technology was created by Satoshi Nakomato in 2008. Since it emerged in 2008 (Nakamoto, 2008), there have been several definitions for blockchain: a distributed accounting technology (Denny et al., 2017), a distributed database (Ferreira et al., 2017), distributed records (Wu & Tran, 2018) or a distributed ledger technology (DLT; Ølnes et al., 2017). Regardless of the definition, all approaches agree that decentralization is one of the benefits that grants this technology highly transformative power in several business models (Diniz, 2017) [2]. The basic principles of this P2P system (Peer-to-Peer system) are described in his work "Bitcoin: P2P electronic cash system". Blockchain is a mechanism that provides a high degree of accounting and identification of information, allows you to distribute this information among users of the network, while working with it to multiple users, recording the time of each transaction. Blockchain technology helps to eliminate the omission of transactions due to errors of people or technology, it is not possible to make changes to the register of transactions. Blockchain technology is the first digital medium for peer-to-peer exchange, based on a targeted protocol of globally distributed computing and encryption without the involvement of a third party - a trustee. Blockchain is a register of transactions, accounts, databases, etc. based on the agreement (SMART CONTRACT) and the target protocol.[3]

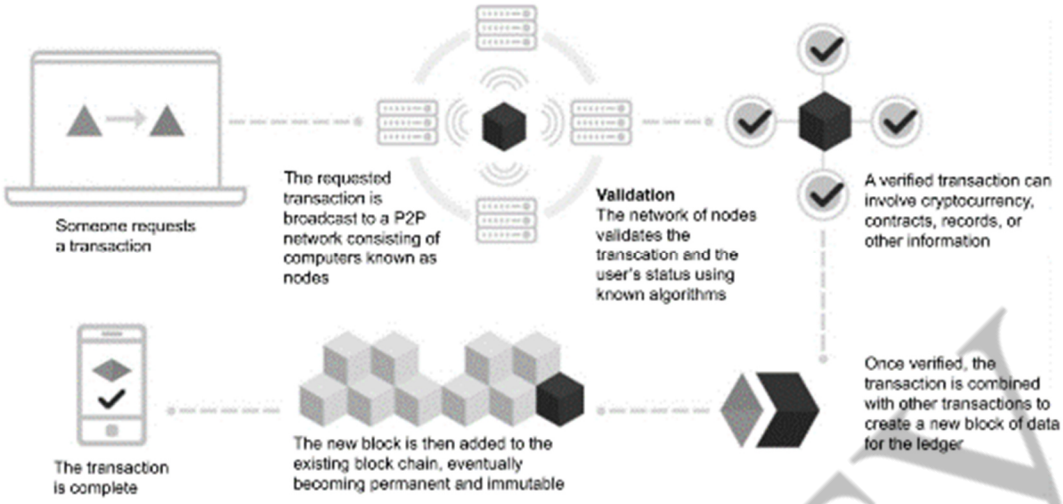

Fig.1: Blockchain illustration

At the figure 1 we can see how goes the process of forming blockchain.

Blockchain is seen as a technology that involves creating long lists of sequential data. Each component of the system remembers the previous one, and making unauthorized changes is immediately blocked. Not one centralized server is used to create encryption, but the computing power of all participants in the process. Any user of a system built on Blockchain can also own it. Blockchain should be seen as the accounting and exchange of ownership of digital assets in a peer-to-peer network that contains structured data in the form of a distributed registry. The main difference between Blockchain and traditional registries is the simultaneous storage of data that is distributed among a number of network nodes without being tied to a specific location. Some authors suggest that Blockchain technology should be seen as a multifunctional and multilevel information technology designed for distributed storage of records of all transactions, which is a more accurate definition. It is a chronological database in which the time at which the record was made is inextricably linked to the data itself, making it non-commutative. All transactions are performed with a cryptographic protocol. The information included in the chain of blocks cannot be changed ex post facto. Based on the above, it can be argued that the essence of Blockchain technology can be described as follows - these are digital records combined into blocks, which are based on an algorithm connected by a "chain" to each other according to the operations performed. The process of encrypting the write process into blocks, known as hashing, is performed by different computers running on the same network. If all computers on the network get the same result as a result of the calculations, the block is assigned a unique digital signature, which cannot be forged. This block can change only as a result of adding new records (performing new operations).[4] In this case, the register of information in the blocks is updated on all computers on the network at the same time. That is, this approach can significantly reduce the risk of hacking, because in this case the thief will have access and key codes to the entire computer network at once.

There are the following types of blockchain:

1) Public blockchain - Blockchain without restrictions, ie there are no restrictions on the formation, reading and conduct of transactions when creating, enabling and using Blockchain technology (creating a single network between the company and all contractors of the company);

2) Private blockchain - Blockchain technology is used by a narrow circle of users (for example, in the middle of the enterprise);

3) Permissionless blockchain - Blockchain technology is used by everyone, ie there are no restrictions on the identity of data processors and transactions;

4) Permissioned blockchain - Blockchain technology is used to create a system in which transaction processing is carried out among clearly defined entities, ie the range of users is limited.[5]

In addition, it should be noted that the use of Blockchain technology is possible with a number of requirements that help prevent risks.

1) reliability and relevance of data entry. Reliability, relevance, accuracy, efficiency of data entry allows management to respond more quickly to the economic situation, so creating an effective organizational and legal mechanism for reliable, efficient data entry in the registers is a priority when using Blockchain technology;

2) control of access to the Blockchain system and user identification. To ensure control over data entry and changes when using Blockchain technology, you need to create a mechanism for managing access rights (individual user identification) both to the system as a whole and to individual records. The system of individual identification of users can be created on the basis of biometrics of personal parameters;

3) database synchronization. Creating conditions under which the performance of a particular operation at any time on any of the nodes produces the same result;

4) control over system administrators and reliability of interfaces. Ensuring the maintenance of reliable information, preventing illegal modification of records in the database encourages constant monitoring of administrative staff and information entry. Therefore, when using Blockchain technology, the function of performing external control over the integrity and reliability of data entered into the system is entrusted to different network users. In this case, when the administrator tries to change the data located on the server, it will be impossible to falsify the dissemination of information on all network nodes in the process of changing the checksum of the chain of operations, thus forming the integrity of the registry. However, in order to exclude the possibility of forging the server's response to erroneous requests and distortions of information, this response must be protected by a digital signature of the server.

2. Advantages and disadvantages and impact of using blockchain technology

It is interesting to further analyze the scope of blockchain technology. Experts identify several areas of application of blockchain technology, which should be considered in more detail. First of all, this is the financial and banking sector, for which most blockchain applications are currently being developed. The list of technological solutions based on blockchain technology that can revolutionize the financial system is quite wide. These are interbank settlements, settlements between legal entities and individuals, insurance. Worldwide, the financial services market is the largest sector of the economy by market capitalization, with the global financial system abounding in

inefficient processes such as cash transactions, asymmetric information, and vulnerable centralized systems that ultimately increase costs and delays for consumers. It is known that every year 45% of financial intermediaries suffer from fraud, such as payment networks of stock exchanges. If blockchain technology replaces only a small part of such transactions, as well as peer-to-peer transactions in other sectors, it can dramatically increase the efficiency of the financial sector. Not surprisingly, IBM, Microsoft and other blockchain developers who have announced the provision of services based on this technology, mainly focus their efforts on the financial sector. It is worth mentioning that the experts of the European Bank Santander estimated the potential savings from the introduction of blockchain technology at 15-20 billion dollars. in a year . The capabilities of blockchain and cryptocurrencies are being studied and tested by many central banks, including in Canada, Singapore and the United Kingdom, and although this technology can pose a serious threat to this area, it can maximize the benefits.[6]

Micropayments are one of the most promising areas of blockchain use. For example, until recently, payments of a few cents were too heavy for Internet users. Developing appropriate blockchain proposals will make such payments possible and practical. This will allow you to effectively monetize social networks, as well as make them an alternative way to pay for small work, such as filling out questionnaires or freelance editing for different clients. Financial market analysts also believe that micropayments can be a very profitable and promising project in the business world. For example, the financial company Wedbush Securities forecasts a bitcoin micro-payment market of $ 925 billion. until 2025. Smart contracts are one of the applications of blockchain technology that is of the greatest interest. A smart contract is an agreement between two parties that is stored in a blockchain. Such agreements can be made between two people, in other words, peer-to-peer, person and organization, or between person and machine. Smart contracts allow you to automate payments and transfers of currency or other assets under agreed conditions. As soon as this condition is fulfilled in the smart contract (sale of goods A on the exchange B), the contract is executed automatically and assets (money, digital currency, property rights, securities) are exchanged between the contracting parties. Subsequently, the transaction is accepted and checked on the blockchain. Smart contracts allow you to exchange an asset, even if third parties are unaware of its transfer. This opens the possibility to disintegrate the entire legal system and create a new form of virtual agreements. In practice, however, being only fragments of code that automatically execute them when the specified conditions are met, smart contracts cannot currently be considered as ordinary contracts from a legal point of view. Nevertheless, they can be used as evidence of a problem, so many areas are exploring the potential of such contracts.

However, it should be noted that experts see even greater use of smart contracts only in the long run, because, despite some attempts to implement them, this technology is in the experimental stage and is not yet ripe for the emergence of primary market products.

There are many research organizations, such as the Scanergy project in Belgium, which are based on the blockchain system and monitor the use of electricity and supply it to the grid. In addition, the cryptocurrency NRGcoin is offered for settlements with

domestic electricity producers when supplying electricity to the grid. Therefore, among the areas of use of blockchain technology that have already emerged today: government agencies, defense and security agencies, international organizations, including the insurance industry. Yes, insurance problems related to excessive centralization, non-transparency and money laundering can be solved today thanks to this technology. Of course, the biggest problem of today's insurance sector is the situation with the return of funds for the insured event. The procedure is so bureaucratic that it is sometimes difficult for an ordinary person to figure out why. The issue of insurance is more important in Ukraine today than ever, it is associated with the reform of many industries, even the introduction of insurance medicine requires comprehensive changes in the insurance industry. Of course, this will revive the development of insurance, but a common system is needed, where the relations between the participants can be tracked and which cannot be unilaterally administered and edited. The availability of such information will facilitate faster decision-making on insurance, and its absence, especially in the context of Ukrainian corruption, non-binding legislation, the possibility of non-performance or delay in fulfilling obligations under the contract, led to business forced to suspend active operations. appetites for risks. Everyone in general suffered from this - the country, the economy. A common and decentralized system will improve the business and investment climate and the conditions for more active insurance. There is great potential for blockchains, and insurance companies should be primarily interested in their implementation, pushing the legislature.[7]

Having such a register on the blockchain would prevent corruption and data censorship, which in turn would make the credit mechanism transparent, understandable and attractive. Note that the most popular area of application of this technology - money transfers based on bitcoin and cryptocurrency in general. Bitcoin is even more popular than the blockchain technology on which it is based, and it is the emergence of which has shown the potential of this distributed registry technology and identified its other practical applications. Yes, the Bitcoin startup Circle, while no longer allowing users to buy and sell cryptocurrencies directly, is creating a protocol that will allow digital wallets to share values through a blockchain. The first IT company in Ukraine to develop based on blockchain technology presented a working model based on flight delay insurance at the Hackathon in 2017. In this model, when buying a ticket, the insurance payment was paid, which was kept in the Escrow agent's account, and the funds were not available to the insurance company until the end of the insured event. The smart contract specified the site-provider of flight data. In case of non-departure of the flight at the specified hour, the client automatically receives funds at his own expense at the same time. The model caused a stir, and at this stage negotiations are underway with Privat Group on the possibility of its implementation. We highlighted the benefits of blockchain technology for business in table 1.

However, the blockchain is not perfect. And it has some obvious shortcomings, especially in terms of mass introduction of technology. To use it, financial institutions, in fact, must abandon their current networks and start all over again. Trying to integrate current payment networks into a blockchain can be so challenging that no one will even try to go that route.

Table 1. Benefits of blockchain technology for business

Transparency	In a blockchain, a complete history of transactions is permanently maintained and simultaneously available to all network users. All users involved in a transaction are aware of any actions taken on any data or transactions executed, thus promoting increased transparency.
Business Continuity	The availability and continuity of services provided is a crucial requirement for all businesses. The absence of a vulnerable single failure point in the blockchain technology means the system is never down, despite some parts' failure, thus supporting business continuity.
Disintermediation	Blockchain infrastructure's being truly decentralized enables a significant level of disintermediation. Technology protocols and elements can replace intermediaries, enhancing efficiency, and reducing friction-related direct and indirect costs between individuals and organizations, due to decreased trust.
Trust	The blockchain mechanism's underlying concept is the establishment of a trustworthy record between untrusted parties. The good design of blockchain-embedded protocols and cryptography property enforce trust and ease its verification.
Smart Contracts	Some functionality can be added to ledgers, as most blockchain applications provide some scripting languages. For instance, a rudimentary stack-based language is contained in bitcoin, whereas a language similar to JavaScript, a Turing complete imperative language, is provided by Ethereum. These programs, so-called smart contracts, are computer codes/software designed to digitally facilitate, verify, and enforce the business logic's negotiation or performance. Smart contracts are selfexecuted and automate the execution of credible transactions and actions (e.g., exchange of property, money, shares, or anything that has a value), without a middleman, as the terms of agreements are fulfilled. Smart contracts can be utilized in traditional systems, but data integrity and data availability to all parties make blockchain the right technology platform to leverage smart contracts

It is also still unclear whether the blockchain will be able to survive outside the cryptocurrency ecosystem and scale to handle a large number of transactions.

Another disadvantage of the blockchain is its high energy dependence, which makes it an expensive technology. Blockchain differentiation is also a concern. There are currently more than 1,400 digital coins, many of which have their own versions of the blockchain. It is unclear which of them will be able to survive and develop in the future, which of them will prefer to use developers and large companies, and which will disappear.[7]

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Object of the research: the stock market where blockchain technology has become entrenched, among American companies.

Blockchain technology allow companies to do without the services of clearing houses, which greatly simplifies the work of the exchange and significantly affects the profitability of shares, as it reduces costs and strengthens the company's market

position. So, let's compare the profitability of companies that use blockchain technology and those that do not yet use these technologies.

Subject of the research: we use data on the activities of the 10 largest companies in the US stock market and examine their average profitability over five years to analyze the dynamics of their development.

So, the first company to use blockchain in the organization of its activities - Amazon. A retail company that is known worldwide for selling mass-produced goods on the Internet. This company was one of the first in the world to implement the blockchain. Yes, this company not only uses this technology in its work, but also is a provider of its own developments for the interpretation of the blockchain in other companies.

Facebook is the company with the largest social network of the same name, which is popular all over the world. This company uses the blockchain to protect its users, as well as for effective promotional activities.

Nestle is a Swiss food company. The company, which uses the blockchain to study the desires of customers, analyzes their individual needs and adjusts production to each region, which significantly increases profits.

Oracle is an American company that is the largest software developer in the world. This company uses blockchain algorithms to develop its own databases, which increases the competitive advantage of their product.

Visa is the world's largest payment system. The company's cards are accepted in more than 150 countries, it is engaged in the development of innovative payment products and technologies. Blockade technology helps reduce the number of cybercrimes and protects customers, as well as enables payments around the world, which, in turn, brings additional income. These companies have been using blockchain technology since 2017 and, according to statistics, their revenue has been growing steadily since this year.

Adobe is a software company, NIKE is an American company that specializes in sports shoes and clothing, Walt Disney is the world's most famous entertainment corporation, and the company is valued at more than $ 130 billion every year. .

Goldman Sachs is one of the largest and most famous investment companies in the world. The company's profits have been rising, but stock prices have been falling in recent days due to the global economy.

McDonald’s is an American corporation and one of the most famous chains of catering establishments, whose profits fluctuate according to the world economic situation.

These companies have been using blockchain technology since 2017 and, according to statistics, their income has been growing steadily since this year, while other companies are still in the process of getting acquainted with the blockchain.

Therefore, the income of companies for five years is given in table. 2.

The use of blockchain technology is directly related to the profitability of companies, as the cost of using databases and maintaining them significantly affects the profits of companies. Let’s explore the relationship between company profitability and the use of technology using clustering techniques.

Table 2. Average annual income of companies, UAH billion

Company	2015	2016	2017	2018	2019
Amazon	107	136	178	233	281
Facebook	179	276	406	558	707
Nestle	88	89	89	91	93
Oracle	88	89	90	91	92
Visa	14	15	18	21	23
Adobe	4,7	5,8	7,2	8,8	11,1
Walt Disney	5,2	5,5	5,5	5,9	6,9
NIKE	3	3,2	3,4	3,6	3,9
Goldman Sachs	3,7	3,6	4,2	4,9	5,6
McDonald's	2,6	2,5	2,2	2,1	2,1

Method which we will use for research is clusterization, whith using a special software application that provides a variety of analysis methods.

Clustering is a method of dividing objects into groups, provided that all objects in the cluster have similar characteristics, and each cluster is as different as possible from the other. We implement this method using Statgraphics Centurion - a software application that provides a variety of analysis methods. The information base for the study will be the average annual profitability of companies for five years, from 2015 to 2019.

To analyze the data, use the method of the nearest neighbor.

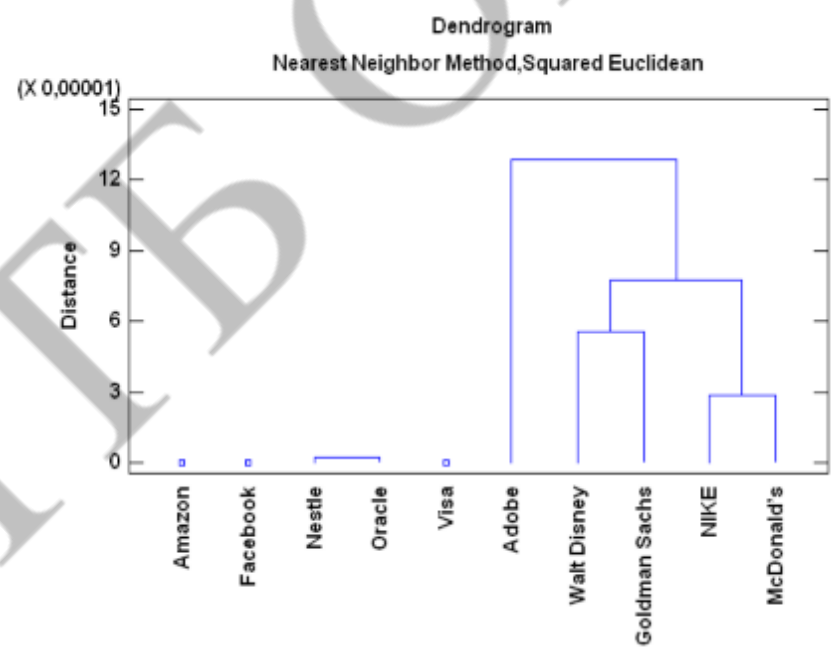

Fig.2 Dendrogram "Nearest Neighbor Method"

As we can see, out of 10 companies, five clusters have been formed for uniform and logical distribution, which allows to display all features of profit distribution. This method is based on measuring the distance using the Euclidean distance square, which allows you to calculate the minimum distance in clusters, taking into account various emissions and noise.

IV. RESULTS

The generalized division of companies into clusters is given in table. 3

Table.3 Clusters of companies formed on the basis of their profitability

Number	Name of the company
1	Amazon
2	Facebook
3	Nestle, Oracle
4	Visa
5	Adobe, Walt Disney, NIKE, Goldman Sachs, McDonald's

Thus, the first cluster included Amazon, which has the largest profit among selected companies. The company quickly mobilized its own resources to use blockchain algorithms to develop and sell its own technologies, which now brings it significant profits. The second, third and fourth clusters included companies with gradually declining profits. Of course, this is not just about using these technologies, as the economic situation in the world is not stable, and the popularity of food companies and their income may fluctuate throughout the year, as young brands are also gaining momentum. The last cluster included five companies that do not use blockchain technology. These companies are quite competitive and have a stable position in the market, but the lack of introduction of advanced technologies does not allow to make higher profits. Yes, Goldman Sachs can use these algorithms to protect investors' investments, to forecast the investment market and to take into account possible risks. And transparency in the direction of investment would significantly increase confidence in the company. The example of Nestle shows that cultural differences and individual preferences play an important role in the development of our own product related to the nutrition of citizens, which allows us to collect and turn blockchain technology into new income.

V. CONCLUSIONS

A blockchain is a distributed database that contains information about all transactions made by system members. The information is stored in the form of a chain of blocks. Each of them records a certain number of transactions.

The introduction of a blockchain increases the speed of exchange, reduces time costs, improves the quality, reliability and availability of services. At the same time transparency and reliability increase, risks decrease. Blockchain projects are used in the banking sector, financial services, payment services, public sector (public services, real estate registers, notary, electronic voting, etc.), transport and logistics, IoT, healthcare, intellectual property management, energy, etc.

Among the advantages of blockchain technology are:

- security and two-level identification of users with private and public keys, as well as digital signatures;
- successive chains prevent unauthorized change of information;

- with the help of high-level programming languages allows you to create business logic that helps in making management decisions.

The disadvantages of this technology are the lack of a single regulatory framework governing the use of this technology. This means that the level of trust of technology users is much lower. The big disadvantage for small companies is the high energy consumption of this technology, and although over time all costs are covered, the initial stages of use are quite expensive.

Analyzing all of the above, we can say that the blockchain is a revolution, as opposed to just evolutionary innovations. Distributed registry technology generally undermines the hierarchy by allowing you to work in a distributed network without intermediaries, using the consensus of participants instead of control. Effective cash management is perhaps the most important role of government institutions. Therefore, it should be understood that in the near future the world's financial institutions will not give full control of the protocol, and therefore systems based on blockchain technology, because a single standard requires more time, must be compatible with many areas of financial activities (insurance, banking, etc. further).

Many companies are becoming users of cloud blockchain technologies, which allows them to make quite high profits and explore a new niche in the market. Clustering has shown that companies with implemented blockchain technology have a high level of profitability and can be more stable in the market in the current or potential crisis. Ukrainian companies should use the experience of foreign companies and develop in this direction, which will significantly improve the quality of the company's work and eliminate high risks of information loss, especially in the field of security.

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AQUACULTURE – A FIELD OF THE FUTURE: NATIONAL PROPERTY, WORLD TRENDS OF DEVELOPMENT

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Annotation. The paper considers aquaculture as the fastest growing livestock sector. Aquaculture in Ukraine is the third most important source of animal protein after livestock and poultry. In addition, the development of aquaculture makes a significant contribution to the employment of the rural population and the population of coastal areas.

Aquaculture in Ukraine as a whole is developing similarly for the whole of Central Europe as a whole: stagnation, and sometimes a decline in the production of marketable products, the main in the recent past in terms of aquaculture facilities.

The development of small and medium-sized enterprises in the field of industrial fishing and fish farming is associated with the predominance of small and medium-sized enterprises in the fisheries sector. The paper characterizes aquaculture as a type of entrepreneurial activity, outlines the role of small business in the development of aquaculture.

The study identified risk factors as groups of threats that hinder the development of the fisheries complex (external and internal), and systematized the risks that limit the development of enterprises in this sector.

Keywords: aquaculture, small, medium enterprise entrepreneurship, agriculture, fisheries sector, risks

I. INTRODUCTION

The world experience of countries shows that small and medium-sized businesses play an important role in the economy. It is the driving force behind development, a criterion of dynamism, openness, equalizing the chances of all social groups and strata of the population in the struggle for well-being. At the same time, small businesses are characterized by: relatively low profitability combined with high labor intensity, the difficulty of introducing new technologies and equipment, due to limited own resources, and increased risk in intense competition.

The fishery sector of Ukraine is a multifunctional complex of the economy, including a wide range of activities from the study and forecasting of the raw material base, the extraction and processing of aquatic biological resources to the organization of trade in fish products, providing employment in related sectors of the country's economy.

The development of small and medium-sized businesses in the field of industrial fishing and fish farming is associated with the predominance of small and medium-sized enterprises in the fisheries sector. Over the past fifteen years, the reform of the fishery sector in Ukraine has led to a halving of the fish catch.

Currently, small and medium-sized businesses in the fisheries sector are experiencing significant difficulties that impede its effective development, in particular: the COVID-19 pandemic, lack of credit resources, low liquidity of assets, which are typical for the country's economy today. The measures currently taken by the state have not fully resolved the accumulated systemic problems facing small and medium-sized businesses in the country's fisheries sector. In this regard, the issues of improving the tools for supporting small businesses and attracting small businesses to aquaculture become topical.

Recently, aquaculture has been one of the fastest growing sectors of food production and is increasingly becoming an important industry that contributes to the food supply of the population.

In Ukraine, there are all opportunities for obtaining social, economic and environmental benefits from the development of aquaculture. At the same time, the organization and development of enterprises in aquaculture is constrained by a number of problems that are identical in composition and content to both the general problems of the development of the fishery sector and the economy of the regions and the country as a whole.

The above circumstances determined the choice of the research topic.

The problems of small business are widely represented in the literature and scientific periodicals.

Issues of the formation and development of entrepreneurship, approaches to determining the factors influencing the development of aquaculture most were studied in the works of such scientists as V. Balukhtyna, V. Zyuz, I. Irtyshcheva, O. Nesterova, M. Stegney and V. Lagodienko, D. Archibisova, and many other domestic scientists.

The information base of the work was the laws of Ukraine, Decrees of the President of Ukraine, resolutions of the Cabinet of Ministers of Ukraine, statistical materials of the State Statistics Service of Ukraine, other ministries and departments, scientific works of leading domestic and foreign scientists, conferences and seminars, monographs, collections and scientific articles; Internet resources, etc.

II. ANALYTICAL REVIEW OF LITERATURE

2.1. Characteristics of aquaculture as a form of entrepreneurial activity

In world practice today, aquaculture, i.e. cultivation of aquatic organisms (fish) under managed or controlled conditions is the most dynamically developing branch of food production. Aquaculture got its development in the 70s of the last century, when economists in many countries came to the conclusion that high rates of exploitation of oceanic fish resources could lead to their gradual complete disappearance. As an alternative to providing the population with fish products, the cultivation of marine and

freshwater crops was proposed, which has become a priority in the fishing industry in many countries.

Aquaculture plays a decisive role in ensuring the country's food security, increasing tax revenues, increasing employment, and in the near future will be able to actively influence the improvement of the economy.

«According to the law of Ukraine, aquaculture, ie artificial reproduction (breeding) of aquatic bioresources - is the activity of breeding (reproduction), cultivation of aquaculture facilities, associated with their subsequent introduction into water bodies (their parts) for restoration natural populations, replenishment of aquatic bioresources and conservation of their biodiversity» [1].

Also, this Law defines aquaculture (fish farming) as agricultural activity for artificial breeding, maintenance and cultivation of aquaculture facilities in fully or partially controlled conditions for agricultural products (aquaculture products) and their sale, feed production, reproduction of biological resources, selection -breeding, introduction, resettlement, acclimatization and reacclimatization of aquatic organisms, replenishment of aquatic bioresources, conservation of their biodiversity, as well as the provision of recreational services» [2]. It should be noted that in a number of regulations [3,4,5,6].

The concepts of «fish farming» «aquaculture» are similar in meaning and according to legislators, have the same meaning and are identified. However, in legal science there are views on the delimitation of these concepts. For example, O.V. Boyko in his dissertation research notes that the content of such concepts is different and therefore they can not be identified. Thus, the concept of «fish farming» is broader in its meaning and includes both aquaculture and mariculture. That is why in order to reveal the content of the second main element of the structure of fisheries - fish farming, it is necessary to study its content and identify subspecies [7].

According to D.S. Archibisova, aquaculture - is the breeding, cultivation and procurement of fish, mollusks, algae and other organisms in all types of aquatic environment; a method used to produce food and other commercial products, restore habitats and replenish wild stocks, and restore populations of endangered and endangered species [8].

According to the Law of Ukraine «On Aquaculture», for aquaculture legal or natural persons may be provided with water bodies, fishery technological reservoirs, parts of water bodies (exclusively for accommodation of garden farms) and water area (water space) of inland sea waters, territorial sea, exclusive (marine) economic zone of Ukraine [9].

According to the Classification of Economic Activities [10] «aquaculture» as a type of economic activity is included in Section A «Agriculture, forestry and fisheries», section 03 «Fisheries and aquaculture», group 03.2 «Fisheries (aquaculture)». This group includes «aquaculture» (or fish farming), ie the process of production, which consists in the cultivation and breeding (including harvesting) of marine organisms and crops (fish, mollusks, crustaceans, plants, crocodiles and amphibians, etc.) using technology designed to increase the productivity of organisms and increase their natural growth in the environment (eg regular stockpiling, fattening and protection from predators). In addition, aquaculture includes individual, cooperative or state

ownership of individual organisms in order to increase their numbers, including their collection. This section contains two Classes 03.21 «Marine fish farming (aquaculture)» and 03.22 «Freshwater fish farming (aquaculture)».

Class 03.21 «Marine fish farming (aquaculture)» includes: breeding of fish in seawater, including breeding of marine aquarium fish keeping caviar of bivalve molluscs (mussels, etc.), lobsters, shrimp, fish fry and its manual cultivation of red algae and other algae , bivalves, other molluscs and other aquatic animals in seawater. This class also includes: fish farming (aquaculture) in salt water, fish farming (aquaculture) in seawater reservoirs, operation of fish farms for marine fish farming, operation of sea worm farms, frog breeding, activities of reserves for sport fishing.

Class 03.22 «Freshwater fish farming (aquaculture)» includes: breeding of fish in fresh water, including breeding of freshwater aquarium fish, breeding of freshwater crustaceans, bivalves, other molluscs and other aquatic animals in fresh water, operation of fish farms , breeding frogs, breeding crocodiles and other amphibians. This class excludes: fish farming (aquaculture) in seawater reservoirs, sport fishing activities.

2.2. The role of small business in the development of aquaculture

Small business is a basic element of the market system of management. Small businesses - the most numerous layer of private owners - small and medium-sized enterprises.

Currently, small businesses are represented in almost all sectors of the economy and the service sector. They function not only in trade, light and food industries, but also appear in mechanical engineering, woodworking, chemical and electrical industries.

The economic dictionary of B. A. Raizberg gives the following definition of a small enterprise - a firm is a small enterprise of any form of ownership, characterized primarily by a limited number of employees (no more than a few hundred) and occupying an extremely small share, in general, in the country, region, the volume of activity, which is profile for the enterprise [11].

According to Article 42 of the Commercial Code of Ukraine, entrepreneurship is defined as «independent, proactive, systematic, at their own risk economic activity carried out by economic entities (entrepreneurs) in order to achieve economic and social results and make a profit.» In particular, Article 55 of the CCU stipulates that «economic entities, depending on the number of employees and income from any activity for the year, may belong to small businesses, including micro, medium or large businesses» [12].

An analysis of the economic literature has shown that the economic essence of the concept of «small business» identifies such concepts as «own business», «small business» or «self-operating firm».

Thus, small business is a special type of business activity, which is carried out at the discretion and risk of individual entities of any form of ownership and corresponds to the legal forms of business organization for profit.

2.3. Problems and risk factors limiting the development of entrepreneurship in aquaculture

Most economists understand risk as the probability (threat) of losing a part of their resources by a person or organization, shortfall in income or the appearance of additional costs as a result of the implementation of a certain production or financial policy. For any business, it is important not to avoid risk in general, but to anticipate it and make the best decision regarding a certain criterion that reflects the main interest of the entrepreneur [13, 14, 15].

Despite the fact that the risk is present in almost all areas of business activity, it is of paramount importance for the sphere of fish farming and fishing, it accompanies almost all types of business operations and all areas of its activity, and the forms of enterprise risk are characterized by great diversity. Features of the manifestation of risk are closely related to the scope of entrepreneurial activity. Researchers of this issue among the most common external and internal threats hindering the development of the fishery complex include:

– aggravation of global competition for the right to harvest aquatic biological resources;
– political instability in certain areas of intensive fishing;
– unstable conjuncture of world prices for fish products;
– ongoing pollution of water bodies;
– a significant rise in the cost of fuel and energy resources;
– imperfection of the regulatory and legal framework in terms of organizing control over the by-catch of aquatic biological resources;
– growth of competitiveness of imported into the territory of Ukraine;
– the imperfection of the legal support for the functioning of the country's fisheries;
– lack of a regulatory framework harmonized with international requirements to ensure the release of safe and high-quality products of industrial fishing and fish farming;
– insufficient level of state support for fisheries, including fisheries and aquaculture;
– significant rise in prices for most types of goods and services used by fisheries;
– low level of use of aquatic biological resources;
– insufficient monitoring of the state of stocks of aquatic biological resources;
– lack of monitoring of the quality of aquatic biological resources, products of industrial fish farming and fishing, their production and processing processes;
– high level of physical deterioration and obsolescence of the fishing fleet and fish processing infrastructure;
– insufficient level of state support to minimize the risk from the introduction of new technological solutions for the processing of aquatic biological resources for the fishing business.

The emerging threats listed above can lead to the emergence and implementation of risk events also in the field of pond aquaculture.

A number of scientists and researchers in aquaculture have repeatedly noted that the low level of fish production is associated with a weak institutional framework (lack of a unified organizational structure, imperfection of the legislative framework) in the fishery sector of the economy.

At the same time, we note that there are a large number of small (up to 5 hectares) reservoirs, the operation of which is not profitable for the state, despite the fact that there is no influx of entrepreneurs into fish farming.

The imperfection of the tax system is especially acute for small businesses, which have many ways to escape into the «shadow» economy and, at the same time, as with the correct organization of the tax business, small enterprises are able to provide significant tax revenues.

III. OBJECT, SUBJECT AND METHODS OF RESEARCH

Object of research: phenomena and processes in the field of pond aquaculture.

Subject of research: economic relations and management decisions, which are the basis for the development of entrepreneurial activity in conditions of economic risks.

Research methods: to solve research problems used general and special research methods:

- dialectical method - at the stage of collecting, systematizing and processing information and factors promoting aquaculture;
- statistical and comparative analysis - in determining the effectiveness of combined cultivation in specialized places according to the technological scheme;
- forecasting - in strategic planning of aquaculture development, determining the level of consumption of fish products in the near future;
- monographic, logical generalization of results - to develop recommendations for the development of entrepreneurial initiatives in the field of pond aquaculture.

The information base of the study consists of legislative acts of Ukraine, statistical materials of the State Statistics Service of Ukraine, scientific works of leading domestic and foreign scientists, materials of conferences and seminars, monographs, collections and scientific articles; Internet resources, etc.

IV. RESULTS OF WORK

Management of the development of any sector of the economy is possible only with an idea of its real state, knowledge of the structure of production, its technological features, as well as the characteristics of the consumer market of a product. And this can be done only if the systematic collection and analysis of statistical information on the volume of aquaculture production as a result of economic activity.

In order to track the volume of aquaculture production and their dynamics, the Law of Ukraine «On Aquaculture» stipulates that aquaculture entities are obliged to «submit to the central executive body implementing state policy in the field of fisheries, reporting information on aquaculture production. According to the State Statistics Service of Ukraine, the volume of extraction of aquatic bioresources over the past three years tends to decrease (see Table 1) [16].

Table 1. Extraction of aquatic bioresources for 2018-2020 years (tons)

Years	Extraction of aquatic bioresources				Including fish
	total	including by major fishing areas			
		aquaculture	inland waters objects	other fishing areas	
2018	86222,5	13576,6	46819,8	25826,1	64737,9
2019	92682,0	12675,4	22928,7	57077,9	58095,8
2020	76508,1	11932,6	23291,4	41284,1	48228,6

According to the latest data of the territorial bodies of the State Fisheries Agency, the number of aquaculture entities is 4,568 enterprises of various forms of ownership, of which reported on the form № 1 A-fish (annual) «Aquaculture production in 2020» 1,870 such enterprises or 41% of the total subjects of aquaculture, and in 2019 the reporting was 51% (see Fig. 1).

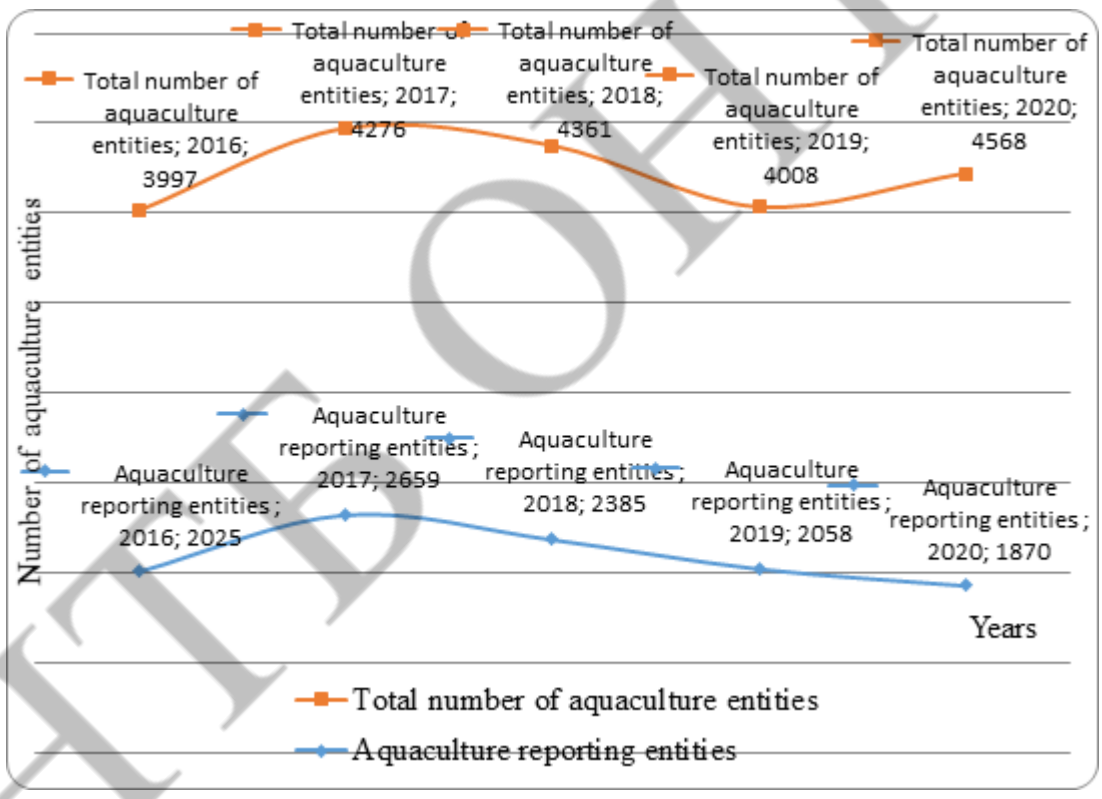

Fig. 1. Dynamics of the number of aquaculture entities

This situation has developed, inter alia, under the influence of the risks associated with entrepreneurial activities in the field of aquaculture.

In this regard, it is important for this study to divide the risks according to the level of financial losses:

- acceptable risk, in the implementation of which the financial losses of the business structure do not exceed the estimated amount of profit on the business transaction;

- critical risk, in which financial losses do not exceed the estimated amount of gross income from the business transaction;

- catastrophic risk, financial losses which threaten the partial and even complete loss of equity and as a consequence the cessation of business.

The general idea of the external risks in the field of aquaculture is shown in Table 2 [13, 14].

Guided by such a classification, it is advisable to single out the most significant risks that can generate negative impacts leading to catastrophic consequences from the whole variety of risks accompanying entrepreneurial activity in the field of aquaculture.

The types of risks presented in the table are of a general nature and are associated with the need to modernize industrial potential, create a social security system, solve problems in the field of employment, improve the monetary and credit and financial system, etc. In this regard, this table requires an explanation of the level of criticality of each type of risk in relation to entrepreneurial activities in the field of aquaculture.

Table 2. External, systematic risks inherent in entrepreneurial activities in aquaculture

Sphere of leakage	Type of risk	Possible consequences of the offensive
1	2	3
Macroeconomic system, state, region	Inflation risk	allowable, critical
	Risk of changes in legislation and judicial practice on issues related to activities (including licensing issues)	critical, catastrophic
	The risk of a decrease in the income of the population, a fall in effective demand	allowable, critical
	Criminogenic risk	allowable, critical
	Risk of changes in the rules of customs control and duties	allowable, critical
	Tax risk	critical, catastrophic
Financial system of the state, region	Currency risk, as an unstable exchange rate and changes in the pricing policy of the central bank in relation to foreign exchange	allowable, critical
	Interest risk as a change in interest rates on loans and borrowings	critical, catastrophic
	Deposit risk	allowable, critical
Industry market and competitive environment	Rise in the cost of fuels and lubricants and spare parts, an increase in energy prices	critical, catastrophic
	Investment risk	allowable, critical
	The risk of reducing the capacity of the domestic market	allowable, critical
	Risk of increasing competitors' offers due to accession to the European Union	allowable, critical
	Underdevelopment of infrastructure, road network, access roads	allowable, critical
	Risk of falling demand due to lower prices in other segments (poultry, seafood, etc.)	allowable, critical

Currently, one of the most important issues for aquaculture is the organization of aquaculture business, in particular, the establishment of fish farms, fish farming in recirculating aquaculture systems, ponds and gardens, breeding technologies and standards of fish production.

Bringing the aquaculture business out of the shadows is also an urgent task. We know from world practice that business needs to be stimulated and supported, especially by small and medium segments. Only in this way it is possible to control the analysis of their effectiveness and obtain reliable statistics. That is why a single state information system is being created, which will contain information on agricultural producers and ensure proper administration of state support. The system will be called the State Agrarian Register, which will include data on agricultural entities wishing to receive support. The system automatically checks their status, quickly checks compliance with the criteria for granting subsidies, determines the possibility of assessing the effectiveness of the proposed support and forms a «single office of farmers.» But let's return to the support of farmers, in particular, we are interested in what areas of support proposed by the developers of the legal act to aquaculture entities.

In order to study the demand for the proposed state support among aquaculture producers in Ukraine, the Budget Institution «Methodological and Technological Center for Aquaculture» is currently collecting information on:

- acquisition of special technological equipment by aquaculture subjects;
- construction or reconstruction of production facilities;
- the amount of costs for growing, breeding and maintenance of aquaculture facilities» [17].

To improve the functioning of the state support system for agriculture, eliminate administrative barriers and costs for agricultural producers in receiving state aid in 2020, the Law of Ukraine «On Amendments to Some Laws of Ukraine on the Functioning of the State Agrarian Register and Improving State Support for Agricultural Producers» was adopted. It is significant for aquaculture entities, because the proposed changes and additions to the entire aquaculture industry have opened up new opportunities for public financial support [18].

Areas of state support that have become available to aquaculture entities with the adoption of this Law:

1. State support for producers engaged in agricultural activities for artificial breeding, maintenance and cultivation of aquaculture facilities shall be provided by:

- partial compensation of up to 30% of expenses, taking into account the restrictions specified in the second paragraph of paragraph 2-1.4 of Article 2-1 of this Law, incurred for such activities;
- providing a subsidy per unit of output or area of a water body.

2. Agricultural producers (up to 50%) and agricultural cooperatives (up to 70%) are reimbursed for the cost of construction and reconstruction of livestock farms and complexes for keeping livestock and poultry, fish farms, apiaries, milking parlors, processing facilities and storage of agricultural products and / or by-products of animal origin belonging to categories II and III, as well as the cost of purchasing machinery, mechanisms and equipment for the production and processing of agricultural products.

V. CONCLUSIONS

All over the world, aquaculture, like agriculture, is subsidized. Existing practices of agricultural production provide support for subsidies to producers (especially small and medium-sized businesses) to increase their competitiveness, sustainable development of rural areas. Aquaculture, as an area of agriculture, needs significant state aid. And this assistance should not only stimulate the development of this business, but also ensure the introduction of new biotechnologies on a sustainable basis.

It is obvious that the development of Ukrainian aquaculture, as well as European, lies in the harmonization of the production sphere, the natural environment and the improvement of relations between members of local communities.

The analysis of the work leads to the conclusion that aquaculture in Ukraine as a whole is developing similarly for the whole of Central Europe as a whole: stagnation, and sometimes a decline in the production of marketable products in the recent past in terms of aquaculture.

The development of aquaculture in Ukraine requires two main prerequisites. The first is the growing consumer demand for freshwater fish species, the cultivation of which is mainly based on the undiscovered potential of inland fishing. The second is the implementation of a set of measures to restore the resource and production potential of the fisheries industry. In particular, it should be noted the feasibility of creating a favorable economic environment to attract investment in the introduction of new resource-saving technologies for intensive pond, pond, river and basin fisheries. This requires: the adoption of a state target program to ensure preferential lending to fisheries enterprises in order to upgrade the material and technical base, restoration of water bodies and hydraulic structures; development of sales infrastructure aimed at selling products through a direct channel from producer to consumer for a greater impact of enterprises on the selling price, which in turn will help reduce consumer prices for fish for the population.

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3. INFORMATION TECHNOLOGIES, AUTOMATION AND ROBOTICS

CYBER-PHYSICAL SYSTEM FOR SMART PARKING BASED ON COMPUTER VISION TECHNOLOGY

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Abstract. *With the rapid growth of transport number on our streets, the need for finding a vacant parking spot today could most of the time be problematic, but even more in the coming future. Smart parking solutions have proved their usefulness for the localization of unoccupied parking spots. Nowadays, surveillance cameras can provide more advanced solutions for smart cities by finding vacant parking spots and providing cars' safety in the public parking area. Based on the analysis, Google Cloud Vision technology has been selected to develop a cyber-physical system for smart parking based on computer vision technology. Moreover, a new model based on the fine-tuned convolutional neural network has been developed to detect empty and occupied slots in the parking lot images collected from the KhNUParking dataset. Based on the achieved results, the performance of parking lots' detections can be simplified, and its accuracy improved. It was also concluded that the Google Cloud Vision technology as parking slots detector and a pre-trained convolutional neural network as a feature extractor and classification were decided to develop a cyber-physical system for smart parking.*

Keywords: *Video-image processing. Smart parking. Smart city. Deep learning. Convolutional neural network. OpenCV. Google Cloud Vision.*

I. INTRODUCTION

Nowadays, the issue of creating smart parking is crucial, especially in large cities. As the number of cars has rapidly increased for the last few years (Figure 1), so does the need for parking spaces and search facilities. Assuming that the average driver spends 20 minutes searching for such a place every day, about 120 hours a year could be spent on something more useful.

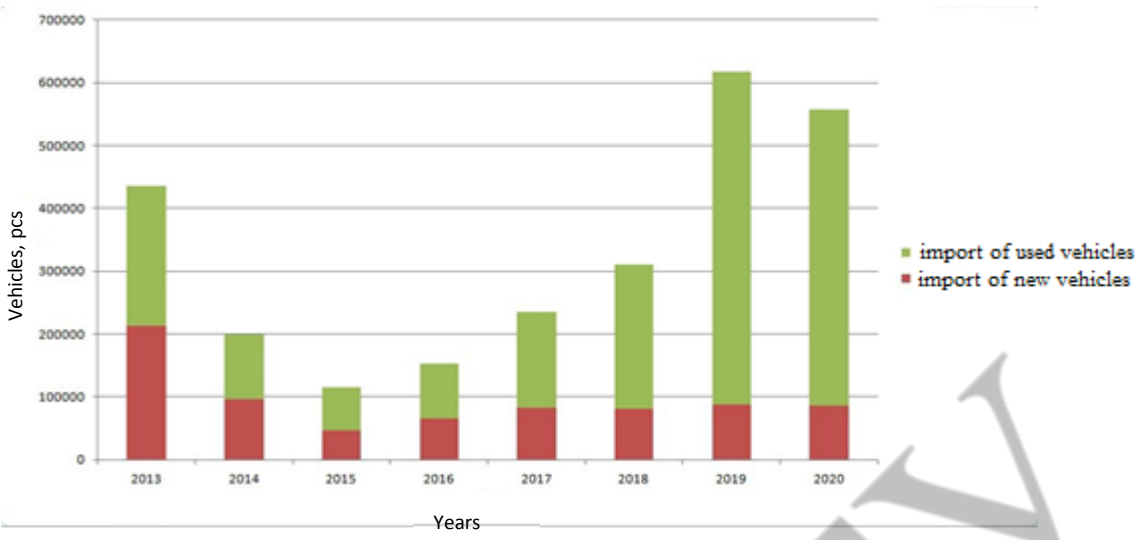


Fig. 1. Increase in vehicle numbers in Ukraine

As shown in Figure 1, the general increase in the number of vehicles includes imports of new cars (red part of the column) and used cars imported from abroad (green part of the column). At the same time, it is noticeable that from 2016 to 2020, the import of new vehicles remains at about the same level, but the share of imports of used cars is gradually increasing. Such an outcome was due to changes in the legislation on customs clearance of vehicles imported from abroad, namely on November 25, 2018; a law was passed to simplify the procedure for customs clearance of used cars imported from abroad [1].

Nowadays, there are many smart parking projects, but ready-for-use examples can be counted on the fingers of one hand, and information about the cost-effective aspect of their implementation is generally minimal. It should be noted that when designing such tools, the most significant financial part of the development is born by the software, not hardware. After considering and comparing different parking detection techniques [2], a conclusion has been made that the method of smart parking using a camera is much more effective than others, considering most of the factors considered. In addition, since most of the parking lots are usually located in public places, privacy and security factors also should be considered. Consequently, the aim of this work is:

1. To analyze modern technologies for image recognition based on artificial neural networks.
2. To select the most appropriate technology for creating a cyber-physical system for smart parking based on the outdoor surveillance camera of the university parking lot.
3. To develop an information model for parking slots detection and vehicle identification.
4. To evaluate the developed model on a testing dataset.

II. LITERATURE ANALYSIS

Multiple studies have been conducted over the past years to find the best approach for smart parking development in the past few years (Table 1).

Table 1 – Analysis of ready existing computer vision approaches for smart parking

Reference	Year	Algorithm / Model	Advantages	Disadvantages
[3]	2018	Deep convolutional neural network, OpenCV	Uses coordinate of each parking space, so less computation is needed.	The features obtained from the benchmark dataset may not be practical for recognizing real outdoor parking lot.
[4]	2019	Haar Cascade, AdaBoost	The car can be detected from any angle of view. The accuracy is 100% for single-car detection	In multiple-car detection, the accuracy is affected by the car and shadow, which results in detecting two cars as one object.
[5]	2020	Hough Transform, OpenCV	With a fixed camera placement and without changes in light intensity, a 100% correct result was obtained.	The light change and shadows negatively affect the classification Results.
[6]	2021	Long short-term memory	The prediction of empty parking spaces based on the computer vision system and the real-time car parking data.	If the car is not parked in the considered lot, it would not be correctly detected by the system.
[7]	2022	Mask R-Convolutional neural network, OpenCV	Based on video and image data, a scalable and relatively inexpensive system can detect empty parking spaces.	The method's accuracy can be improved using a better camera and a faster processing unit.

As can be seen from Table 1, a deep learning approach, particularly convolutional neural networks (CNNs), has been most frequently used over the past five years and has shown the most robust recognition of parking lots, among other approaches.

Thus, considering the abovementioned analysis, two computer vision technologies were chosen for further research – OpenCV library + artificial neural network and Google Cloud Vision API.

2.1. OpenCV Computer Vision Library + CNN

One of the popular technologies for image recognition is the OpenCV computer vision library [8]. This set of tools serves as a so-called infrastructure for applying computer vision techniques in information systems. OpenCV is used, among other things, to resize input images, convert them to vector form, and detect the features of target objects in the image. At the same time, one of the most popular approaches to detecting features in the image today is deep learning, in particular CNN [9–11]. The CNN model combines many functional operations that transmit the input image as feature vectors into the resulting data to estimate the belonging of the identified objects to predefined classes. The CNN architecture utilized in this study is from the authors' previous work [12] and is depicted in Figure 2.

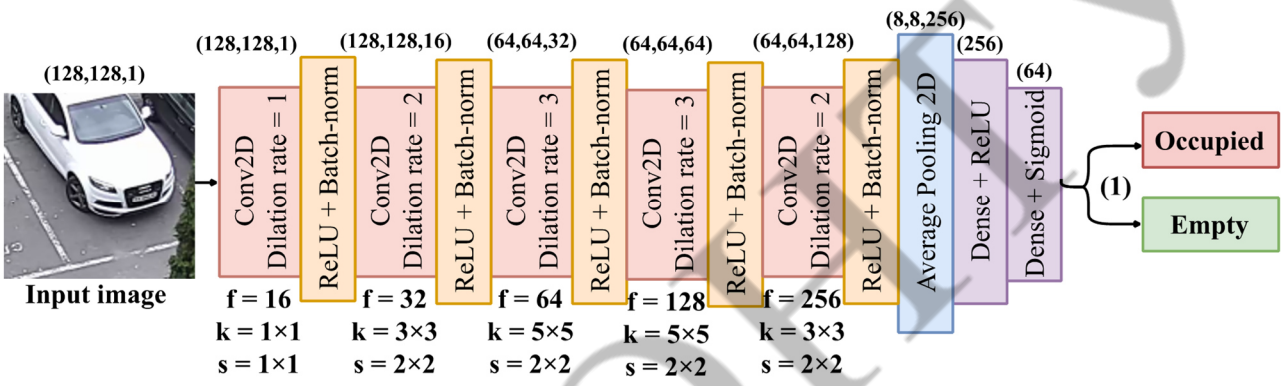


Fig. 2. The scheme of convolutional neural network used in this work

According to the classification results from our previous work [13], we conclude that combining the GCV API system and OpenCV + CNN tools may achieve more robust performance and higher classification accuracy.

2.2. Google Cloud Vision API (GCV API)

Another equally well-known image recognition technology is the Google Cloud Vision API (GCV API) [14]. The GCV API is a de facto set of prepared machine learning models and algorithms that service users can quickly implement to meet their business needs. The principle of the GCV API is to perform two steps: 1) assigning labels to the original image; 2) automatic recognition of objects in the image by predefined classes. The GCV API is a universal classifier that identifies various moving and still objects in an image.

In our previous work [13], we conducted a preliminary experiment: ten images were used from the video surveillance camera of one of the parking lots of Khmelnytskyi National University. The images were preliminarily prepared: the contours were cropped to bring the focus as close as possible to the location of the cars. In addition, the objects in the image were magnified to increase the likelihood of finding the object.

The experiment was to test the same image using two of the most popular image recognition technologies. The object identification results on the target image, performed using OpenCV + CNN and GCV API technologies, are shown in Figure 3.

a b

Fig. 3. Identified objects on the target image that correspond to the searched cars, found by:
a – OpenCV + CNN, b – GCV API [13]

Figure 2 shows that GCV API technology coped much better with the task of identifying cars on the image (Figure 3a) than OpenCV + CNN technology (Figure 3b). Hence, the GCV API system as parking slots detector and a pre-trained CNN as a feature extractor were decided to use to develop a cyber-physical system for smart parking.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Object of research: software and hardware of the cyber-physical system of smart parking.

Subject of research: image recognition technologies using artificial neural networks for smart parking.

Research methods: theoretical – methods of systematic and comparative analysis of scientific sources, scientific and technical, specialized literature for clarifying aspects of technological approaches and selection of the best technologies for solving scientific and applied problems; synthesis, generalization, and conceptualization to formulate the main provisions of the research; design and modeling for processing the results of the experiment; empirical methods – development and experimental verification of the method of image recognition from surveillance cameras based on artificial neural networks.

Expected scientific results: improvement of existing methods and algorithms for training convolutional neural networks for image recognition and implementation of these methods and algorithms in the smart parking system; the development of the parking slots recognition model.

Expected practical value: development of information system as a computer vision model for smart parking based on image recognition technology using artificial neural networks and its further implementation as a mobile application.

The authors compiled **Dataset (KhNUParking)** from the collected images extracted from an external closed-circuit television (CCTV). The CCTV was installed on Campus 3 of Khmelnytskyi National University, Khmelnytskyi, Ukraine. The images show parking spaces of the outdoor parking lot between campuses 3 and 4 of the university (Figure 4).

a b

Fig. 4. The samples of the KhNUParking dataset presenting targeted parking spaces:
a – almost all parking lots are empty, b – nearly all are fully occupied

The KhNUParking dataset contained 100 images, each of which is 853 × 480 pixels. The dataset was split into training (70%) and validation (30%) subsets. Also, a subset of 100 images was created to test the classification models. Finally, the authors provided the ground truth annotations of the parking slots delineations (33 slots) and the occupancy (3300) for evaluating the accuracy.

PKLot: we gathered a subset of the original PKLot dataset [15] with 390 randomly sampled images of 1280 × 720 pixels. The vehicles in the PKLot dataset were parked only in up-down orientation.

Experimental setup: all computational experiments were performed on the Python v3.8 stack with Keras as the back end. The calculations were executed on 8-core Ryzen 2700 and a single GPU card GeForce GTX1080 with 8 GB of memory.

Methodology: the proposed approach for computer vision technology is depicted in Figure 5.

In this work, we utilized a neural network model based on pre-trained CNN as a feature extractor and a two-layer perceptron as a classification module. The pre-trained CNN contained 1000 classes (pre-trained with the ImageNet dataset). To prepare the model for detecting occupied and empty parking spaces, the last fully connected layers in the network were replaced with two classes that correspond to “Empty” or “Occupied.” In this work, the testing models were evaluated for binary classification accuracy and run-time – average time in seconds to read images from the hard disk and crop them. The binary classification accuracy was calculated by the formula below:

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}},$$

where TP represents true positive cases in the testing dataset, TN stands for true negative cases, FN denotes false positive, and FN represents false negative cases.

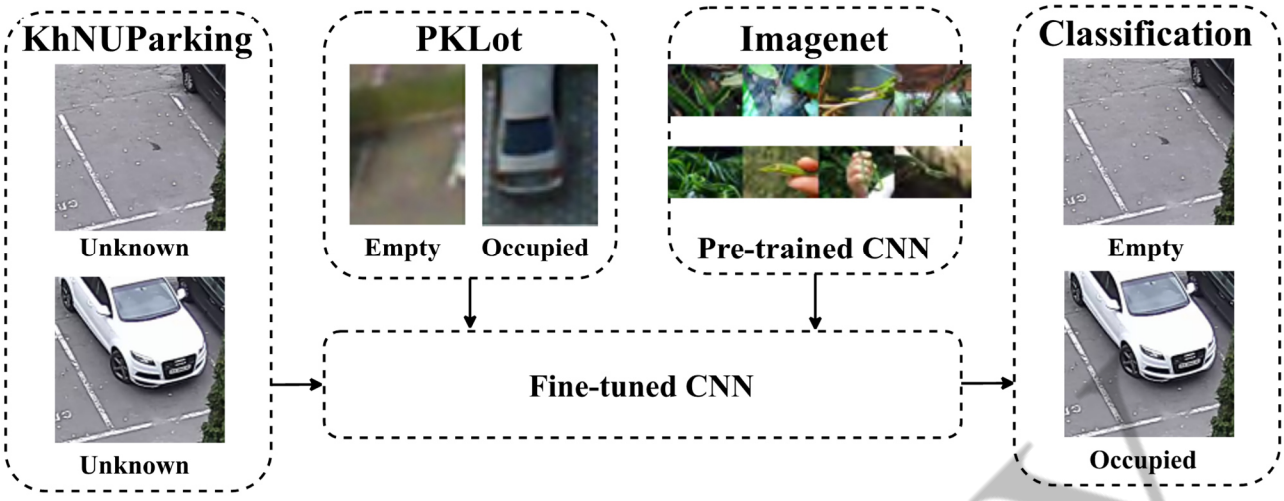
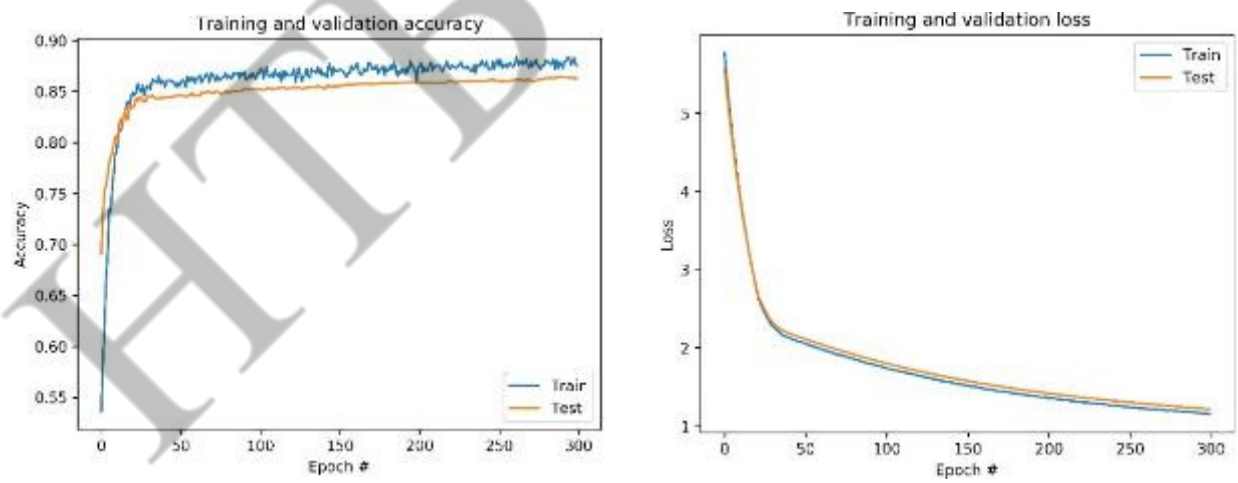


Fig. 5. The proposed approach for smart parking cyber-physical system

The data augmentation technique was also performed on the fine-tuning dataset to reduce over-fitting. Two transformations were applied: 1) reflection along X and Y axes and 2) change the X and Y scales of the images. Furthermore, the input images were resized according to the input size of the CNN, which was 128 × 128.

IV. RESULTS

The network was pre-trained with a stochastic gradient descent with a momentum of 0.8, an initial learning rate of 0.005, and a batch size of 64. The number of epochs was set to 20. Furthermore, the training data was shuffled at each epoch to remove any dataset bias due to image sequences. The pre-training process took roughly 50 minutes on a single GPU. The training and validation accuracy and loss curves are presented in Figure 6.



a b

Fig. 6. Training and validation curves of the pre-training procedure:
a – the fine-tuning and validation accuracy,
b – the fine-tuning and validation loss

The prepared model based on pre-trained CNN was tested with 100 KhNUParking images. It would crop out individual 33 parking slots of each image. After that, these

cropped images were passed to the fine-tuned CNN for classification. The ground truth of the KhNUParking dataset contained the occupancy status (3300) and delineation of the parking slots (33). Here, we presented the delineations of parking lots as bounding boxes that are used to crop the individual parking slots. A bounding box is defined by $[x, y, w, h]$, where $[x, y]$ represents the middle of the box and w and h stand for the width and height of the boxes, respectively. Figure 7 presents the classification results obtained by the testing dataset.

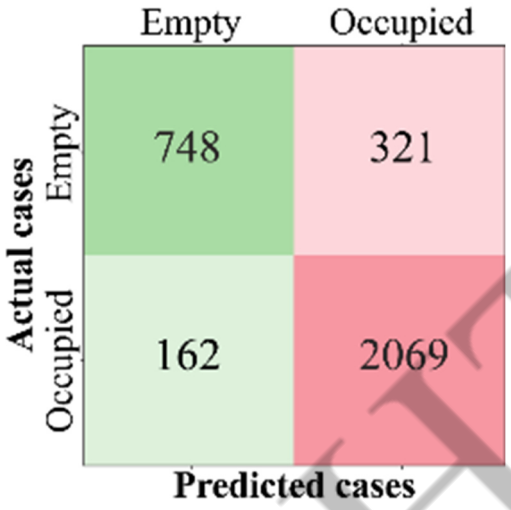


Fig. 7. The confusion matrix of the prediction results

As it is seen from Figure 7, 748 empty parking spaces and 2069 occupied parking lots were correctly identified; meanwhile, 321 vacant lots were classified wrongly, and 162 occupied spaces were recognized as open. So, the overall classification accuracy was 85.34%. From these results, we might assume that the proposed fine-tuned CNN is slightly less precise while identifying empty parking slots.

Upon visualizing a few of the wrongly identified parking spaces in Figure 8, it was observed that those parking lots mostly contained parts of vehicles, people, or other objects inside the image crop.

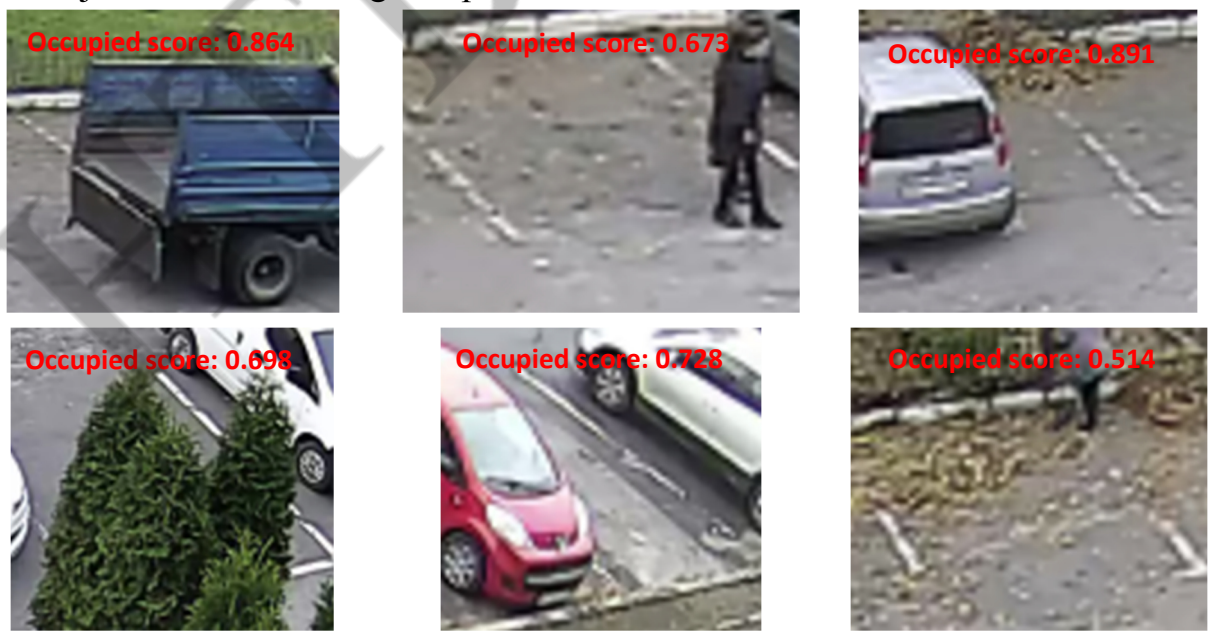


Fig. 8. A few falsely classified parking spaces with their respective classification scores

Finally, the occupancy of the parking slots is visualized in Figure 9.

Fig. 9. The visualization sample of the parking lot: red color represents the occupied slots, green color – empty slots

Several models, namely AlexNet [9], VGG-16 [10], and MobileNetV2 [11], were compared with the fined-tuned CNN in terms of their efficiency and accuracies. The classification results obtained from all models are shown in Table 2.

Table 2. The comparison of well-known neural network architectures with our proposed fine-tuned CNN based on the KhNUParking dataset

Approach	Run time on CPU, seconds	Accuracy, %
Google Cloud Vision API [4]	0.21	58.90
AlexNet [9]	0.54	77.31
VGG-16 [10]	0.62	84.10
MobileNetV2 [11]	0.96	89.26
Our fine-tuned CNN	0.15	85.34

Table 2 presents the run-time on CPU (efficiency) and accuracy achieved by comparing neural network models. The table shows that the generalizing ability of all models is high enough for this quality of parking spaces, yet MobileNetV2 achieved the highest accuracy. Concurrently, the proposed CNN scored a relatively good performance of 85.34%. As for run-time, our fine-tuned CNN showed the best efficiency, scoring only 0.15 seconds to read the images from the hard disk. Overall, our fine-tuned CNN can process approximately 66 parking lots in one second on a CPU with 85.34% accuracy.

V. CONCLUSIONS

Therefore, during the study, an analysis of information technologies for image recognition based on computer vision was conducted. A new model based on fine-tuned CNN has been developed to detect empty and occupied slots in the parking lot images collected from the KhNUParking dataset. Based on the achieved results, the performance of parking lots' detections can be simplified, and its accuracy improved.

Further investigation will be devoted to developing the server- and client-based parts in the form of a mobile app that tracks the availability of vacant places at the university's parking lot.

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MODELLING AND INVESTIGATION OF THE INFLUENCE OF BICYCLE FRAME DESIGN PARAMETERS ON ITS ERGONOMIC PROPERTIES

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Abstract. *It is impossible to imagine the modern world without the widespread use of such an environmentally friendly mode of transport as the bicycle. Many developers around the whole world have created a large number of models of this type of transport. Development of bicycling is linked to the emergence of new technologies, materials and design concepts. There are many variations in bicycle frame designs. The study of the influence of bicycle design parameters on its handling and comfort is an urgent scientific and technical task.*
The subject of the study is the design parameters of the bicycle frame.

The soundness and robustness of the scientific positions are ensured by the use of the fundamental principles and methods used in geometry, physics, and the modern SolidWorks Simulation package.

Practical value. The use of the obtained results makes it easier to select a bicycle according to people's parameters. The parametric model of bicycle frame was also developed, which is the basis for further detailed analysis of bicycle operation under different kinds of loads.

Keywords: *frame design parameters, ergonomic properties, loads, displacement, manoeuvrabilit, wheelbase, controllability.*

I. INTRODUCTION

It is impossible to imagine the modern world without the widespread use of such an environmentally friendly mode of transport as the bicycle. Many developers around the whole world have created a large number of models of this type of transport. Development of bicycling is linked to the emergence of new technologies, materials and design concepts. There are many variations in bicycle frame designs. The study of the influence of bicycle design parameters on its handling and comfort is an urgent scientific and technical task.

The subject of the study is the mechanical processes that occur when using a bicycle.

The subject of the study is the design parameters of the bicycle frame.
The aim of the study is to determine the nature of the relationship between the ergonomic properties of the bicycle and the design parameters of the frame.

In order to achieve the goal, the following tasks need to be solved:

1. Analyse the different types of bicycles and identify the design parameters and the limitations on them.
2. Determine the criteria for the quality of the bicycle and analyse the influence of its design parameters on its ergonomic properties by means of analytical studies.
3. Build a parametric three dimensional model of the bike and its frame.

4. Using state-of-the-art methods of tri-modelling and structural analysis packages, analyse the strength of the bicycle frame structure.

Research methods: The research is based on the analysis and classification of bicycles, analytical studies, and the use of modern methods of trivimetric modelling and scintillation analysis packages.

In the course of the work, a parametric trivimetric bicycle model had to be created and a computer experiment had to be carried out using this model. The results of the investigation on the model show the correlation between the design parameters of the frame and the properties of the bicycle.

Scientific positions:

The radius of the bicycle's turning circle is directly proportional to the length of the wheelbase and wrapped proportionally to the cosine of the front wheel's understeer.

The bike's manoeuvrability and stability is affected by the wheelbase, handlebar grip, carriage position and the seat tube and handlebar grip.

The strength of the frame is influenced by the material, the parameters and the orientation of the cross-section of its components. The maximum forces exerted by the cyclist's weight are localised at the junction of the lower and inner tubes, so the strength of the frame is also greatly influenced by the welding quality of the frame components.

The soundness and robustness of the scientific positions are ensured by the use of the fundamental principles and methods used in geometry, physics, and the modern SolidWorks Simulation package.

II. LITERATURE ANALYSIS
ANALYSIS OF THE STATE OF PLAY AND STATEMENT OF RESEARCH OBJECTIVES

2.1. Relevance

The development of new mechanics is based on the testing of different types of materials, component bases, processing and integration technologies and long-term performance tests under different operating conditions. As for the bikes themselves, the new models have to take into account the requirements for ergonomics and price. Therefore, the task of computer model of the bicycle for research on the correlation between the design parameters of the bicycle and its ergonomic properties is very relevant. Detection of such correlations can simplify the task of finding a balance between using new, expensive materials and reducing the cost of the final model without losing the quality and properties attributed to each individual model.

The use of computer-aided simulation allows substantial savings in terms of new, expensive materials and reduced testing time. In the end, the result is a lower cost of production and greater competitiveness on the market.

We therefore consider the topic of our study to be relevant and useful.

2.2. Varieties of bicycles and their classification

The purpose of bicycles can be divided into 6 big groups [1], namely: mountain bikes, road bikes, racing bikes, touring bikes, track bikes and BMX bikes.

Mountain bikes (Fig.1a) are designed for off-road riding. These bikes are distinguished from the others by their very sturdy frames and wheels, wide tyres with high tread and a strong kerb, which are essential if the driver is to be able to withstand road shocks.

Road bikes (Fig.1 b) are designed for cycling and walking. These bikes are equipped with full, front and rear frames and a lancet guard to keep the rider clean. The tyre and frame weights are medium to high. The seat is both straight and very straight.

Fig.1 – Bicycle types [1]
a – dirt bike; b – road bike; c – track bike; d – touring bike; e – racing bike;
f – bike for performing tricks

Track bikes (Fig. 1 c) are designed for riding on a cycle track. This type of bike is similar in appearance to road bikes. Due to the short wheelbase, the frame stiffness increases. The bike has only one gear. The track bike can only be ridden in a single gear.

Touring bikes (Fig. 1 d) are designed for long journeys and cycling. They are suitable for riding on unpaved roads as well as on municipal roads. Fitted with lights, fenders and luggage compartment. The handlebar is straight.

2.3. Summary of the section

Bicycles can be divided into six major groups, namely: mountain bikes, road bikes, dirt bikes, dirt bikes, touring bikes, trail bikes and BMX bikes for performing tricks.

The parameters of the bike frame depend on the intended use of the bike.
The parameters of the bike frame affect the bike's ride, handling characteristics, manoeuvrability, directional stability and usability.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

INVESTIGATION OF THE INFLUENCE OF BICYCLE PARAMETERS ON THE BIKE'S RIDE

Let's look at the ergonomic properties of the bicycle. These include the suitability of the frame height, the size of the bicycle wheel to people's height; the seat angle; manoeuvrability and controllability, i.e. the dependence of the bicycle turning radius on the handlebar turning angle; rudder safety; the position of the bicycle centre of gravity with the rider for different track gradients.

3.1. Parametric bicycle frame model

The geometry of the bike frame can be characterised by a set of parameters, including the length of the frame components.

The standard [2] developed by the Research and Development Institute for Standardization and Certification in Mechanical Engineering has the following basic bicycle parameters. These include the limitations that must be observed when designing a new bicycle.

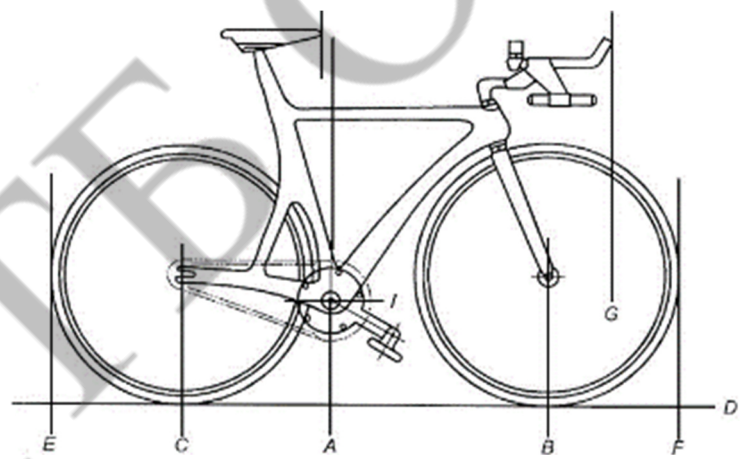


Fig. 2. Basic bicycle parameters and dimensions

Dimensions: length EF ≤ 1.9 m; width no more than 0.55 m and for VMX no more than 0.74 m.

The distance between the horizontal line drawn through the centre of the carriage I and the ground surface D must be at least 0.2 m and no more than 0.3 m.

The distance between the vertical lines drawn through the centre of carriage A and the centre of the front wheel B is 0.43 - 0.75 m.

The distance between the vertical lines drawn through the centre of carriage A and the centre of the rear wheel C is 0.25 - 0.55 m.

The distance between the vertical lines drawn across the front seat point H and the centre of carriage A must be at least 0.05 m behind the carriage, except on sports bikes. For sports bikes, this distance can be zero.

The distance between the inner edges of the front fork tips must be no more than 0.105 m, between the inner edges of the rear fork tips no more than 0.135 m;

A vertical line drawn through any point on the frame of the bike G must not be more than 0.15 m in front of a vertical line that runs through the centre of the front wheel B.

The diameter of the wheels of bicycles, except for BMX sport bikes, must be at least 0.49 m and no more than 0.7 m including the tyre. BMX sport bikes must have a wheel diameter of at least 0.49 m and no more than 0.5 m. The wheel diameter of transport bikes for children must be at least 0.3 m and for children at least 0.4 m.

Parametric model of the frame is created using Solidworks computer program (fig.3). The parametric trivimetric model of the bicycle frame is created with this layout.

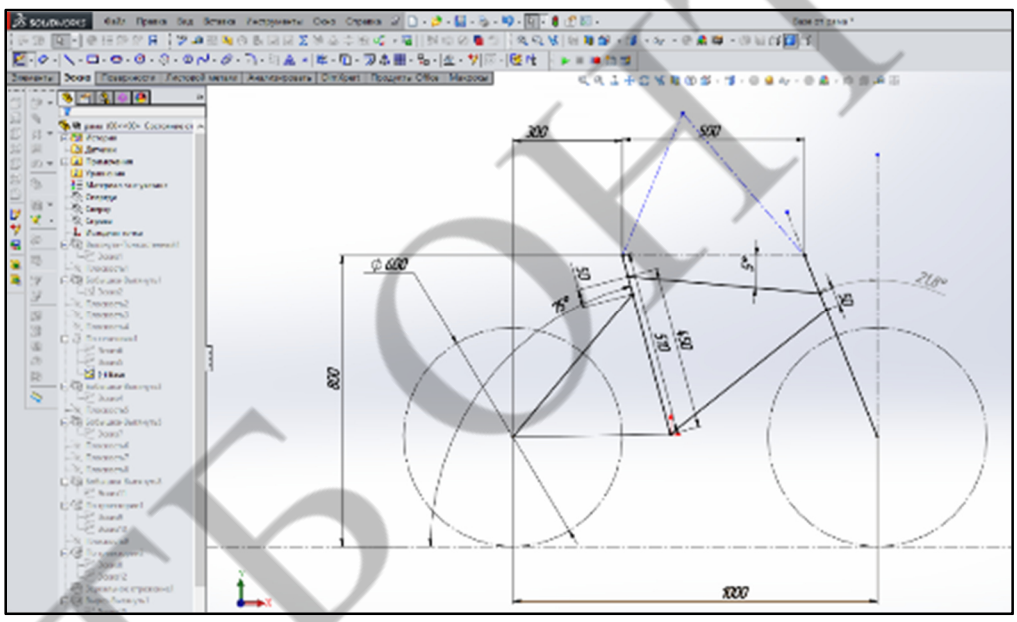


Fig. 3. - Parametric design of a bicycle frame in Solidworks

3.2. Influence of bike design parameters on bike ride

The main design parameters of the frame and their influence on the performance of the bike are described below.

The wheelbase is the distance L between the front and rear wheel axles of the bike. It has a great effect on the bike's handling and is one of the most important characteristics that affects its manoeuvrability and handling. Short wheelbase bikes are more manoeuvrable and long wheelbase bikes make for a more comfortable, forward-looking and controllable vehicle.

The base length affects manoeuvrability. The greater this distance, the more radius must be set when turning (manoeuvrability is reduced), the same reason for increased stability.

Figure 4 shows a checklist for determining the steering angle of a bicycle for different wheelbase lengths. Let's look at the boundary cases where the rotational

gradient of the front wheel (it should be noted that the gradient of the handlebar and wheel can be different values due to the handlebar grip) is 0° and 90°. In the first case, the radius of the stake describing the bicycle is of an inconsistent value. In the second case, the stake can be drawn through the 2 points where the bike touches the

ground. For the front wheel, the ratio at the point is identical to the standard centre line of the front wheel. The minimum turning circle of the bike is then half the length of the wheelbase, i.e. 0.5L.

Let us consider the relationship between the radius of rotation and the angle of rotation α of the front wheel. Let's create a block with the centre at the origin of coordinates (point O) and radius R equal to the radius of rotation. At one of the points on the circle, locate a point that conditionally corresponds to the torsion of the rear wheel of the bicycle (point C). From point C, a chord of length L, i.e. the length of the wheelbase, is drawn. The point B, which corresponds to the contact point of the front wheel, marks the point where the chord intersects the stake. The tension to the stake at point B coincides with the front wheel's tension. The length of side OBC=OS=R can be found in the tricycle OC, which is rectosecondary. Thus, radius of turn is equal to $R = \frac{L}{2\cos(2\alpha)}$.

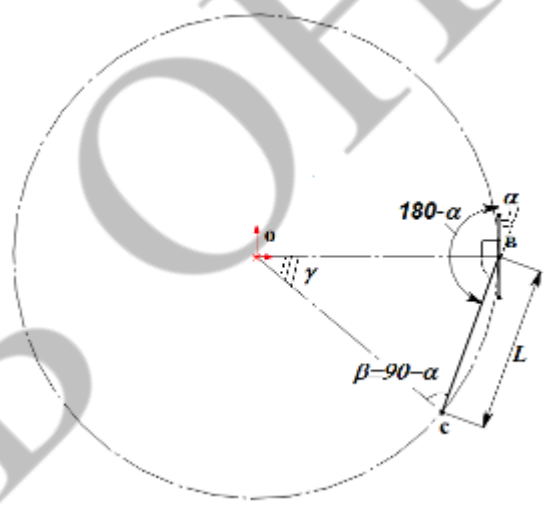


Fig. 4- Exercise for determining the bicycle's turning radius for different wheelbase lengths

The radius of the bicycle's turning circle is proportional to the length of the wheelbase and wrapped in proportion to the cosine of the front wheel's understeer.

Let's analyse how the bike's kerb endurance Δ influences the bike's controllability (Fig. 5). Kernel grip Δ influences the way the bike reacts to a turn. The shorter the grip, the more manoeuvrable and less stable the bike. Point 1 (boundary point of the handlebar) in Fig. 5 will travel a greater distance when the kerm is turned by α the greater the Δ. Therefore, point 1 will follow a path equal to the sum of the length of the arc from the bend α along the radius Δ and the length of the arc from the bend α along the radius 1/2, where 1 is the length of the handlebar.

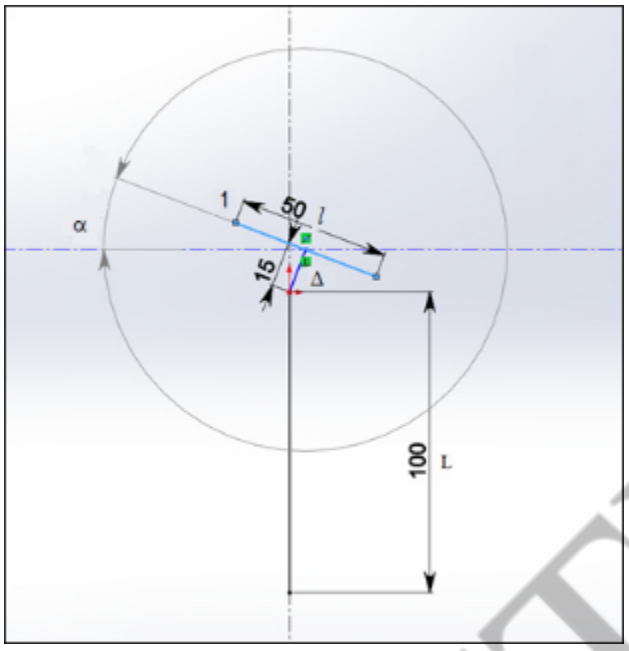


Fig. 5 - Impact of the wheelbase and the arm length on the steering angle

The position of the carriage affects the clearance between the ground and the obstacles on the road and the lower leg position of the rider, the position of the centre of gravity and the stability of the ride.

The lower carriage gives more stability, allowing for easier gimbal operation, but with a greater risk of the pedal catching in the ground. The higher carriage gives more clearance, allowing for easier rotation, but with less stability because the centre of gravity of the burner is displaced.

The shorter rear frame rim gives the rear wheel more contact with the ground and less slippage. As well as the sidewall of the tailpipe, that is, the sidewall between the tailpipe and the line parallel to the ground. A smaller value, an ice bend, causes the rider's weight to be shifted to the rear wheel and increases torque, but reduces speed. A steeper cushion moves the rider's weight forwards, forces the suspension fork to work and ensures a higher sitting position for quick pedalling. The smaller the cushion, the closer the centre of gravity of the bike with the rider to the rear wheel, the greater the alignment (ice cushion). The handlebar grip is measured from the handlebar or head tube to a line parallel to the ground. A slimmer grip allows for smoother control of the bike. A steeper grip is more responsive to manoeuvres. But turning the kernel is also affected by other factors, such as the length of the gauge and the length of the kernel, the clearance and the visibility of the forks.

The steadiness of steering is influenced by the nature of the cyclist's steering, as inertial forces cannot be ignored. The greater the wheelbase, the more stable the ride, as the turning angle is smaller and the less inertia. The centre acceleration is radially directed to the centre of the stake. The greater the radius of rotation, the lower the acceleration.

3.3 Conclusions

To investigate the bicycle frame model, we created a three-dimensional model (Fig. 6) of the bike in SolidWorks 2014 [3, 4].

Figure 6 - Trivimirnaya model of the own bicycle

This bicycle is classified as a road bicycle and has a frame of open structure, with the head tube close to the frame and with a curve closer to the seat tube.

The bicycle (Fig. 7) consists of a frame (6) to which the wheels (4,2) are attached, a frame (1) with a fork of the fork that turns the front wheel (2), pedals on rods (5) and a seat (3). The pedals rotate the wheel via a lancet transmission, a bicycle transmission is used to change the speed of the bicycle, which is a set of various diameters of sprockets.

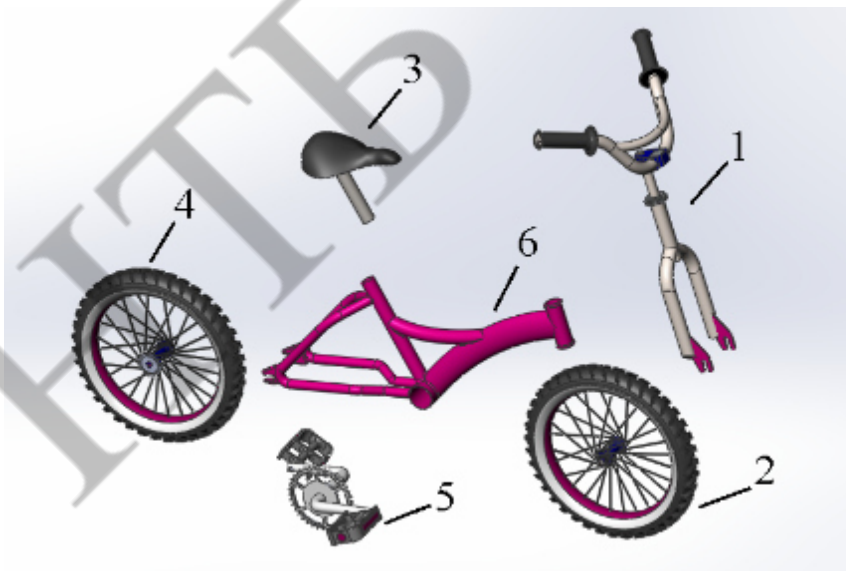


Figure 7 - Bicycle parts

We can analyse the bicycle frame structure (Fig. 8.) It consists of an upper tube (6) - we don't have it here because the bike is a female model, lower (4) and seat tube (2), upper (1) and lower (3) trunk legs, a head tube (5).

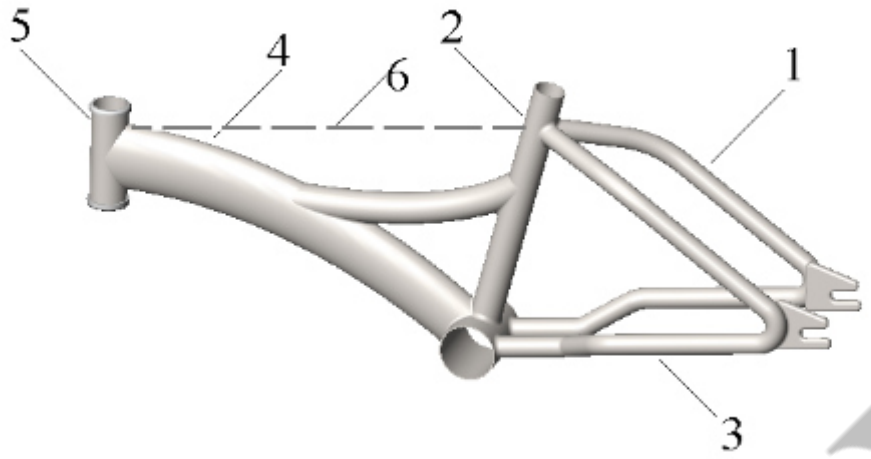


Figure 8 - Bicycle frame

The bicycle frame construction is often a combination of round or elliptical metal tubes.

Let's analyse how the orientation of the pipe cut influences its strength and stiffness properties. For this purpose, we will consider a test problem, a cantilever beam of rectangular crosscut will be subjected to a force which causes bending of the beam in different directions.

The basic variant is a square cut, side length 10 mm, girder length 100 mm, load 700 N (Fig. 9). Let's calculate the effect of positioning two squares of 10 mm side width in horizontal and vertical direction on the girder joint with the same other parameters.

Calculation was performed using SolidWorks Simulation package, which implements the method of joined elements. Accuracy of obtained results is achieved by solving this problem using analytical methods, the difference in results does not exceed 5%.

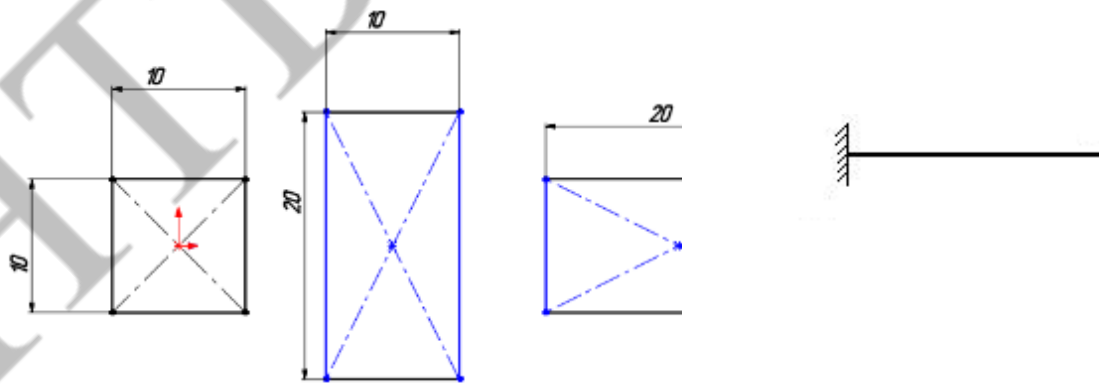
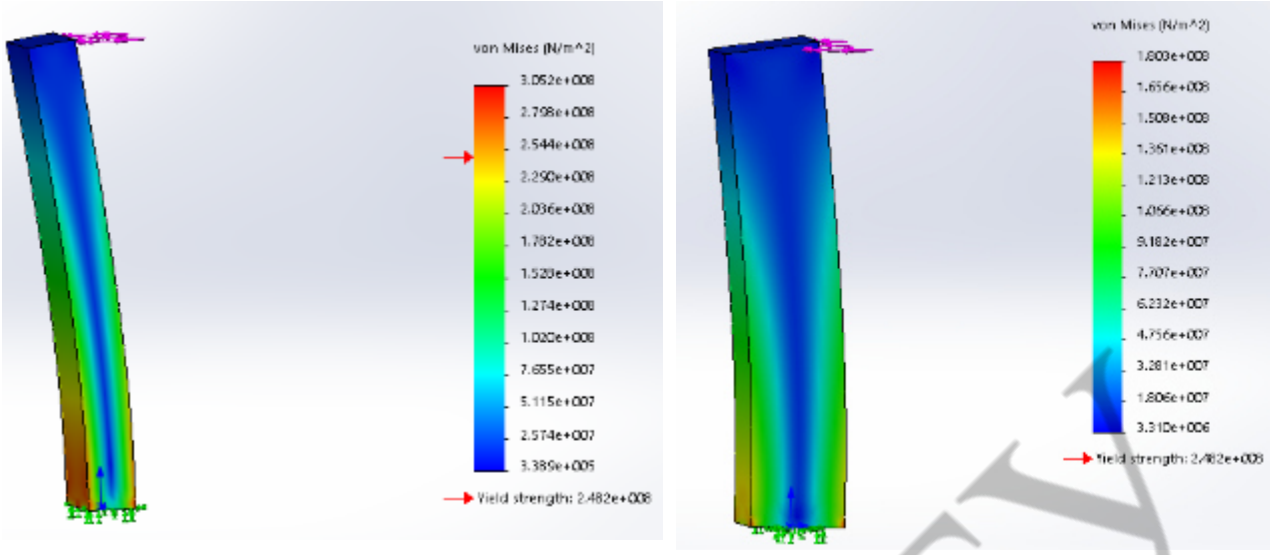


Figure 9 - Revision and calculation scheme of the test problems

The results are shown in Fig. 10, which shows that locating the found side of the rip perpendicular to the acting force increases the stiffness and strength of the beam, but the greatest effect is achieved by locating the found side of the rip parallel to the line of action of the applied force.



a) Cutting dimensions 10×20 mm b) Cutting dimensions 20×10 mm

Fig. 10 - Influence of intersection orientation on girder loads

The shape of the beam and the material of which it is made have a great influence on the strength of the beam. The higher the overlap along the force line, the stronger the girder is. This is why the profile of the bike's lower tube is shaped like an elipse, with the longest part of the tube vertical.

3.4. Frame calculation

To obtain a complete picture of the distribution of loads in the structure, we carry out the frame calculation. We use SolidWorks Simulation engineering analysis package. The dimensioning scheme is shown in Fig. 11. The frame is symmetric, that is why half of the model is used to reduce the calculated complexity. The action of the other part was replaced by the boundary conditions of symmetry. At the point where the steering tube is connected to the steering fork, the boundary conditions - no radial displacement - are imposed. At the point where the rear wheel fork is coupled with the rear wheel axle, boundary conditions are imposed - no radial movement. At the point where the seat tube is connected to the seat, a load of 700 N is applied from the cyclist's weight.

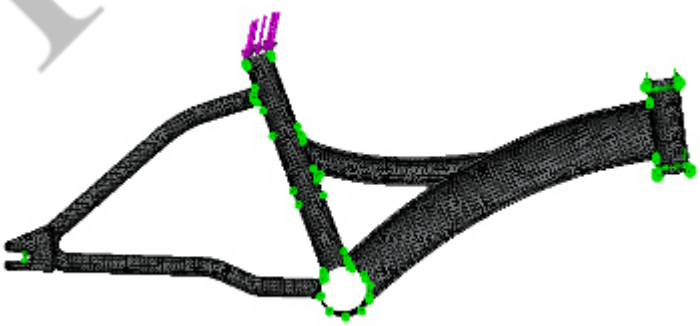
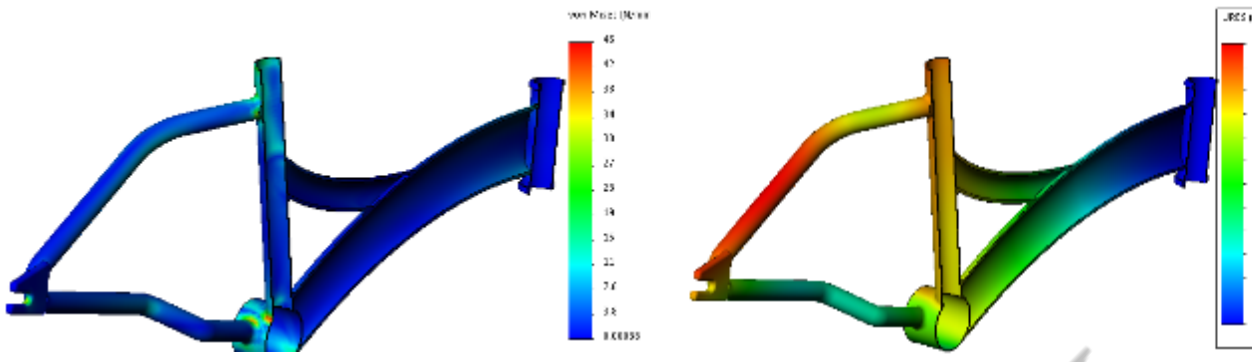


Fig. 11 - Stitching of frame end pieces (Size 5 mm)

Calculations have been carried out with different sizes of the laminated elements and have shown sufficient accuracy of the results obtained. The error does not exceed 15%.

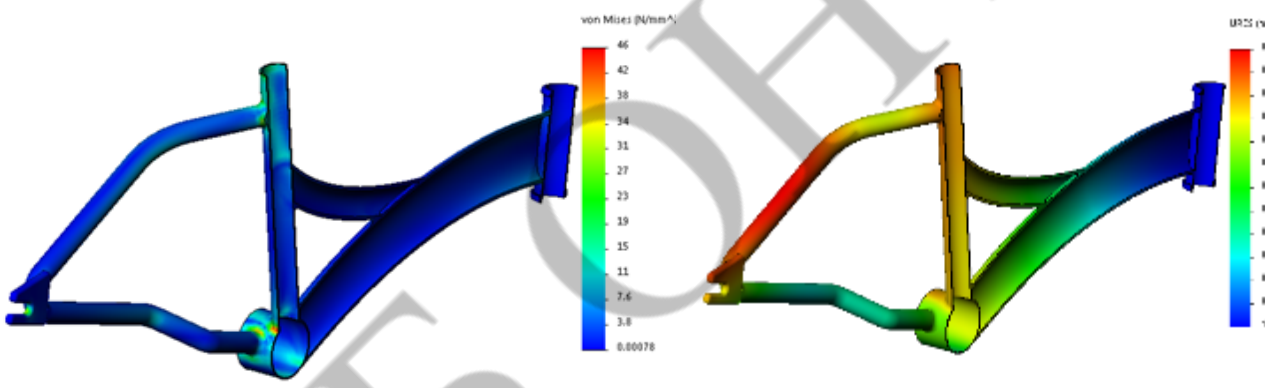
Fig. 3.7 and 3.8 show the results of calculations of the stress-strain state of the frame made of cheap structural carbon steel 3 and aluminium alloy 6061.



a) tension b) relocation

Fig. 12 - The stress-deformed state of the frame in steel 3

The weight of the frame made of steel is 4 kg. The tensile strength [5] for this steel is 195-235 MPa. The maximum frame load is 45 MPa which is localized at the junction of the lower and middle pipes. It can be concluded that the low quality of welding of these pipes can lead to a decrease in the strength of the frame, the appearance of cracks, etc.



a) tension b) relocation

Fig. 13 - The stress-deformed condition of the frame with aluminium alloy 6061

The frame made of aluminium alloy 6061 has a mass of 1.4 kg. The plinth strength for this alloy [6] is 275 MPa, the maximum load did not change at all - 46 MPa. The difference in loads is insignificant but the plinth strength of the aluminium alloy of 275 MPa is even higher than that of carbon steel 195-235 MPa.

The displacement of the frame points has decreased from 0.06 mm to 0.2 mm. This means that the aluminium frame is less rigid, but still sufficiently strong. The maximum displacement of points is at the upper strut of the tricycle

3.5 Summary of the section

A frame made of aluminium alloy 6061 and carbon steel 3 has been dimensioned. The frame in aluminium will be less than 2 times smaller than that in carbon steel. The stiffness of an aluminium frame is 3 times less than that of carbon steel. The maximum stresses for both frames are localized at the connection point of the lower and middle pipes, so the strength of the frame is greatly influenced by the

quality of welding of the frame elements. The maximum load for both frames is about 45 MPa at interval of plinth for steel 195-235 MPa, for aluminum alloy 275 MPa. The disadvantage of the 6061 alloy frame is its high price.

IV. RESULTS

The main scientific findings:

1. The radius of the bicycle's turning circle is directly proportional to the length of the wheelbase and is turned in proportion to the cosine of the front wheel's understeer.
2. Gain Δ affects how the bike reacts when turning. The shorter the grip, the more manoeuvrable and less stable the bike is.
3. The lower carriage gives more stability, allowing for easier gimbal operation, but there is a greater risk of the pedal catching in the ground. A higher carriage gives more clearance, which allows for easier rotation, but less stability.
4. The seat tube bend shifts the cyclist's weight and influences the wheel alignment parameters.
5. The smaller handlebars allow for smoother handling of the bike.
6. To increase strength, the largest dimension of the frame lower pipe cross-section must be vertically aligned. The higher the cut, the stronger the girder.
7. The strength analysis of a steel 3 frame and an aluminum 6061 frame showed that the strength of the aluminum frame is reduced by a factor of 2 as compared to the steel frame, the level and localization of loads remains at the same level, but the stiffness is reduced. The price of an aluminium frame is up to 10 times higher than a steel frame.

V. CONCLUSIONS

In the course of the work, a parametric model of the bicycle frame was developed; the influence of the design parameters of the bicycle on its handling and ergonomic properties was investigated; a trivimetric model of the bicycle and its frame was developed and the influence of its design parameters on its strength was analysed.

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DECISION SUPPORT SYSTEM FOR SUPPLYING LOGISTICS WHEN SUPPLYING RESIDENTS OF SMALL CITIES WITH DRINKING WATER IN EXTREME CASES

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Abstract. *This work is devoted to solving the problem of water delivery to residents of small settlements with a temporary disruption of their traditional water supply. The existing software tools are considered, their shortcomings are analyzed. The task of developing specialized software is formulated – a decision support system that allows you to calculate the optimal number of tanks, pave the way for each tank, and also determine the places of their best location in each district to maximize the satisfaction of all its inhabitants. Models and methods of the traveling salesman problem, finding the center of a cluster taking into account the weights of objects, connecting google maps to an autonomous application are described. An example of using the developed system for calculating the route and position of tanks providing the city of Toretsk in Donetsk region is given. The ways of further improvement of the model and application are outlined.*

Keywords: *water delivery, traveling salesman problem, optimal route, cluster center, google maps.*

I. INTRODUCTION

The task of providing water to settlements that have suffered as a result of environmental disasters or military operations is currently extremely urgent. Provision of drinking tap water is a strategic task of the state to ensure the life and sanitary and hygienic safety of the population [1-2].

If the work of the water supply system, available in most cities, is disrupted as a result of man-made disasters or other extreme events, then the delivery of water to the consumer is carried out using specialized vehicles [3]. In the districts (microdistricts, individual quarters, workers' settlements) of the city, temporary points of bottling of drinking water from tank trucks into consumer containers are being created [4].

The purpose of the work is to find the optimal travel routes and locations for vehicles that carry a certain amount of water for injured or deprived people of resources, using specialized software of our own design.

The object of the research is the delivery of water to the consumer using specialized road transport. The subject of the research is models, methods and information technologies for solving the problem.

II. LITERATURE ANALYSIS

Currently, there is a number of software solutions that allow you to calculate the optimal route for transport.

The Route4Me Route Planner [5], equipped with an English interface, allows you to calculate the best route when you need to go to several places. However, the calculated route is not always accurate.

ABM Rinkai TMS [6] is a program for automating the transport logistics of an enterprise. One solution combines route planning, execution control, customer information, analysis and assessment of the efficiency of using transport resources, including rented cars. The cloud service provided for rent does not require installation on the company's servers. Features are in access exclusively through the site (online), as well as the availability of paid content.

"Ant Logistics" [7] is a cloud-based transport management system: automatic route planning, assessment of the profitability of delivery points, GPS control of traffic routes, analytical reporting. The system cannot ensure the accuracy of the route construction, has a rather long registration period and does not have a demo version.

Google Maps [8] is a collection of applications built on top of a free mapping service and technology provided by Google. Solves the main problem such as finding the optimal route from one point to another. It can be used as an aid when developing your own application.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

We will consider the problem of providing water to the inhabitants of the city of Toretsk [9]. The settlement is located the closest to the demarcation line, accidents on the water supply network are frequent, their elimination is associated with a number of problems, and the city must be provided with water for several days using specialized vehicles.

The city is conditionally divided into six micro-districts, each of which is a home to a certain number of residents (Table 1).

Table 1. Number of inhabitants, people

No. nn	Microdistrict (name)	Population, people
1	Samanny	3325
2	Microdistrict	9392
3	Center	11495
4	Private sector	3870
5	Central market	3395
6	Zabalka	2901

Water is supplied from the starting point (as a rule, this is the Samanny area), and the car must then go around all the districts of the city (Table 2). The entire journey follows straight lines, there is no shortcut or detour. As a rule, there is only one tank, which increases the time of delivery of water to certain areas. Also, due to the difference in the number of people in different areas, it is difficult to calculate the time of arrival of the car in each of them.

Table 2. Distance between microdistricts, m

	Samanny	Microdistrict	Private sector	Center	Central market	Zabalka
Samanny	X	1310	900	1860	4800	4640
Microdistrict	1310	X	803	2420	4530	4175
Private sector	900	803	X	295	4050	3520
Center	1860	1390	295	X	1370	546
Central market	4800	4530	4050	1370	X	4920
Zabalka	4640	4175	3520	546	4920	X

There are two main tasks to solve:

– to determine the optimal route for the movement of specialized equipment and draw up its schedule;

– to determine the optimal placement of tanks in each area.

We assume the following:

– there are N specialized vehicles (tank trucks), $N \geq 1$;

– there is a list of M districts (micro-districts) of the city, indicating the size of the population Si in each (total for the city of residents);

– there is a table of distances between areas, taking into account the possibility or prohibition of direct passage between each pair of areas;

– the beginning of the path can be from different places: a) all cars leave from one selected point; b) each car can start moving from the point chosen for it;

– there may be restrictions on the volume of dispensed water per person.

We also assume that all specialized vehicles (tank trucks) are the same (have the same speed characteristics and can carry the same volume of water).

It is necessary to solve the following tasks.

1. Assuming that only one machine is operating, calculate its optimal route (the total path length should be minimal). The starting point of the path (the first of the neighborhoods) is specified by the user.

2. Having the optimal path, draw up a schedule of movement along the calculated route (time of arrival in each microdistrict), taking into account the average service time of one resident and the percentage of the population leaving for water.

3. Calculate the recommended (optimal) number of cars N (1..Nmax), based on the restrictions: a) the minimum and maximum volumes of water per inhabitant; b) allocated fuel limits. Movements between microdistricts can be ignored here.

4. Assuming that N cars are working, calculate the optimal route of movement of each of them so that: a) the total length of each path is minimal; b) the total population in the neighborhoods served by each vehicle was approximately the same. Also draw up traffic schedules along the calculated routes (arrival time in each microdistrict).

5. Determine in each district such a location for the cistern so that it is equidistant from all nearby houses and as convenient as possible for residents.

The first point is solved by using the classical problem of finding the optimal path - the “traveling salesman problem” [10-11], which looks like this: there are N

cities that the traveling salesman must go around with minimal costs; a traveling salesman must visit each of the cities exactly once. In our case, the task will look like this:

$$F(X) = \sum_{i=1}^{M}\sum_{j=1}^{M} C_{ij} X_{ij} \rightarrow \min, \quad (1)$$

M is the number of microdistricts with tank stops for water consumers;

C_{ij}, i, j = 1..M is the "cost matrix", where C_{ij} is the "transition costs" from the i-th micro-district to the j-th, that is, the distance between these micro-districts;

X_{ij} is transition matrix with components:

X_{ij} = 1, if the tank makes a move from the i-th microdistrict to the j-th,

X_{ij} = 0, if the tank does not move,

where i, j = 1..M, i ≠ j.

We have restrictions:

$$\sum_{i=1}^{M} X_{ij} = 1, \; j = 1..M, \quad (2)$$

$$\sum_{j=1}^{M} X_{ij} = 1, \; i = 1..M, \quad (3)$$

Condition (2) means that the tank leaves each area only once; condition (3) – enters each region only once; condition (4) guarantees that a route containing microdistricts M is closed and has no closed internal loops.

Since movement along one-way streets is possible, the distance between the i-th and j-th microdistricts, on the one hand, and the j-th and i-th, on the other hand, may be different:

$$C_{ik} \neq C_{ji} \quad (5)$$

Thus, we have an asymmetric problem statement. Since the number of microdistricts in the city of Toretsk is 6, to solve the problem, you can use the exhaustive search method, which requires no more than (n-1)! options (5! = 120).

The solution of tasks 2 – 4 follows from the solution of the first task - the determination of the optimal path. To find the optimal number of transport units, it is necessary to repeat the calculation of the best routes for different values of the number N, and then choose the most suitable one. The timetable is compiled automatically after entering the time to enter the route.

The last point of the assignment can be mathematically described as follows. Each of N districts has Mi houses (i = 1..N), each house Dj (j = 1..M_i) has conditional coordinates D_{jx} and D_{jy}. It is necessary to define such C_{ix} and C_{iy} so that the average distance from the house to the collection center (machine location) was minimal:

$$F_i(C_{ix}, C_{iy}) = \frac{\sum_{j=1}^{M_i} \sqrt{(D_{jx} - C_{ix})^2 + (D_{jy} - C_{iy})^2}}{M_i} \rightarrow \min, i = 1..N \quad (6)$$

We will find the centers of the aggregates of houses in this way. First, we find the preliminary coordinates:

$$C_{ix} = \frac{\sum_{j=1}^{M_i} D_{jx}}{M_i}, C_{iy} = \frac{\sum_{j=1}^{M_i} D_{jy}}{M_i} i = 1..N \quad (7)$$

Then we refine these coordinates by the coordinate descent method [12]. We also use the following assumptions: we consider the coordinates of a house to be its "geometric center" (the number of houses of a "special shape" is small, and we do not take them into account); since in each district there are houses of approximately the same number of storeys, the number of inhabitants in each house is calculated in proportion to the area of this house.

We will calculate the centers of aggregates of houses in three ways:

- "usual" geometric center of the cluster;
- taking into account the number of houses (see the previous paragraph);
- taking into account the number of inhabitants.

The last step is to connect to the Google Maps service application and demonstrate all calculations on the maps.

Next, we design the application and implement its software implementation in the visual programming environment.

IV. RESULTS

The structure of the designed system in the form of a class diagram [13] is shown in Fig. 1.

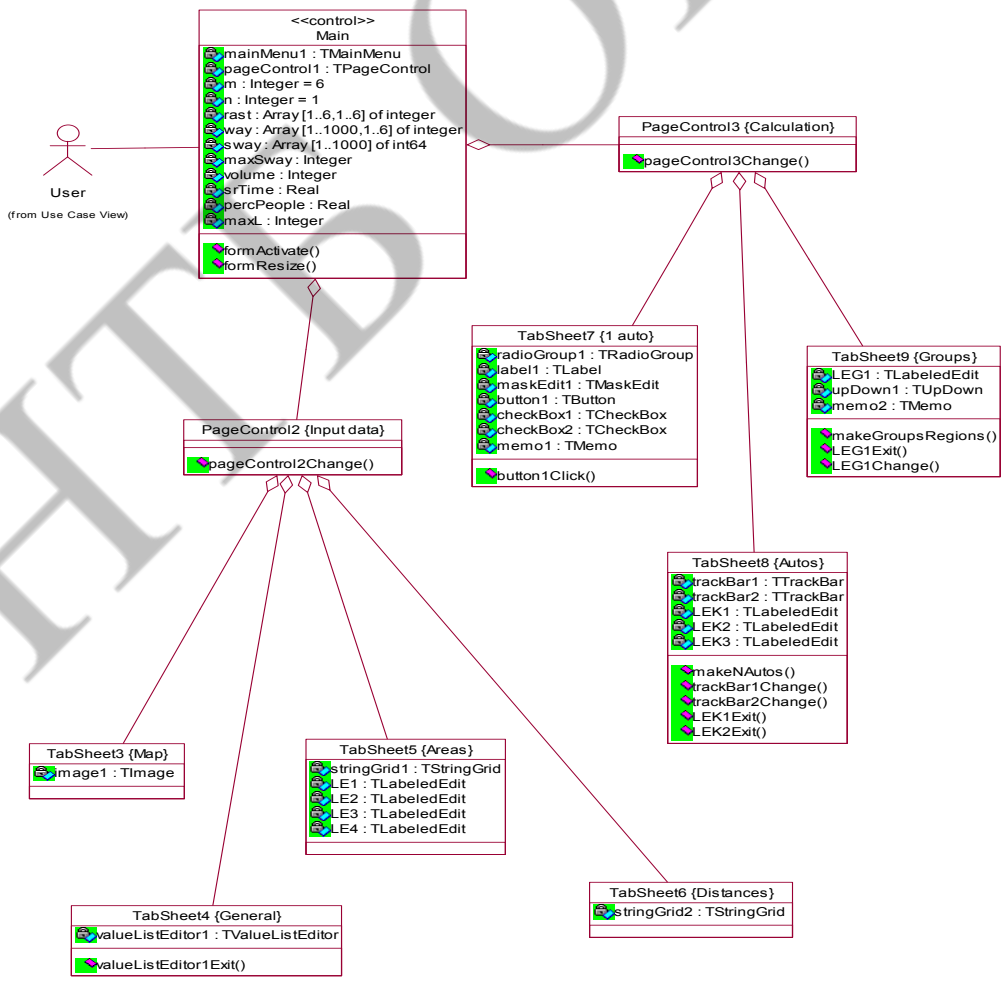


Fig.1. Class diagram

The main tabs of the application form are shown in the following figures. Fig. 3 provides general information that we need for calculations. The entered data on the population in the districts, restrictions on the volume of supplied water, the total number of residents, the time of service to the population in minutes and hours are shown in Fig. 3. Data in Fig. 4 show a list of distances between districts. Fig. 5 shows a map of the city in question.

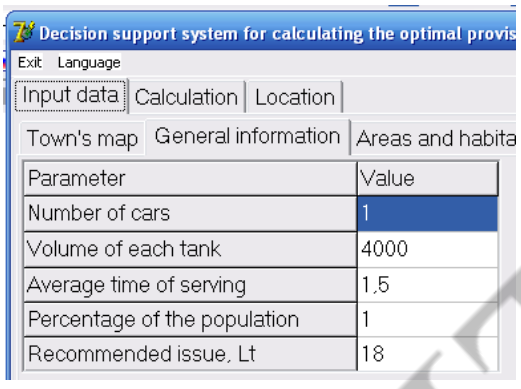


Fig.2. General Information

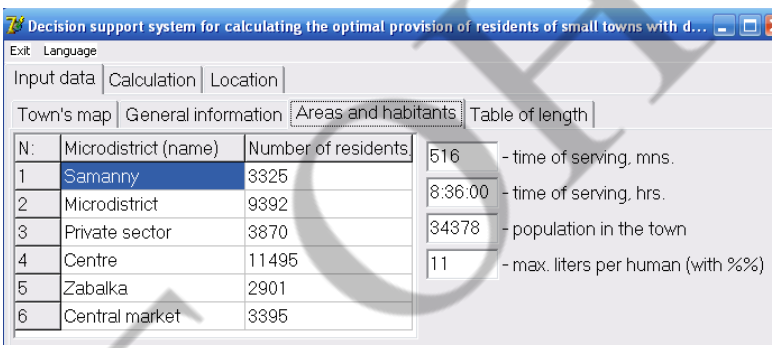


Fig. 3. Data on the number of population in the regions

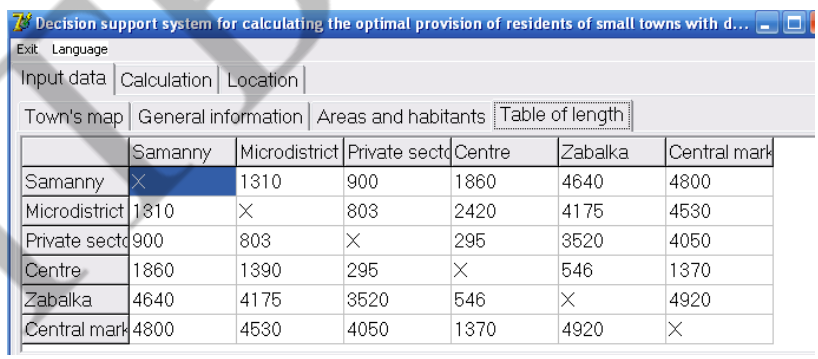


Fig. 4. Distances between areas

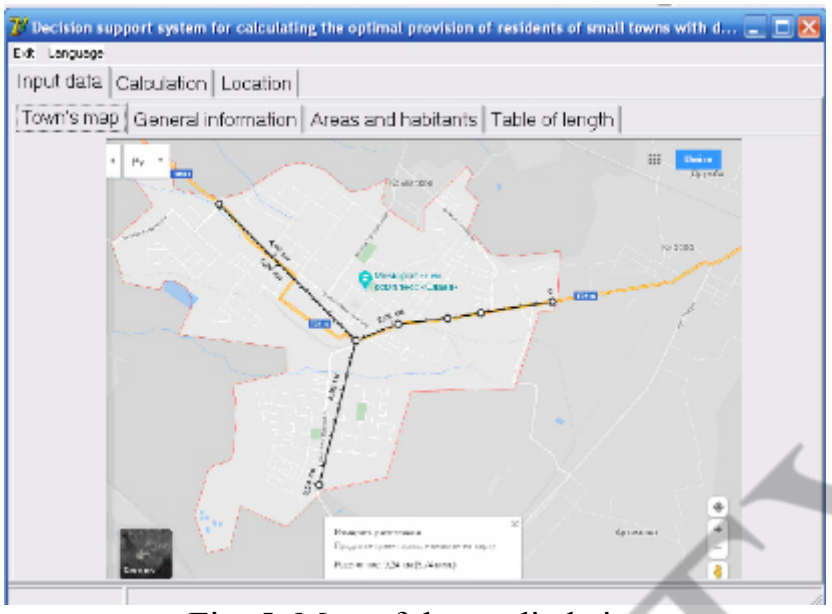


Fig. 5. Map of the studied city

In Fig. 6 shows the construction of the route from 9:00, taking into account the time of service by one car.

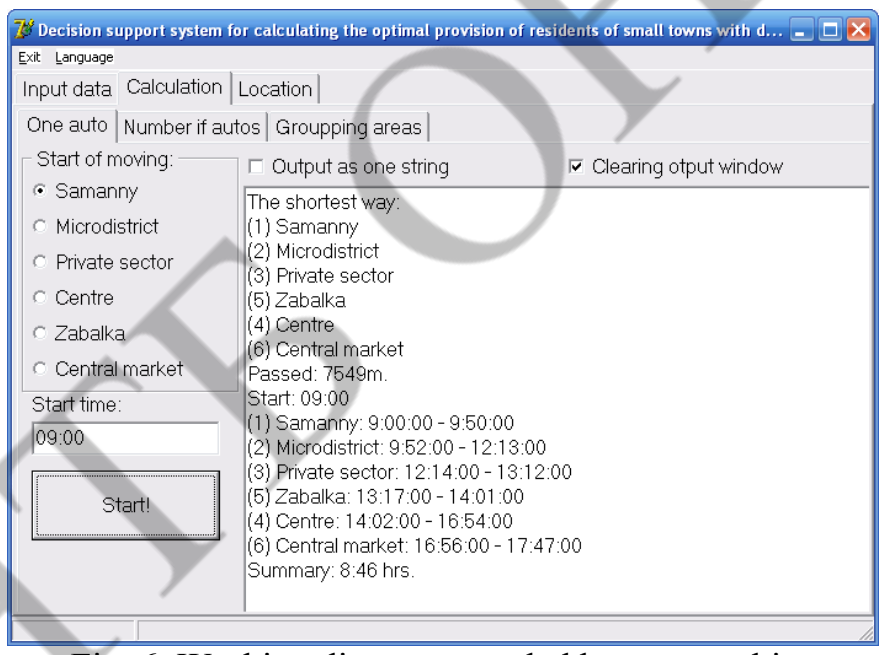


Fig. 6. Working distance traveled by one machine

Using the enumeration method, we found that the maximum possible and required number of cars is three units, as shown in Fig. 7. At the end of each line, the number of residents served by the specified car is indicated.

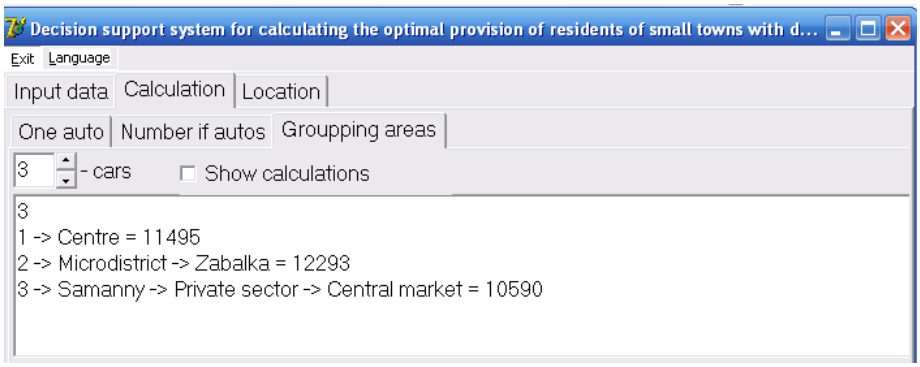


Fig. 7. Required maximum car availability

The problems considered were described in [14-16], the implementation is presented in [17].

But now let's look at the "Location" tab, where maps of the districts are loaded in the form of graphic files-schemes with the indication of houses (the maps were previously saved from the Google service). The system administrator marks residential buildings on the diagram, then the algorithm determines the center of the “cluster”, and the administrator “corrects” it on the map so that it “hits” the road.

In the lower right corner, the coordinates of the "center" and the average total "deviation" (ie the average path to the tank) are shown.

The blue "point" is the geometric center of the district, the red point is the center, taking into account the location of houses and residents (you can mark "taking into account residents"). In fig. 8 - 9 show examples of calculation for the Zabalka region.

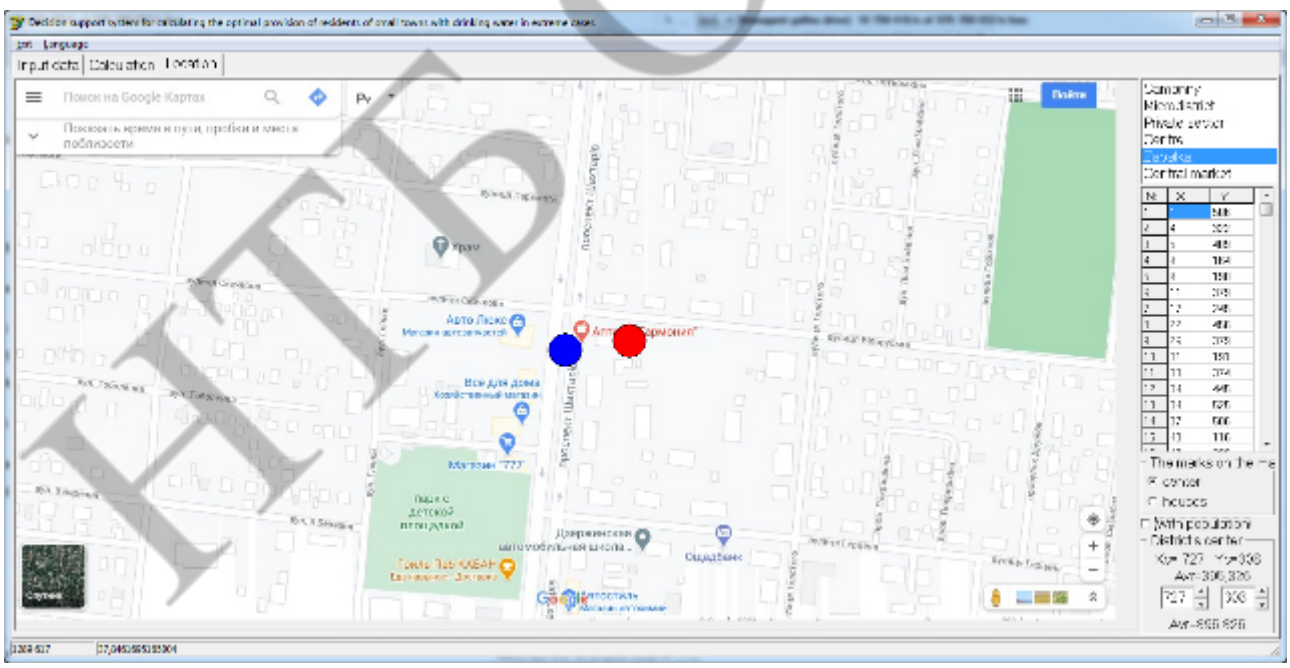


Fig. 8. Calculation of the centers of the Zabalka district, taking into account houses

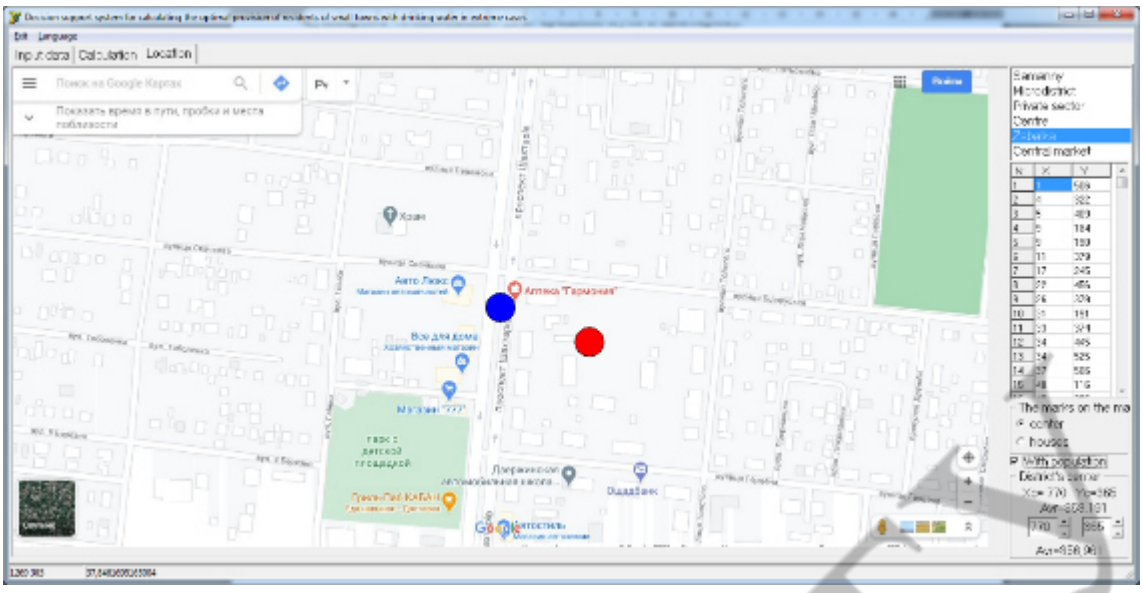
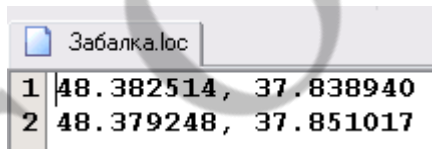


Fig. 9. Calculation of the centers of the Zabalka district, taking into account residents

As you can see, the geometrical center of the district, the center, taking into account the location of the houses, and the center, taking into account the inhabitants, are different.

The next stage of work was to determine the exact coordinates of the location of the tank on the ground. Files are created that contain GPS coordinates (Fig. 10).



Забалка.loc

```
1 48.382514, 37.838940
2 48.379248, 37.851017
```

Fig. 10. Coordinates of the Zabalka region

When switching to the "Input data" / "City map" item, the system checks the availability of Internet access, and if there is such, it loads a Google map with an automatic display of the district center (Fig. 11).

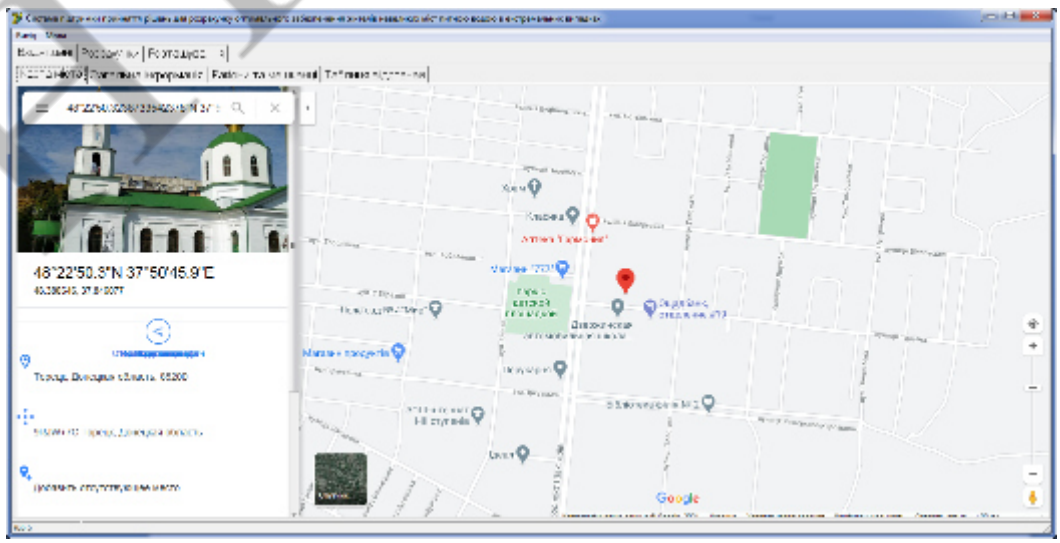


Fig. 11. Google-map of the Zabalka area

Next, we repeat the calculations for other areas of the city (Fig. 12 - 17).

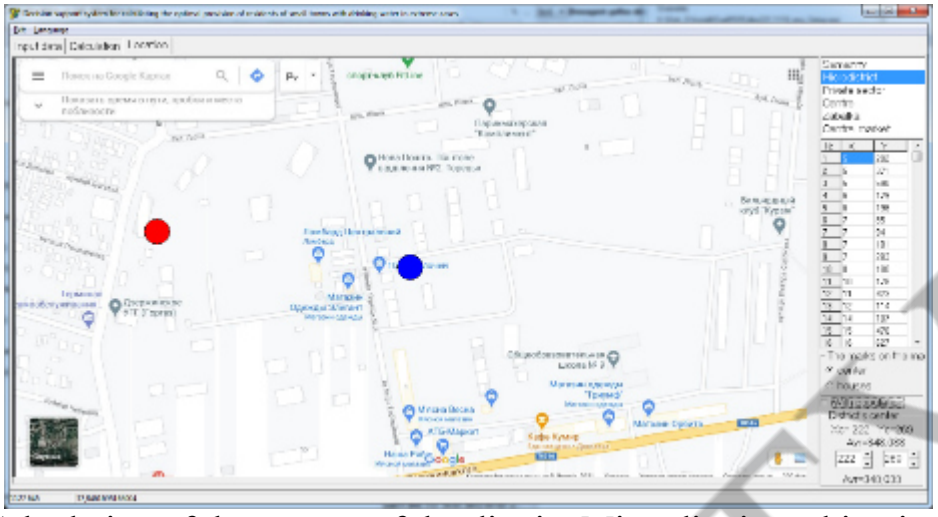


Fig. 12. Calculation of the centers of the district Microdistrict, taking into account houses

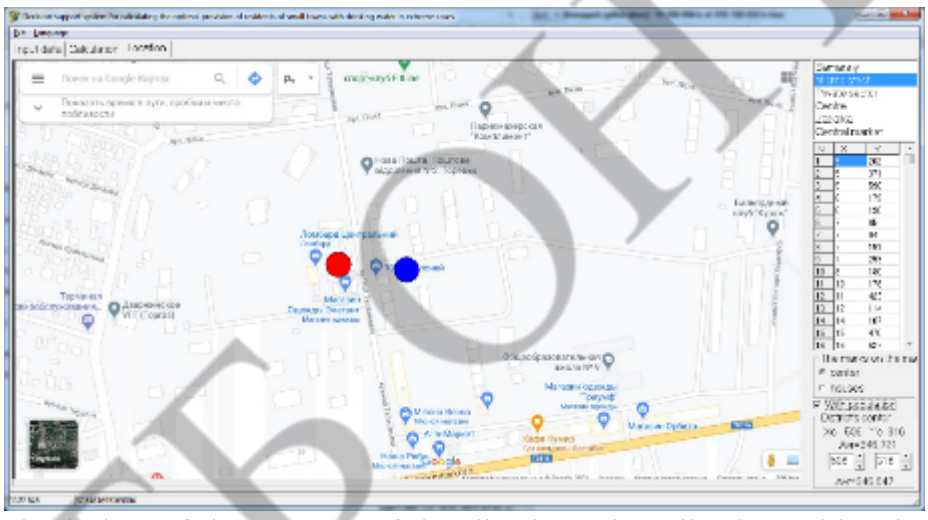


Fig. 13. Calculation of the centers of the district Microdistrict, taking into account residents

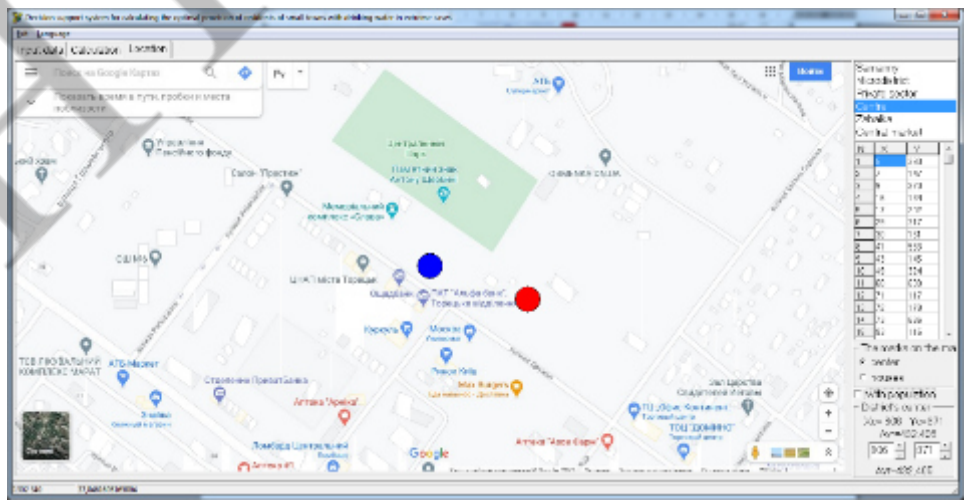


Fig. 14. Calculation of the centers of the Center district, taking into account houses

Fig. 15. Calculation of the centers of the Center district, taking into account residents

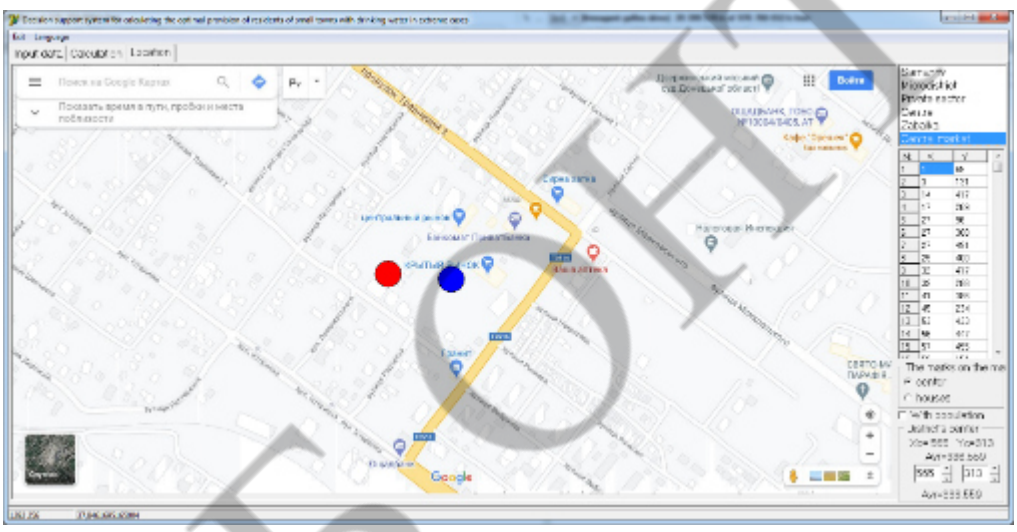


Fig. 14. Calculation of the centers of the Central Market district, taking into account houses

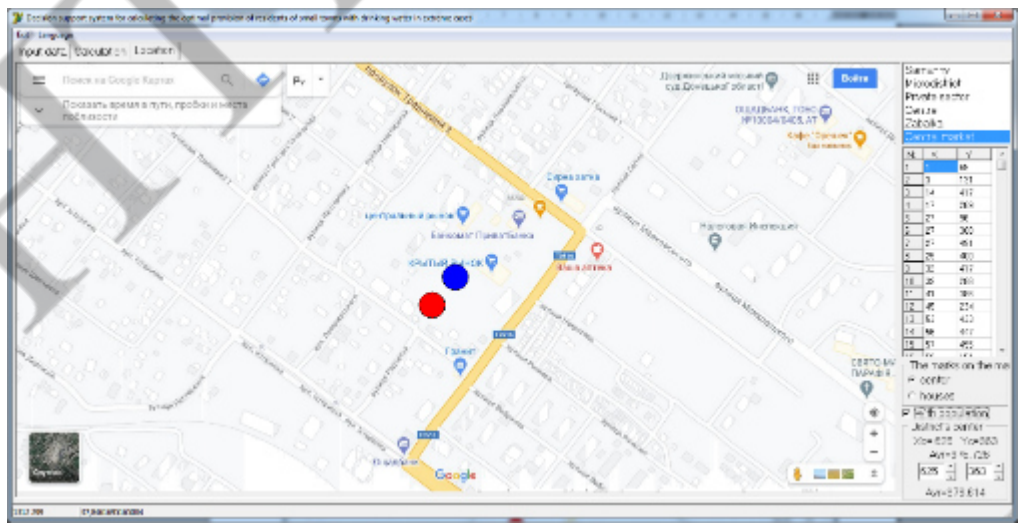


Fig. 15. Calculation of the centers of the Central Market district, taking into account residents

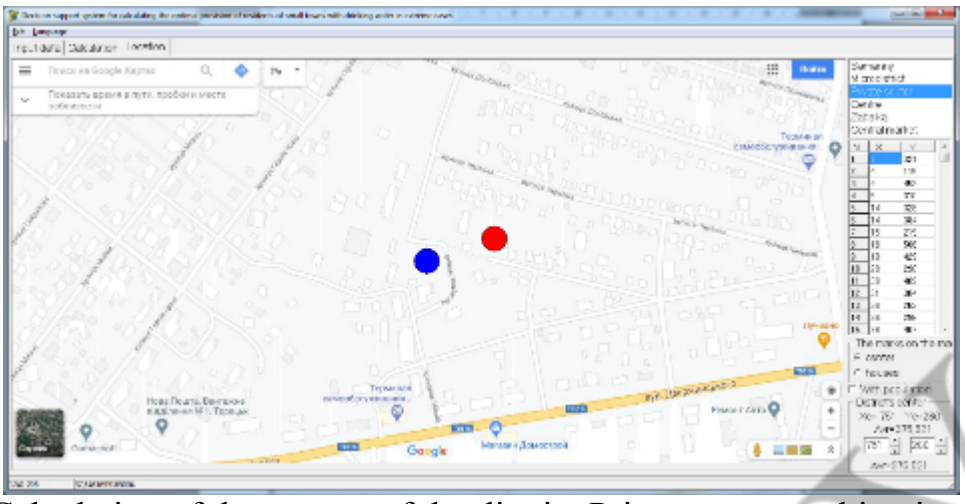


Fig. 16. Calculation of the centers of the district Private sector, taking into account houses

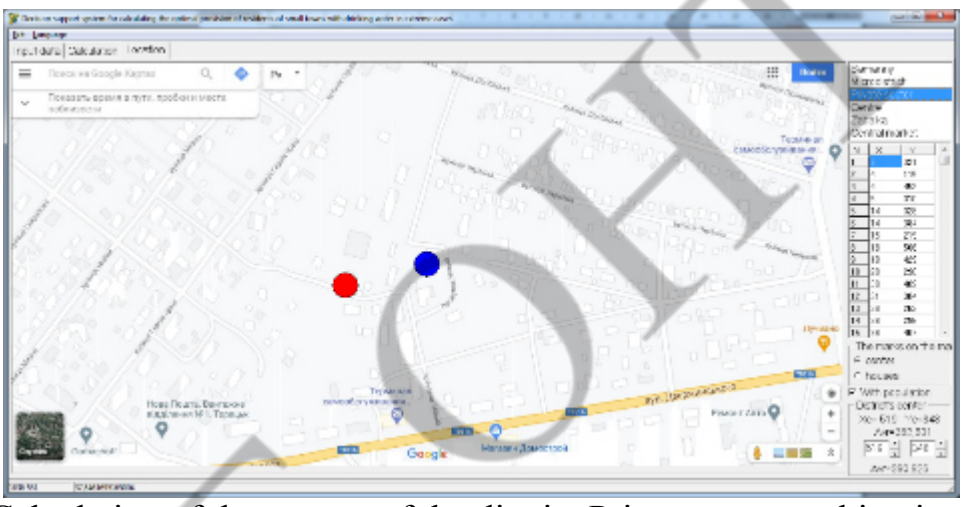


Fig. 17. Calculation of the centers of the district Private sector, taking into account residents

V. CONCLUSIONS

The work is devoted to the creation of an application that allows you to calculate the optimal route of the tank, providing residents of small cities with water in case of damage to the water supply system, as well as to determine the optimal location of the tank in each area to maximize the satisfaction of all its inhabitants [18].

Models and methods were used - the traveling salesman problem, finding the center of a cluster taking into account the weights of objects, connecting google maps to an offline application.

An example of using the developed application for calculating the route and position of tanks providing the city of Toretsk is given. However, when entering data for another city, the system will show the same satisfactory results.

The ways of further improving the model and application are outlined: if there are statistical data on accidents that occurred earlier on the water supply system of a given city, and the duration of repair work in each case, it is necessary to provide (ie predict) the duration of repair work to restore the city's water supply [19].

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USE OF WEB-TECHNOLOGIES IN THE PROBLEM OF DIGITALIZATION OF THE DORMITORY

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Abstract. *The paper considers the use of digital technologies in the field of education on the example of the development of software for automation of internal university processes, namely in the dormitory. The digitalization system was implemented on the basis of the development of two modules: an electronic check in and a module for monitoring indoor air indicators. The development of modules was based on the idea of developing an Internet system for digitalization of the dormitory and software implementation of modules.*

The electronic check-in module is intended for local use on the computer of the person responsible for registering students in dormitories, and for students using cellphone.

The concept of developing a module for monitoring the characteristics of indoor air on the example of Internet of Things technology, in which various gadgets connected to the Internet interact with each other.

The paper analyzes the existing methods of data transmission from sensors for the collection and accumulation of information flows of the dormitory ecosystem. Based on the obtained data and a monitoring system with a user interface with a chatbot was built.

All this will completely transfer some processes that exist in the dormitory and dean's office, to a mobile device or personal computer.

The developed methods will allow to optimize the internal processes of the dormitory, improve the life and ensure the health of the dormitory students from the influence of negative factors.

Keywords: *microprocessor, sensors, GoogleExcel, GoogleForm, internet of things, Processing, TelegramBot, Wi-Fi, interface.*

I. INTRODUCTION

Now is the era of the spread of digital technologies, which penetrate deeply into the very essence of many organizations and radically change the nature of innovation. Digital innovation is part of quality learning around the world.

Ukraine is already investing in information technology to remain competitive in the global market. The use of the latest information technology in the management of educational institutions helps to ensure the efficiency, effectiveness and efficiency of the administration and educational institution. One of the priority areas of education reform at the present stage is the introduction of digital and web-technologies.

In order to maintain the competitiveness of our specialists in Ukraine, digitalization is being actively carried out. The term "digitalization" it is a general term for the digital transformation of society and the economy. Since the modern world has

taken the direction of digitalization, the fact that the educational process will continue to move to electronic format is inevitable.

The modern educational process in higher education and related fields increasingly requires the use of digital and web technologies. Universities are always interested in the proper condition of their dormitories and the high standard of living of their students. We want to offer digitalization in the field of education. Our development will help solve one of the problems of using digital and web-technologies in the field of education, namely in the dormitory.

The dormitory, as part of the higher education process, also needs innovation. The idea of digitalization of the dormitory arose precisely because of the non-optimized internal processes that take place in the dormitory

Our system will completely transfer some processes that exist in the hostel, to a mobile device or personal computer.

II. LITERATURE ANALYSIS

A review and analysis of dormitory Internet information systems revealed that there are many different systems in terms of design and functionality, but there are almost no full-fledged ones, including those designed for electronic settlement using mobile devices.

Existing systems do not allow you to choose a room and register in the online queue for the commandant, but only provide background information and allow you to leave an application for settlement.

To formulate the requirements for functionality for the development of the Internet system of the dormitory of higher education, several existing systems were considered, namely: information resource of Vasyl Stefanyk Precarpathian National University, platform for digitalization of the dormitory of Kyiv Mohyla Academy (in test version), National University software module "Studgorodok").

Consider the systems contain a lot of information that is very useful for students and parents of future residents of the dormitory, but the disadvantages of these systems are that they all use paid Microsoft products, run only on Windows, and complex client-server system and distributed databases data contribute to material complications in the implementation of these complexes

An analysis of existing solutions suggests that none of the considered Internet systems fully meet all the criteria for providing functionality and information content.

We researched all the internal processes of the dormitory and identified a number of problems that can be solved by digitalizing this process.

The architecture of our platform for creating a dormitory digitalization system will be divided into several modules that will work separately and, if necessary, will be able to exchange data.

We can highlight the following modules:

- Module of electronic settlement and registration of students in dormitories;
- Module for monitoring climate control indicators
- Automation of dormitory electronics;
- Module with internal social network [1].

Consider the first two modules of the system, which were implemented in the work.

1. The module of electronic settlement and accounting of students in the dormitories of the university is an urgent technical task, the solution of which will improve the lives of students

The processes of settlement and registration of students are currently not classified or standardized - there are no unambiguous, or any special software that would help reduce the cost of paper and would increase the level of information support of the university.

Due to the lack of automation of the settlement process in dormitories, queues are formed and large, undesirable crowds of people (especially in quarantine). Dormitory commandants and deans during this period were loaded with a large influx of students. The module responsible for the settlement must implement functionality that will reflect the current state of all rooms in the dormitory, be able to choose the floor, room, student who already lived in it, number of places and employment in order to optimize the amount of information to send to the client.

It should also implement an online queue for the commandant, for which you need to implement an algorithm in the theory of queuing, which will optimize the queue and assign a specific time of admission to each student depending on the student's capabilities and employment of the commandant and dean. This task will be the next step in the process of digitalization of the hostel.

It was the task of the software to develop software that would reduce the amount of paperwork, make the dormitory settlement process more transparent to students, and speed up the process.

To achieve this goal during the study, the following tasks were solved:

– to analyze the legal framework that ensures the accommodation of students in dormitories at the national and university levels;

– identify ways and means to achieve this goal, which will be adequate to the material level of the university and the educational system of Ukraine;

– analyze the process of settling students in dormitories, identify places that require a lot of time and operations that can be automated;

– to test the ease of use of the developed software.

2. Module for monitoring indoor air indicators

This module was developed on the example of the Internet of Things "Smart" dormitory, in which different devices interact with each other. Connected data sensors and export of meteorological data to remote storage, will control and influence the work of many processes.

The whole project is Minimum viable product — MVP, which is a product with minimal functionality that can be given to users to use in their tasks. Minimum viable product is used to test ideas in the development of programs with minimal resources. how much the product will be valuable and in demand in the market [2,3]. For our task, Minimum viable product is used to test ideas in the development of programs with minimal resource costs.

The current changes in technology and data transmission, many call the fourth industrial revolution. The most relevant topics in 2020 are artificial intelligence, neural

networks and the Internet of Things. The Internet of Things (IoT) is a concept that allows physical objects to interact with each other or with the outside world, partially or completely without human intervention.

This term was introduced when the number of things and objects connected to the Internet exceeded the number of people. The Internet of Things can be defined as a set of intelligent objects that can respond to the environment and process information, bridging the gap between the physical and virtual worlds and sending it to other objects using Internet protocols [4,6]. It has built-in "sensors" and software that allows the transfer and exchange of data between the physical world and computer systems in automatic mode, using standard communication protocols.

As a result, "the Internet will no longer be a network of connected computers, but will become a network of integrated objects" [5,11]. Currently, with the help of systems such as GSM, WiFi, Bluetooth, ZigBee, Z-Wave, but also beacons, photocells or wireless sensor networks (Wireless Sensor), a new network concept is being created.

An Internet of Things network can help improve eco-processes in a dormitory, home, or business.

Thanks to "smart" hardware and installed software, the device is able to "feel" what is happening around and communicate it to the user through a certain communication channel.

The aim of the study to develop a model for monitoring air indicators was to analyze sensors, data transmission channels and the accumulation of information flows of the ecosystem in the room. with the interface of interaction with the user through a chatbot.

The system will allow you to monitor the ecosystem data in the room where the user lives and respond quickly to dangerous situations that may occur at the facility in real time and at a distance.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Almost all universities in our country offer affordable accommodation in dormitories. Students are usually housed for 10 months - the academic year, after which the student must leave the dormitory. After the summer holidays, students who want to live in a dormitory have to go through a difficult bureaucratic process. Every year, when settling in the dormitories of the university, students and employees of the university are subjected to psychological and physical overload. Confusion caused by difficult paperwork, non-transparency of the settlement process can freeze the first days of the educational process, which can be fatal in further studies, and cause stress to university staff, which will result in their productivity.

The purpose of this work was to develop a system that will help keep the nerves of both students and university officials, reduce the amount of paperwork, make the process of settling in dormitories more transparent for students, save money.

And the development of indoor air monitoring system will allow students to ensure their health from the effects of negative factors and avoid accidents.

The object of research is the process of organizing the management of university dormitories. It is not possible to analyze the object without the subject of research. The dormitory digitalization system was chosen as the subject of the study. The choice of

such a subject area was caused by non-optimized internal processes of the dormitory.

The aim of the study was to develop two modules: one of the modules of the client-server platform for digitalization of a modern dormitory, namely, the module "Electronic Settlement" and identification of students living in the dormitory, and the module for monitoring indoor air.

The research methods for the development of system modules were based on the idea of developing an Internet system for dormitory digitalization and software implementation of modules. During the implementation of the module of electronic settlement of students it was necessary to determine the categories of users of the system, the ability to access the Web-system, to analyze the regulatory framework. The e-student module includes the development of a GooglForm student questionnaire, the creation of an electronic "Standard contract" based on data from the questionnaire, the development of Google Spreadsheets, which is used by the dean's office to create "chess" for populated students. An Excel page with relevant data is created in parallel for the guide. The e-settlement module is intended for local use on the computer of the person responsible for registration of students in dormitories, and for students - with the use of mobile devices.

The concept of developing a module for monitoring indoor air indicators is considered on the example of Internet of Things technology. The development of the system was based on Minimum viable product - a product with minimal functionality. and minimal resource costs. The concept of system development is considered on the example of a smart dormitory, where one of the components of the system is the technology of the Internet of Things, in which different devices are connected to the Internet and interact with each other. The sensors will allow the device to send data to a computer program that will collect and analyze them. This will effectively identify the problem in case of deviations from the standard during the operation of devices and will facilitate the prediction of possible accidents, malfunctions.

IV. RESULTS

Consider the implementation of the first module of the dormitory digitalization system – the module of electronic settlement.

The e-settlement module includes the development of a Google Form for a student living in a dormitory and the creation of an electronic "Standard Agreement", according to the data drawn from the questionnaire. An Excel page with the relevant data is created in parallel for the manual.

Each student has the opportunity to fill out a questionnaire:

– choose a room;
– draw up a document and submit it to the dean's office remotely;
– get a list of necessary documents for settlement in a dormitory;
– avoid the queue for approval of documents in the dean's office and reception by the commandant to resolve personal issues.

The task of electronic settlement also includes the development of a QR-code of a student living in a dormitory.

The algorithm of the system has the following stages:

1. When a student settles in a dormitory, he will be given a QR-code. When scanning the QR-code, it will be redirected to the Google Site, through which the student will be able to get acquainted with detailed information about the university dormitories, contacts of their leaders and the rules of living and using dormitories (Fig. 1).

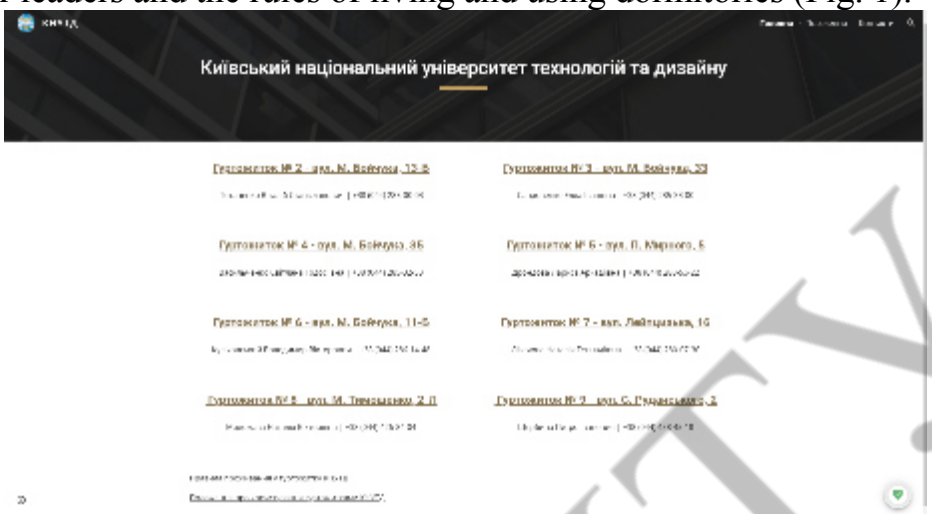

Figure 1. Google Site for student navigation.

2. On the page "Settlement" the student has an opportunity to get acquainted with free rooms (fig. 2) and to submit the electronic application for settlement to a hostel.

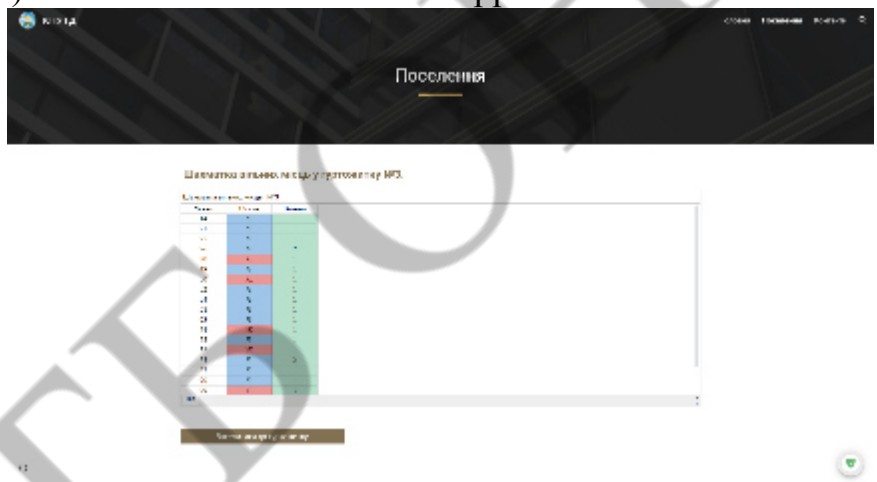

Figure 2. Google Site - "Settlement" page.

3. By clicking the "Settle in the dormitory" button, the student will be redirected to the Google Form to fill in the data required for the contract (Fig. 3).

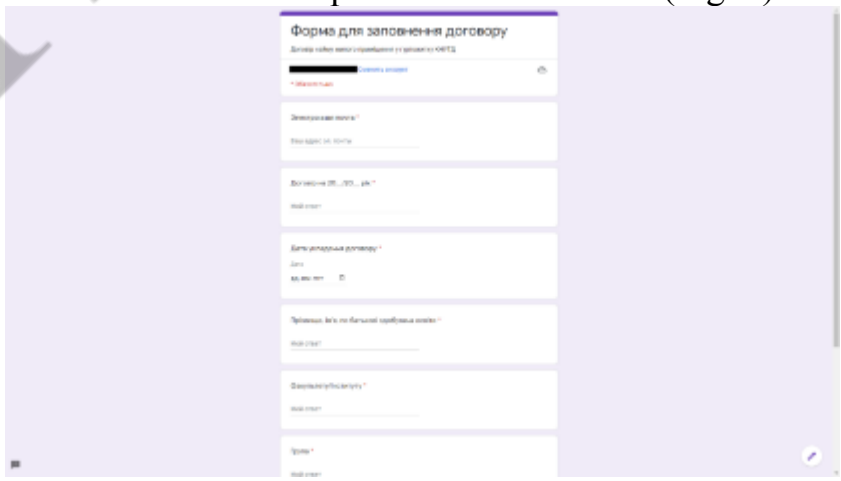

Figure 3. Google Form to fill in the data.

4. After filling in the form with data and sending it, 4 events will take place:

– All student data is sent to the Google Spreadsheet (Fig. 4), which will be used by the dean's office to create a checkerboard for settled students (Fig. 5).

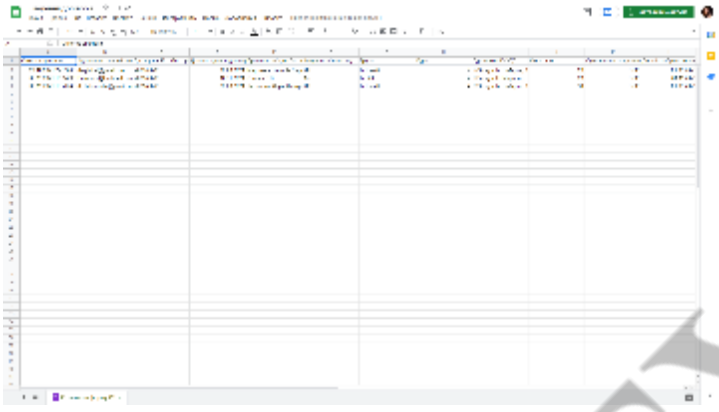

Figure 4. Google Excel as a list of students who have completed the form.

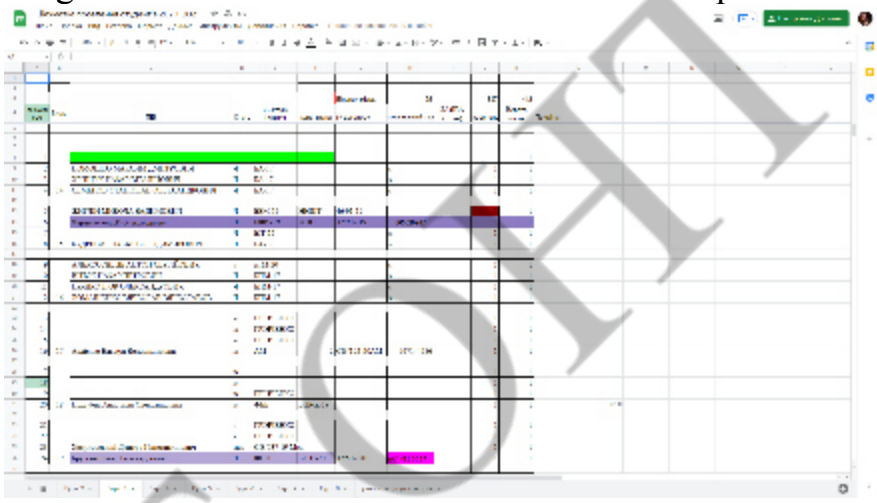

Figure 5. Google Excel as a document for settled students.

– A contract is created in Google Docs (Fig. 6).

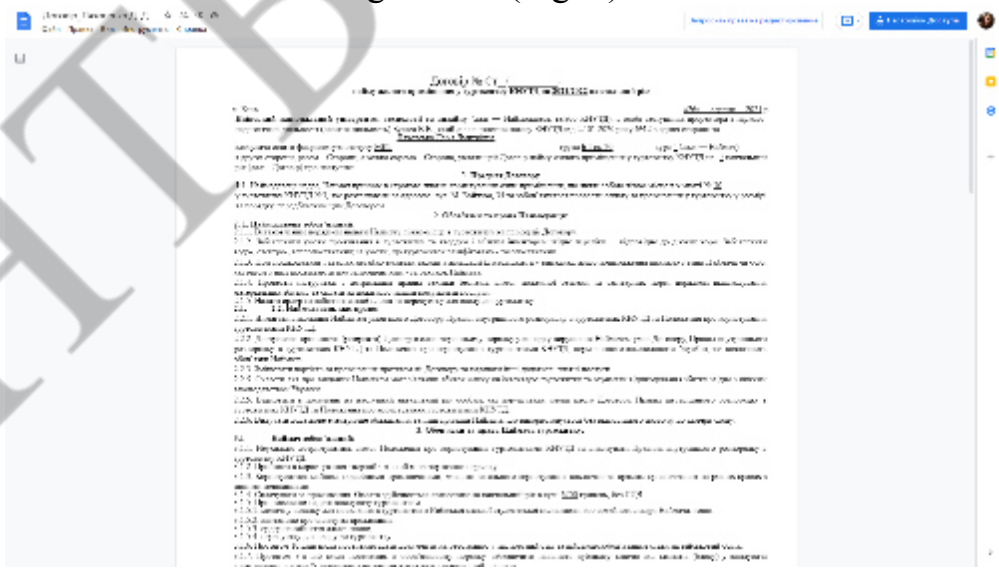

Figure 6. Google Docs Agreement.

– A QR code is created with brief information about the student.

– The contract and QR-code are sent to the mail specified by the student (Fig. 7).

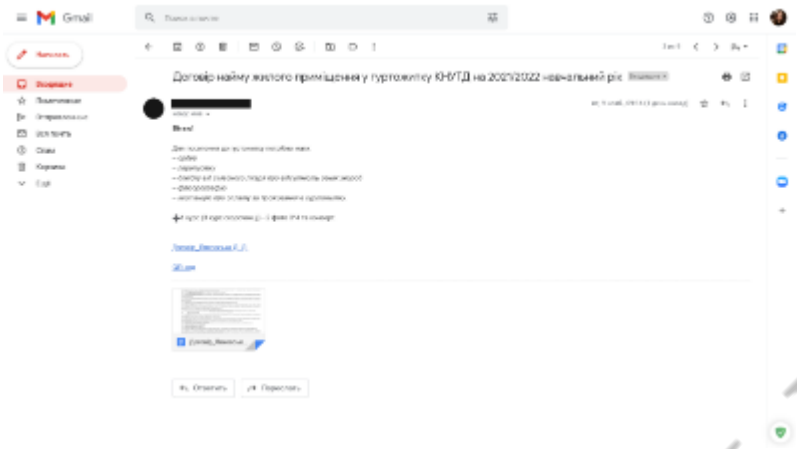

Figure 7. Letter with a document and QR-code.

5. Then the student has to print out and sign the contract.

The generated QR-code will be further used by the student to enter the dormitory.

All this will transfer some processes that exist in the dormitory and in the dean's office, in a mobile device or personal computer, will identify students in the dormitory and will make a modern system of entrance to the dormitory and student accommodation.

Electronic settlement is a part of the task of digitalization of the dormitory, which we have already implemented and is undergoing a testing phase on the example of the dormitory №3.

All the problems that exist in the dormitory are not unfounded, it lasts for years and the creation of our application can be a turning point in relation to the organization of student life.

2. The second module of the dormitory digitalization system - the module of monitoring of indicators of air in the room

To implement the task, the following development components were used:

1. Software (software) development environment for microcontrollers;
2. Processing programming language (based on Java);
3. Program code and subsystem elements.

In the course of solving the problem, microcontrollers such as Arduino UNO, Arduino Nano, MEGA, Espressi were analyzed. Based on the analysis, we chose a wireless microcontroller that can be installed in an intelligent device. A smart device is a device that can be controlled over a Wi-Fi network.

The monitoring module, as a set of sensors, is represented by two sensors: one (digital) for measuring temperature, humidity and atmospheric pressure from Bosch BME280; another sensor is analog for measuring ultraviolet radiation GYL8511, which emits an output signal and further in the code we can operate with the values we need [3].

The ESP8266 microcontroller was chosen to develop the element base, which is currently one of the highly integrated solutions for working with Wi-Fi [4].

A user-friendly interface is required for the full operation of any automated database. TelegramBot was chosen as the interface for storing information system data. The services send the result to the device, and the result itself will be in the bot itself.

The search is conducted in the form of communication in the interface, which specifies what data will be collected. The functions of the Telegram bot have the ability to execute commands in chat. These commands will directly trigger certain actions or request new information.

We chose NodeRED as a programming tool. It allows you to connect hardware devices, APIs and Internet services. The RedBot package for NodeRED was used to write the bot.

Algorithm for testing the main functions of the system.

1. Create wireless access points. The module connects to Wi-Fi with Internet access. An access point is created.

2. At a certain IP address, go to configuration mode. Checking the system to create an access point (Fig. 1). The created access point is password protected to ensure the security of the subsystem settings and to avoid changing the settings by the user who was not granted access.

3. Specify the name and password of the Wi-Fi network to which the monitoring module should be connected

4. Select the server to send data. Indicate the dormitory number and the room to which the module with sensors will be attached.

5. Set the interval of data exchange (Timing of information). In the settings, specify the period of time after which the update will take place, for example 20 minutes. Every 20 minutes it will dump data to the server.

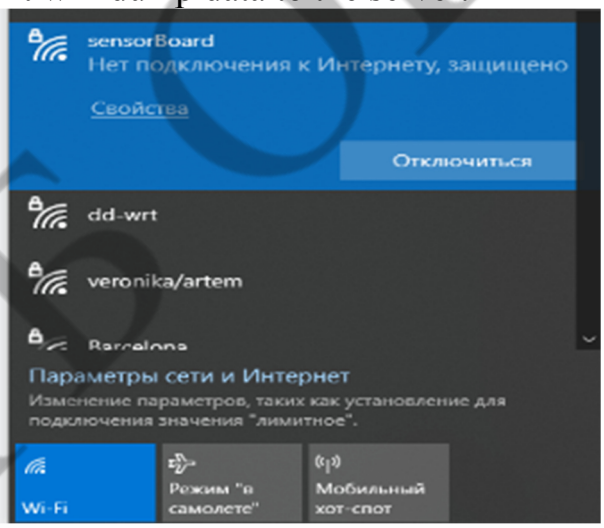

Fig.8 - Created wireless access point

Upon successful connection, all information from the monitoring module, in particular location data and sensor readings, is generated in the data packet and sent to the address specified in the settings. server at a specified interval

On the NodeRED side, HTTP codes and the user code block process this data and store / send notifications to the user.

6. To start communication with the bot, click "start". The user receives a message in which you can actually see what can be useful for this bot (Fig. 9).

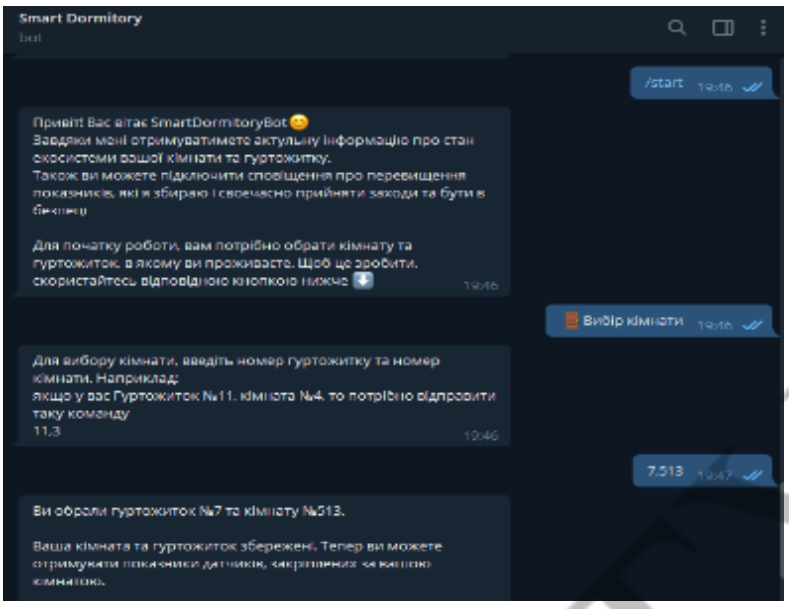

Fig.9. Communication with the bot. Choosing a room

There is a separate custom keyboard with different commands, the variety of which depends on the selected action (Fig. 10). The "Main Menu" and "Back" buttons remain unchanged.

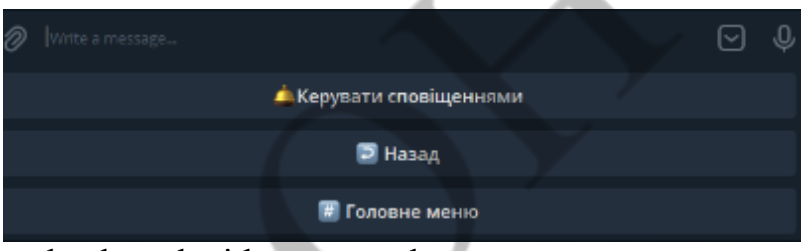

Fig.10. Custom keyboard with commands

7. By clicking on "View indicators", the user will receive all the data on the state of the ecosystem of the room, which are studied: air temperature, humidity level in the room, CO2 level, air quality (Fig. 11).

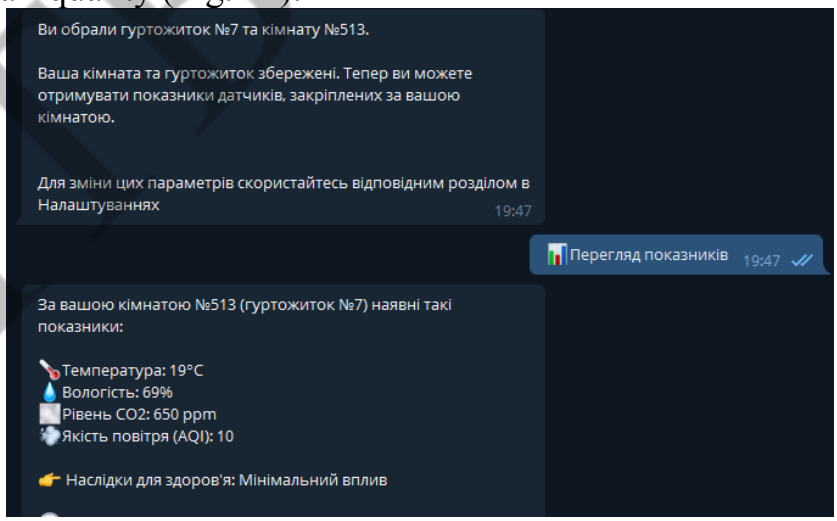

Fig.11. View room ecosystem performance

Example,

1. Indicator of the concentration of CO2, characterizes the accumulation of viruses in the air, which is especially important today during the pandemic of coronavirus infection

2. Changing the temperature in the dormitory rooms will show where there is

unauthorized use of heaters and other devices that can lead to a fire hazardous situation.

To protect your health from the effects of negative factors, you can enable notifications of changes or exceedances of certain indicators. (Fig. 12).

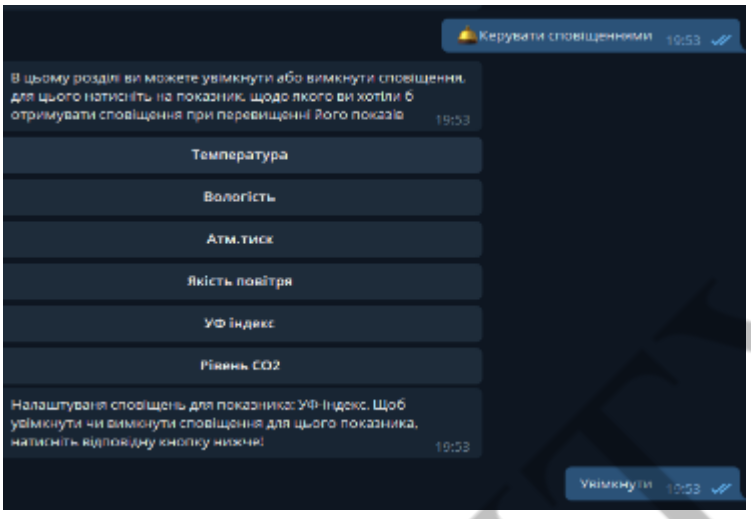

Fig.12 - Enable notifications of changes in indicators

V. CONCLUSIONS

The issues of digitalization of the dormitory on the basis of development of two modules were considered in the work: the module of electronic settlement and the module of monitoring of indicators of air indoors. This is part of the task of digitalization of the dormitory, which has already been implemented by us and is undergoing testing at the dormitory №3 and №7 of the Kyiv National University of Technology and Design in May-September 2021.

The first module - e-settlement module, can be used in any university or other organization that requires automation of the process of settling people in dormitories and accounting for the current state of occupancy of the dormitory in real time. The use of this software product will reduce the time spent by the staff involved in organizing the settlement process, and as a consequence reduce the material costs of the settlement.

The second module - the module of monitoring of indicators of air in the room will give the chance to trace data in a dormitory room, will send notifications on their changes and promptly react to dangerous situations in case of deviations from the standard. The development of the module was considered on the example of a smart dormitory, where one of the components of the system is the technology of the Internet of Things.

All the problems that exist in the dormitory are not unfounded, it lasts for years and the creation of our application can be a turning point in relation to the organization of student life.

The developed models and methods of their application allow to optimize the internal processes of the dormitory and will be able to improve the lives of students in the dormitory and ensure the health of students from the effects of negative factors.

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IMPROVING THE LEVEL OF DETAILING IN THE FORMATION OF REALISTIC THREE-DIMENSIONAL SCENES

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Abstract. *The issue of increasing the level of detail in the formation of realistic three-dimensional scenes is considered. An expression is obtained to determine the vector at any point on the surface bounded by a triangle; splitting the output triangle into components with the same area, to achieve a balanced load of shader processors; The obtained relations for detailing the surfaces of three-dimensional objects by Serpinsky triangulation; For the first time, it is proposed to perform triangulations of three-dimensional objects depending on the maximum values of colour intensities on the edges of the triangle, which allows the use of adaptive triangulation.*

Keywords: *rendering, triangulation, vectors of normals, polygonal network, detailing of surfaces, normalization of vectors, barycentric coordinates*

I. INTRODUCTION

The graphic form [1-13] of the representation is the most informative, so realistic images are useful in almost all engineers and scientific tasks for the visual reproduction of real objects.

At the present stage of the development of computer graphics, the development of new methods and means to increase the realism of the formation of three-dimensional images is a priority [1, 2], as traditional approaches do not always provide the required quality of image formation.

The aim of the work – is to improve the realism of the formation of three-dimensional images by increasing the detailing of the surfaces of the scene.

Scientific innovation.

1. An expression is obtained to determine the vector at an arbitrary point of the surface bounded by a triangle by the values of the vectors at its vertices and the barycentric coordinates of the current point, which allows to detail of the surface to increase realism.
2. The proposed division of the output triangle into components with the same area allows achieving a balanced load of shader processors.
3. The obtained relations for detailing the surfaces of three-dimensional objects by Serpinsky triangulation, which makes it possible to increase the realism of the formation of three-dimensional images.
4. For the first time, it has been proposed to perform triangulations of three-dimensional objects depending on the maximum values of colour intensity on the edges of a triangle, which makes it possible to use adaptive triangulation.

The practical significance of the work is to develop on the basis of theoretical research algorithms and triangulation programs and integrate them into the professional graphics engine idx3d.

8 scientific works have been published on the topic of research, including one article in a professional publication.

II. LITERATURE ANALYSIS

To simplify the task of constructing three-dimensional graphic objects, its surface is approximated by piecewise-linear sections [1-3], using a network of spatial triangles in the predominant event.

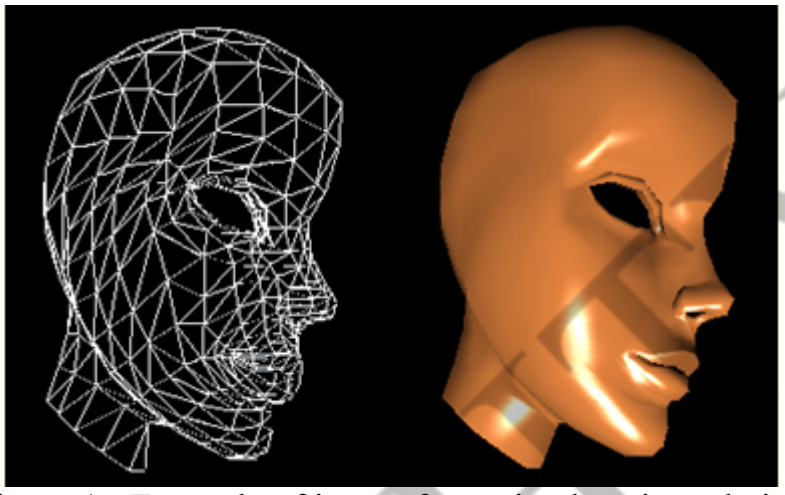

Figure 1 - Example of image formation by triangulation

The most common division of images into triangles is explained by the following reasons [1-3]: a) a triangle is the simplest polygon, the vertices of which uniquely define the face; b) any surface can be divided into triangles; c) the computational complexity of algorithms for dividing areas into triangles is significantly less than when using other polygons; d) the implementation of rendering procedures is the easiest for the area bounded by a triangle; e) for a triangle it is easy to determine its three nearest neighbours that have common faces with it.

Any surface can be represented, with the required accuracy, by a network of triangles [1-3], the accuracy of the approximation is determined by the number of triangles and the method of their selection. At the same time, it is important to reach a compromise between the quality of the final visualization and the load on graphics.

The number of triangles in a network is largely determined by the complexity of the object. For example, building a model of the human head requires about 60 thousand triangles.

Triangulation is an important procedure when using three-dimensional modelling to diagnose diseases in medical practice [7, 11].

Of course, the use of a triangle as the simplest polygon leads to the fact that the surface is insufficiently smoothed. One possible approach to improving the quality of image formation is to condense the network of triangles until an acceptable by some criteria local surface smoothness is achieved.

Triangulation of surfaces for the subsequent painting is carried out.

When painting a 3D object, normalized vectors [1, 2] to the object surface, light source and observer, as well as auxiliary vectors depending on the choice of lighting model are determined. Vector normalization requires three-division operations, three multiplication operations, two addition operations, and a square root finding operation,

which are quite time-consuming. In this regard, the urgent issue is to simplify the normalization procedure in order to implement it in hardware.

NVIDIA scientists have obtained a formula for the approximate normalization of vectors using a single step of Newton-Rafson iteration: $\vec{N}_n \approx \vec{N} \cdot (3 - \vec{N} \cdot \vec{N}) / 3$ [1] Although the given formula is quite simple, large errors in determining the orthogonal components of the vector limit its use for painting problems.

R. Lyon [1, 2], using the Taylor series decomposition of the expression, $1/\sqrt{\vec{N} \cdot \vec{N}}$, obtained a formula for the approximate normalization of the normal vector

$$\vec{N}_n \approx \vec{N}\left(1 - \frac{1}{2}\left(\left(\vec{N} \cdot \vec{N}\right) - 1\right) + \frac{3}{8}\left(\left(\vec{N} \cdot \vec{N}\right) - 1\right)^2\right), \quad (1)$$

in which the division operation is replaced by an offset, which simplifies hardware implementation. Unfortunately, the formula has a large approximation error, which limits its application.

The interpolation of unit vectors between the initial and final vectors can be performed by the formula [1]

$$\vec{N}(w) = \vec{N}_a \frac{\sin((1-w)\psi)}{\sin\psi} + \vec{N}_b \frac{\sin(w\psi)}{\sin\psi}, \quad (2)$$

where $w \in [0,1]$, while ψ – is the angle between the vectors $\vec{N}_a$ and $\vec{N}_b$. The calculation of vectors involves determining the sine, the resource-intensive function of the arccosine to find the unknowns w and ψ, as well as performing the division operation.

The given short analysis of painting problems has shown that it is necessary not only to perform triangulation, but also to find vectors to the vertices of the obtained triangles.

2. Development of methods for improving the level of detail in the formation of realistic three-dimensional scenes

2.1 Balanced triangulation of the triangle

When developing methods to increase the level of detail in the formation of realistic three-dimensional scenes, it is important to achieve a balanced load of shader processors. This can be achieved by dividing the original triangle into constituent triangles with the same area.

Let's prove that in a triangle with vertices $P_1(x_1,y_1)$, $P_2(x_2,y_2)$, $P_3(x_3,y_3)$ there is a point with coordinates

$$x = \frac{x_1 + x_2 + x_3}{3}, \qquad y = \frac{y_1 + y_2 + y_3}{3},$$

which is connected to the vertices P1, P2, P_3 divides $\Delta P_1 P_2 P_3$ into triangles of equal areas.

Let $P_1P_2P_3$ – be a given triangle, the coordinates of the point O satisfy the following conditions:

$$x = \frac{x_1 + x_2 + x_3}{3}, \qquad y = \frac{y_1 + y_2 + y_3}{3}. \qquad (3)$$

Areas $\Delta P_1 P_2 O$, $\Delta P_2 P_3 O$, $\Delta P_3 P_1 O$ (Fig. 2) are respectively equal to:

$$S_1 = \frac{1}{2}\begin{vmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ \frac{x_1 + x_2 + x_3}{3} & \frac{y_1 + y_2 + y_3}{3} & 1 \end{vmatrix} \qquad S_2 = \frac{1}{2}\begin{vmatrix} x_2 & y_2 & 1 \\ x_3 & y_3 & 1 \\ \frac{x_1 + x_2 + x_3}{3} & \frac{y_1 + y_2 + y_3}{3} & 1 \end{vmatrix}$$

$$S_3 = \frac{1}{2}\begin{vmatrix} x_3 & y_3 & 1 \\ x_1 & y_1 & 1 \\ \frac{x_1 + x_2 + x_3}{3} & \frac{y_1 + y_2 + y_3}{3} & 1 \end{vmatrix}$$

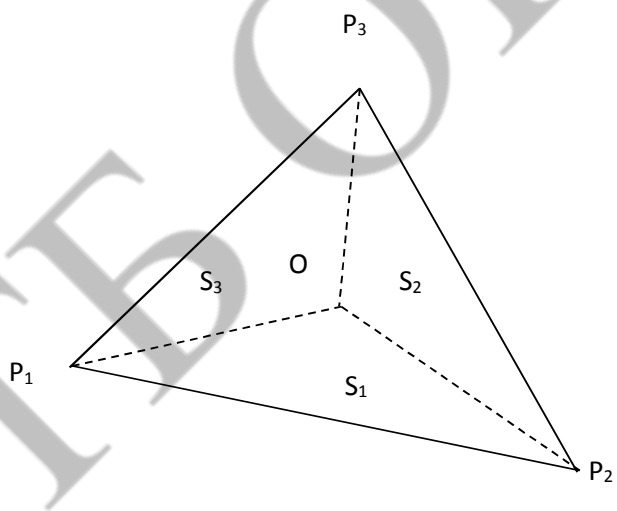

Figure 2 - Triangulation of a triangle into comparable triangles of equal areas

Let's find the values of S1, S2, S3.

$$S_1 = \frac{1}{2}(x_1 y_2 + y_1 \frac{x_1 + x_2 + x_3}{3} + x_2 \frac{y_1 + y_2 + y_3}{3} - y_2 \frac{x_1 + x_2 + x_3}{3} - x_2 \cdot y_1 - x_1 \frac{y_1 + y_2 + y_3}{3}),$$

$$S_1 = (x_1 y_2 - x_1 y_3 - x_2 y_1 + x_2 y_3 + x_3 \cdot y_1 - x_3 y_2)/6;$$

$$S_2 = \frac{1}{2}(x_2 y_3 + y_2 \frac{x_1 + x_2 + x_3}{3} + x_3 \frac{y_1 + y_2 + y_3}{3} - y_3 \frac{x_1 + x_2 + x_3}{3} - x_3 \cdot y_2 - x_2 \frac{y_1 + y_2 + y_3}{3}),$$

$$S_2 = (x_1 y_2 - x_1 y_3 - x_2 y_1 + x_2 y_3 + x_3 \cdot y_1 - x_3 y_2)/6;$$

$$S_3 = \frac{1}{2}(x_3 y_1 + y_3 \frac{x_1 + x_2 + x_3}{3} + x_1 \frac{y_1 + y_2 + y_3}{3} - y_1 \frac{x_1 + x_2 + x_3}{3} - x_1 \cdot y_3 - x_3 \frac{y_1 + y_2 + y_3}{3}),$$

$$S_3 = (x_1 y_2 - x_1 y_3 - x_2 y_1 + x_2 y_3 + x_3 \cdot y_1 - x_3 y_2)/6.$$

Comparing the expressions for S1, S2, S3, conclude that S1 = S2 = S3. Therefore, the condition is correct.

As the vectors include three components, to each of which it can apply the proved property, the vector of the normal at the point will be equal to

$$\vec{N}_o = \frac{N_{p1} + N_{p2} + N_{p3}}{3} \quad (4)$$

The resulting formulas can be obtained for balanced [1] triangulation in computer graphics problems.

2.2. Definition of vectors for Serpinsky triangulation

In the Serpinsky triangulation of the 1st order, the triangle is divided into 4 components by connecting the midpoints of its sides (Fig. 3). The result is four triangles that are equal in area. The constituent triangles are painted in parallel.

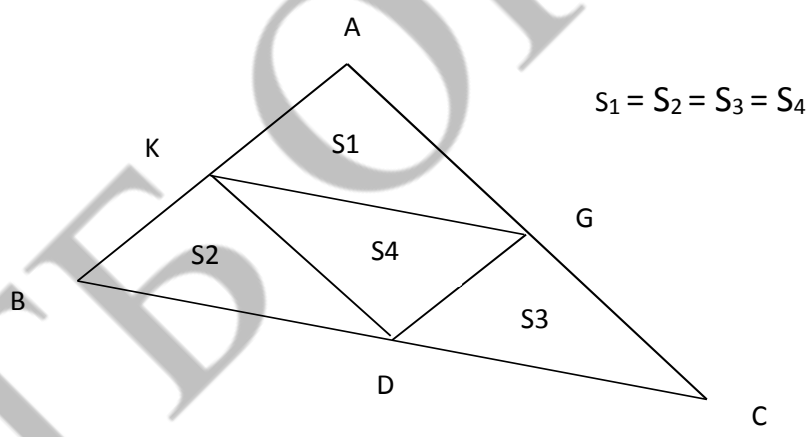

Figure 3 - Dividing a triangle into components using Serpinsky triangulation

When implementing Guro painting, only one dye is used, which paints one of the triangles, and the results of its work are transferred to all other triangles with a certain offset in the coordinates and the corresponding color intensity transformations of the points. Due to the parallelization of the computational process, the output triangle will be painted 4 times faster.

When painting according to Fong, it is necessary to find the normals in the midpoints of the edges of the triangle.

Let`s prove that the increase in color intensity along the corresponding edges of the four constituent triangles is a constant value.

Let`s find the vector $\vec{N}_{(1/2)}$, which forms with the vectors $\vec{N}_a$ and $\vec{N}_b$ the angle $\psi/2$

According to formula (2) it can be written

$$\vec{N}_{(1/2)} = \vec{N}_a \frac{sin(\frac{1}{2}\cdot\psi)}{sin\psi} + \vec{N}_b \frac{sin(\frac{1}{2}\cdot\psi)}{sin\psi} = \frac{\vec{N}_a + \vec{N}_b}{2\,cos\frac{\psi}{2}} = \frac{\vec{N}_a + \vec{N}_b}{\sqrt{2\cdot(1+cos\psi)}}.$$

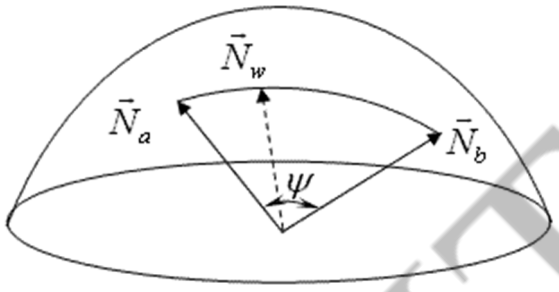

Figure 4 - Outputs $\vec{N}_a$, $\vec{N}_b$ and flow $\vec{N}_w$ vectors of normals

Let`s find the vector of the normal $\vec{N}_{(1/2^2)}$, which forms the same angles between the vectors $\vec{N}_a$, $\vec{N}_{1/2}$.

$$\vec{N}_{(1/2^2)} = \frac{\vec{N}_a + \vec{N}_{1/2}}{\sqrt{2(1+cos\frac{\psi}{2})}} = \frac{\vec{N}_a + \vec{N}_{1/2}}{\sqrt{2(1+\sqrt{\frac{1+cos\psi}{2}})}} = \frac{\vec{N}_a + \vec{N}_{1/2}}{\sqrt{2+\sqrt{2(1+cos\psi)}}}.$$

After the first iteration, the angle between the vectors of the normals changes from zero to 90^0, therefore $\sqrt{2} \le z_{2^n} \le 2$. The expression $\frac{1}{\sqrt{2+z_{2^n}}}$ was approximated by a number of Chebyshev. When using a first-degree polynomial

$$\frac{1}{\sqrt{2+z_{2^n}}} \approx -0{,}07\cdot z_{2^n} + 0{,}64.$$

The maximum absolute approximation error does not exceed 0,0005, and the relative 0,12%. When using the second-degree polynomial

$$\frac{1}{\sqrt{2+z_{2^n}}} \approx 0{,}014\cdot z^2_{2^n} - 0{,}119\cdot z_{2^n} + 0{,}681.$$

the maximum absolute error of the approximation does not exceed $2\cdot 10^{-5}$, and the relative 0,004 %. The first formula should be used for low-resolution screens for which the triangles that make up the surface of a three-dimensional object are small enough.

The analysis showed that when using the last approximation formula, the time

of calculation of the vector $\vec{N}_{(1/2^n)}$ is reduced by 2,5 times compared to the classical implementation. Figure 5 shows an example of object formation using different triangulation network densities.

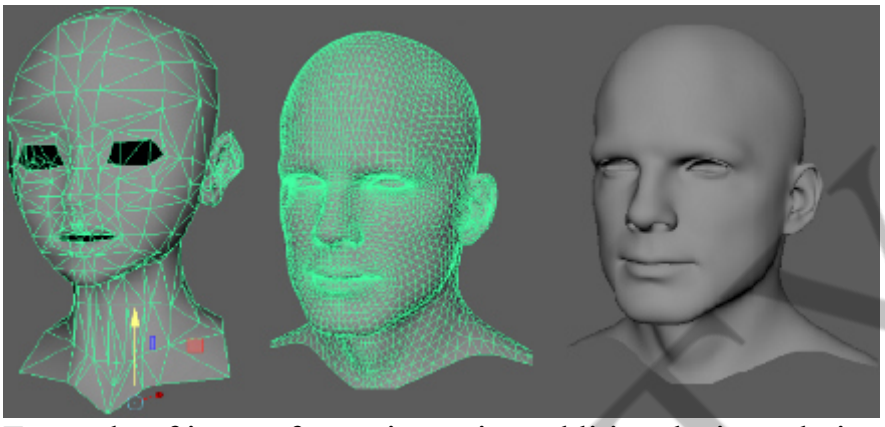

Figure 5 - Example of image formation using additional triangulation

The resulting formulas can be obtained for balanced [1] triangulation in computer graphics problems.

2.3. The method of triangulation of three-dimensional objects depending on the maximum values of color intensity on the edges of the triangle

Find the highest intensity of the specular component of color on the edges of the triangle (Fig. 6).

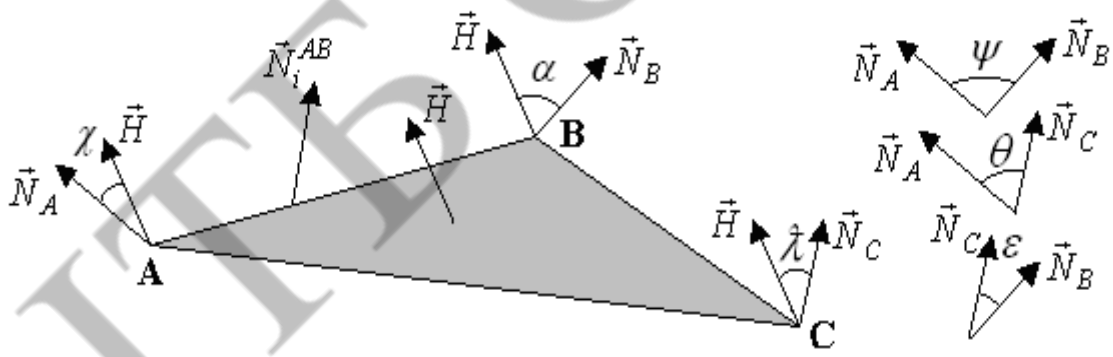

Figure 6 - Vectors of the normal of the ABC triangle

The vectors of normals to the points of the edge AB can be found from the parametric equation $\vec{N}_i^{AB} = \vec{N}_A + t_1 \cdot (\vec{N}_B - \vec{N}_A)$. Let's perform normalization of the vector $\vec{N}_i^{AB}$.

$$\frac{\vec{N}_i^{AB}}{\left|\vec{N}_i^{AB}\right|} = \frac{\vec{N}_A + t_1 \cdot (\vec{N}_B - \vec{N}_A)}{\sqrt{(\vec{N}_A)^2 + 2 \cdot t_1 \cdot \vec{N}_A \cdot (\vec{N}_B - \vec{N}_A) + t_1^2 \cdot (\vec{N}_B - \vec{N}_A)^2}}.$$

As $\vec{N}_A$, $\vec{N}_B$ - are single vectors, then $\vec{N}_A^2 = \vec{N}_B^2 = 1$. Given the last equation, as well as the fact that $\vec{N}_A \cdot \vec{N}_B = cos\psi$, find

$$\frac{\vec{N}_i^{AB}}{\left|\vec{N}_i^{AB}\right|} = \frac{\vec{N}_A + t_1 \cdot (\vec{N}_B - \vec{N}_A)}{\sqrt{2 \cdot t_1^2 \cdot (1 - \cos\psi) - 2 \cdot t_1 \cdot (1 - \cos\psi) + 1}}.$$

Let`s find the positions on the edges of the triangle ABC, where the glare is most intense. This can be judged by the value of the cosine of the angle between the vector $\vec{H}$ and the unit vectors of normals to the points of the edge.

For example, for the edge AB

$$\frac{\vec{N}_i^{AB} \cdot \vec{H}}{\left|\vec{N}_i^{AB}\right|} = \frac{(\vec{N}_A + t_1 \cdot (\vec{N}_B - \vec{N}_A)) \cdot \vec{H}}{\sqrt{2t_1^2(1 - \cos\psi) - 2t_1(1 - \cos\psi) + 1}} = \frac{\cos\chi + t_1(\cos\alpha - \cos\chi)}{\sqrt{2t_1^2(1 - \cos\psi) - 2t_1(1 - \cos\psi) + 1}},$$

where χ, α - respectively, the angles between the vector $\vec{H}$ and the vectors $\vec{N}_A, \vec{N}_B$. In the above expression, all quantities are scalar.

Let`s find t_1, at which the scalar component of the color on the edge AB has the maximum value. To do this, find the derivative of the previous expression and equate it to zero.

$$\left(\frac{\vec{N}_i^{AB} \cdot \vec{H}}{\left|\vec{N}_i^{AB}\right|}\right)' = \frac{t_1(1 - \cos\psi) \cdot (\cos\alpha - \cos\chi) - \cos\chi \cdot \cos\psi + \cos\alpha}{(2t_1^2(1 - \cos\psi) - 2t_1(1 - \cos\psi) + 1)^{3/2}} = 0.$$

The last equation has a root

$$t_1 = \frac{\cos\chi \cdot \cos\psi - \cos\alpha}{(\cos\psi - 1)(\cos\alpha + \cos\chi)}. \tag{5}$$

Similarly, for the edges AC i BC the values of the parameters t_2, t_3, at which the maximum value of the speculative component of color is achieved, respectively, are

$$t_2 = \frac{\cos\chi \cdot \cos\theta - \cos\lambda}{(\cos\theta - 1)(\cos\lambda + \cos\chi)}, \quad t_3 = \frac{\cos\alpha \cdot \cos\varepsilon - \cos\lambda}{(\cos\varepsilon - 1)(\cos\lambda + \cos\alpha)}. \tag{6}$$

By value t it is easy to find the coordinates x, y on the edges of the triangle, where the speculative component of color is maximum. For example, for the edge AB

$$x = \lceil x_A + t \cdot (x_B - x_A) \rceil, \quad y = \lceil y_A + t \cdot (y_B - y_A) \rceil.$$

In determining the diffuse component of color instead of the vector $\vec{H}$ using the vector $\vec{L}$.

The output triangle can be divided into several, depending on the maximum values of color intensity at points t_1, t_2, t_3. If all three values of color intensity are greater than the threshold, then the triangle is divided into four components (Fig. 7, a). In the case when only in one of the points t_1, t_2, t_3 the value of color intensity is reached, more than the threshold, the triangle is divided into two components (Fig. 7, b). If the maximum values of the speculative component of color on the edges of the triangle are greater than the threshold value at only two points, the triangle can be divided into three components as shown in Fig. 7, s, d. In the latter case, at the point D, which bisecting the segment AC, it is easy to find the value of color intensity as the

average value of color intensity at points A and C .

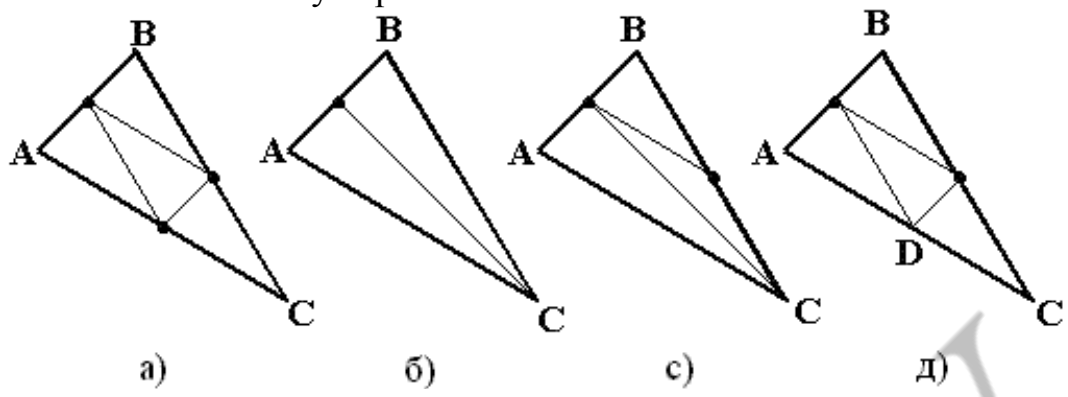

Figure 7 - Dividing the triangle into components

The proposed approach allows to increase the realism of the Guro method compared to the classical implementation by more detailed reproduction of glare on the surface of three-dimensional graphics. Figure 8 shows an example of the formation of a three-dimensional object using the Fong method.

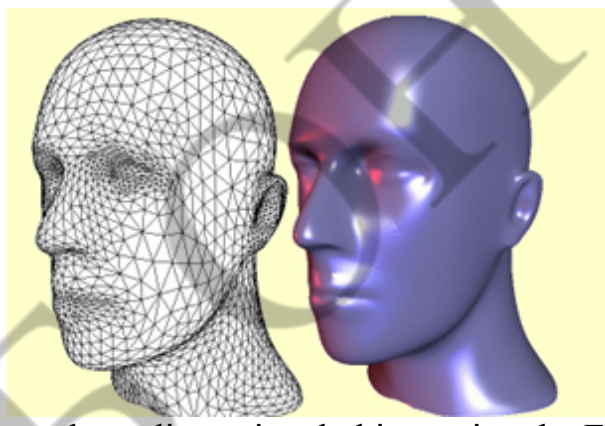

Figure 8 - Forming a three-dimensional object using the Fong method

2.4. Determination of a vector at an arbitrary point on a surface bounded by a triangle

Consider the division of the original triangle into components with an arbitrary interior point [8].

When a triangle is divided into components, it is necessary to determine not only the addresses of the components of the triangles, but also the vectors of the normals. Consider the method of determining the vectors of normals at any point of the triangle, which will make it possible to divide the triangle into its components.

It is convenient to use the barycentric coordinate system, while working with triangles [2]. Figure 9 shows a triangle $A_1A_2A_3$, at which point C – is an arbitrary point located inside a given triangle. If the point C is connected to the vertices of the triangle $A_1A_2A_3$, then it will divide this triangle into triangles A_1CA_2, A_3CA_2 and A_1CA_3, whose area will be s_1, s_2 and s_3 accordingly.

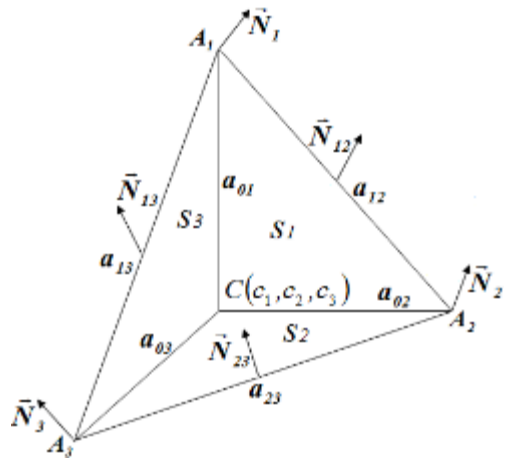

Figure 9 - Dividing the output triangle into 3 components

The barycentric coordinates of the point C are defined as the ratio of the areas of the constituent triangles [2, 8], into which the point C of the triangle divides $A_1 A_2 A_3$, to its total area.

$$c_1 = \frac{s_1}{\sum_{i=1}^{3} s_i}, \qquad c_2 = \frac{s_2}{\sum_{i=1}^{3} s_i}, \qquad c_3 = \frac{s_3}{\sum_{i=1}^{3} s_i}, \tag{7}$$

$$c_1 + c_2 + c_3 = 1. \tag{8}$$

For any point lying on one side of the triangle, the corresponding barycentric coordinate will be equal to 0, which simplifies the calculations. For example, for a point that lies on the side A_1A_2, the values of the area $s_3 = 0$ i and, accordingly, the barycentric coordinate will be equal to $c_3 = 0$, while $c_1 = 1 - c_2$.

If the point C is considered as a pixel of the graphic image, then with the help of barycentric coordinates you can find other parameters of the point, necessary for its visualization, namely the value of light intensity, texture coordinates or normal vector at this point.

Consider how the vector of normal along one of the sides of a triangle will change $A_1 A_2 A_3$, namely along the side A_1A_2, provided that the vectors of normals $\vec{N}_1$ and $\vec{N}_2$ are known. Find the vector $\vec{N}_{12}$ at the midpoint of the side A_1A_2, by the formula:

$$\vec{N}_{12} = \frac{\vec{N}_1 + \vec{N}_2}{\sqrt{(\vec{N}_1 + \vec{N}_2)}} = \frac{\vec{N}_1 + \vec{N}_2}{\sqrt{\vec{N}_1^2 + \vec{N}_2^2 + 2\vec{N}_1 \cdot \vec{N}_2)}} \frac{\vec{N}_1 + \vec{N}_2}{\sqrt{2(1 + \cos\psi_{12})}}, \tag{9}$$

where ψ_{12} – is the angle between the vectors of normals $\vec{N}_1$ and $\vec{N}_2$. Note that the vectors $\vec{N}_1$, $\vec{N}_2$, $\vec{N}_3$ are normalized. The scalar product of two vectors is the product of the modules of these vectors by the cosine of the angle between them. Considering that the vectors $\vec{N}_1$ i $\vec{N}_2$ are normalized, their modules are equal to one, therefore

$$\vec{N}_1 \cdot \vec{N}_2 = \left|\vec{N}_1\right| \cdot \left|\vec{N}_2\right| \cdot cos\psi_{12} = 1 \cdot 1 \cdot cos\psi_{12} = cos\psi_{12}. \tag{10}$$

Considering equation (10), replace in formula (9) $cos\psi_{12}$ by $\vec{N}_1 \cdot \vec{N}_2$.

The change in the vector of the normal along the side can be described by the quadratic Bézier curve [1, 2]:

$$\vec{N}(t) = (1-t)^2\, T_1 + 2\,t(1-t)\,T_2 + t^2 T_3, \tag{11}$$

where t – is a parameter that varies along the side A_1A_2 and lies in the range [0;1], T_1, T_2 and T_3 – reference points..

If $t=0$, then $\vec{N}(0)=\vec{N}_1=T_1$. When $t=1$, $\vec{N}(1)=\vec{N}_2=T_3$. If $t=0{,}5$, then $N(0.5)=\vec{N}_{12}=0{,}25\,T_1+2\cdot 0{,}25\cdot T_2+0{,}25\,T_3=0{,}25\,\vec{N}_1+0{,}5\,T_2+0{,}25\,\vec{N}_2$.

From the last equation find

$$T_2=\frac{\vec{N}_{12}-0{,}25\,\vec{N}_1-0{,}25\,\vec{N}_2}{0{,}5}=2\frac{\vec{N}_1+\vec{N}_2}{\sqrt{2(1+\vec{N}_1\cdot\vec{N}_2)}}-0{,}5\,\vec{N}_1-0{,}5\,\vec{N}_2.$$

Then $2T_2=4\dfrac{\vec{N}_1+\vec{N}_2}{\sqrt{2(1+\vec{N}_1\cdot\vec{N}_2)}}-\vec{N}_1-\vec{N}_2$.

Considering that in this case $c_3=0$, then $c_1=1-t$, $c_2=t$. The equation in the barycentric coordinates will look like this

$$\vec{N}(c_1,c_2)=\vec{N}_1\cdot c_1^{\,2}+\vec{N}_2\cdot c_2^{\,2}+\left(4\frac{\vec{N}_1+\vec{N}_2}{\sqrt{2(1+\vec{N}_1\cdot\vec{N}_2)}}-\vec{N}_1-\vec{N}_2\right)\cdot c_1c_2. \tag{12}$$

Similarly, you can display a change in the normal along the sides A_2A_3 i A_3A_1

$$\vec{N}(c_2,c_3)=\vec{N}_2\cdot c_2^{\,2}+\vec{N}_3\cdot c_3^{\,2}+\left(4\frac{\vec{N}_2+\vec{N}_3}{\sqrt{2(1+\vec{N}_2\cdot\vec{N}_3)}}-\vec{N}_2-\vec{N}_3\right)\cdot c_2c_3, \tag{13}$$

$$\vec{N}(c_3,c_1)=\vec{N}_3\cdot c_3^{\,2}+\vec{N}_1\cdot c_1^{\,2}+\left(4\frac{\vec{N}_3+\vec{N}_1}{\sqrt{2(1+\vec{N}_3\cdot\vec{N}_1)}}-\vec{N}_3-\vec{N}_1\right)\cdot c_3c_1. \tag{14}$$

The function of changing the normal vector on the surface of a triangle $A_1A_2A_3$ can be represented by the sum of equations (12)–(14), subtracting the product of the normal vector by the square of the corresponding barycentric coordinate at the vertices of the triangle:

$$\vec{N}(c_1,c_2,c_3)=\vec{N}_1c_1^{\,2}+\vec{N}_2c_2^{\,2}+\left(4\frac{\vec{N}_1+\vec{N}_2}{\sqrt{2(1+\vec{N}_1\cdot\vec{N}_2)}}-\vec{N}_1-\vec{N}_2\right)c_1c_2+\vec{N}_2c_2^{\,2}+$$

$$+\vec{N}_3c_3^{\,2}+\left(4\frac{\vec{N}_2+\vec{N}_3}{\sqrt{2(1+\vec{N}_2\cdot\vec{N}_3)}}-\vec{N}_2-\vec{N}_3\right)c_2c_3+\vec{N}_3c_3^{\,2}+\vec{N}_1c_1^{\,2}+$$

$$+\left(4\frac{\vec{N}_3+\vec{N}_1}{\sqrt{2(1+\vec{N}_3\cdot\vec{N}_1)}}-\vec{N}_3-\vec{N}_1\right)c_3c_1-\vec{N}_1c_1^{\,2}-\vec{N}_2c_2^{\,2}-\vec{N}_3c_3^{\,2}.$$

Simplifying, we obtain the following formula

$$\vec{N}(c_1,c_2,c_3)=\vec{N}_1c_1^{\,2}+\vec{N}_2c_2^{\,2}+\vec{N}_3c_3^{\,2}+\left(4\frac{\vec{N}_1+\vec{N}_2}{\sqrt{2(1+\vec{N}_1\cdot\vec{N}_2)}}-\vec{N}_1-\vec{N}_2\right)c_1c_2+$$
$$+\left(4\frac{\vec{N}_2+\vec{N}_3}{\sqrt{2(1+\vec{N}_2\cdot\vec{N}_3)}}-\vec{N}_2-\vec{N}_3\right)c_2c_3+\left(4\frac{\vec{N}_3+\vec{N}_1}{\sqrt{2(1+\vec{N}_3\cdot\vec{N}_1)}}-\vec{N}_3-\vec{N}_1\right)c_3c_1.$$

Having opened brackets and regrouped members, we will receive

$$\vec{N}(c_1,c_2,c_3)=\vec{N}_1c_1(c_1-c_2-c_3)+\vec{N}_2c_2(c_2-c_1-c_3)+\vec{N}_3c_3(c_3-c_2-c_1)+$$
$$+4\frac{\vec{N}_1+\vec{N}_2}{\sqrt{2(1+\vec{N}_1\cdot\vec{N}_2)}}\cdot c_1c_2+4\frac{\vec{N}_2+\vec{N}_3}{\sqrt{2(1+\vec{N}_2\cdot\vec{N}_3)}}\cdot c_2c_3+4\frac{\vec{N}_3+\vec{N}_1}{\sqrt{2(1+\vec{N}_3\cdot\vec{N}_1)}}\cdot c_3c_1.$$

The last formula can be simplified by performing the transformation in parentheses. It is known that if add and subtract 1 to the expression, its value will not change. Taking into account this property and equation (14) find

$$\begin{aligned}
c_1-c_2-c_3&=c_1-1+1-c_2-c_3=c_1-1+c_1=2c_1-1,\\
c_2-c_1-c_3&=c_2-1+1-c_1-c_3=c_2-1+c_2=2c_2-1,\\
c_3-c_2-c_1&=c_3-1+1-c_2-c_1=c_3-1+c_3=2c_3-1.
\end{aligned}\tag{15}$$

Considering (15) the formula for determination $\vec{N}(c_1,c_2,c_3)$ will look like

$$\begin{aligned}
\vec{N}(c_1,c_2,c_3)&=\vec{N}_1c_1(2c_1-1)+\vec{N}_2c_2(2c_2-1)+4\frac{\vec{N}_1+\vec{N}_2}{\sqrt{2(1+\vec{N}_1\cdot\vec{N}_2)}}c_1c_2+\\
&+\vec{N}_3c_3(2c_3-1)+4\frac{\vec{N}_2+\vec{N}_3}{\sqrt{2(1+\vec{N}_2\cdot\vec{N}_3)}}c_2c_3+4\frac{\vec{N}_3+\vec{N}_1}{\sqrt{2(1+\vec{N}_3\cdot\vec{N}_1)}}c_3c_1.
\end{aligned}\tag{16}$$

Expressions $4\frac{\vec{N}_1+\vec{N}_2}{\sqrt{2(1+\vec{N}_1\cdot\vec{N}_2)}}$, $4\frac{\vec{N}_2+\vec{N}_3}{\sqrt{2(1+\vec{N}_2\cdot\vec{N}_3)}}$ and $4\frac{\vec{N}_3+\vec{N}_1}{\sqrt{2(1+\vec{N}_3\cdot\vec{N}_1)}}$ are constant for any point of the surface bounded by a triangle, so there is no need to calculate them for each point. Denote these expressions by $\vec{M}_{12}$, $\vec{M}_{23}$ and $\vec{M}_{31}$. Equation (16) will look like

$$\begin{aligned}
\vec{N}(c_1,c_2,c_3)&=\vec{N}_1c_1(2c_1-1)+\vec{N}_2c_2(2c_2-1)+\vec{N}_3c_3(2c_3-1)+\\
&+\vec{M}_{12}c_1c_2+\vec{M}_{23}c_2c_3+\vec{M}_{31}c_3c_1.
\end{aligned}\tag{17}$$

The obtained expression allows to find the vector at any point of the surface bounded by a triangle, according to the values of the vectors in its vertices and the barycentric coordinates of the current point.

3. Software implementation

A computer program based on an open professional conveyor for modeling and testing methods has been developed.

To develop a software product, the Java programming language was chosen, the implementation of which is adapted to different platforms (the most famous of which are Win32, Unix/x86, Unix/Alpha, Solaris/Sparc, MacOS). A large number of libraries have been developed for the Java language, which greatly simplifies the development of software products. The advantage of the Java language is that the software module with an interface based on Swing or AWT can be easily adapted for use in the form of a Java applet, which allows you to use the software module directly from an Internet browser.

The software module is based on the idx3d library, which has basic functions for working with 3D models and three-dimensional geometry. The object-oriented model of the software module is shown in Fig. 11.

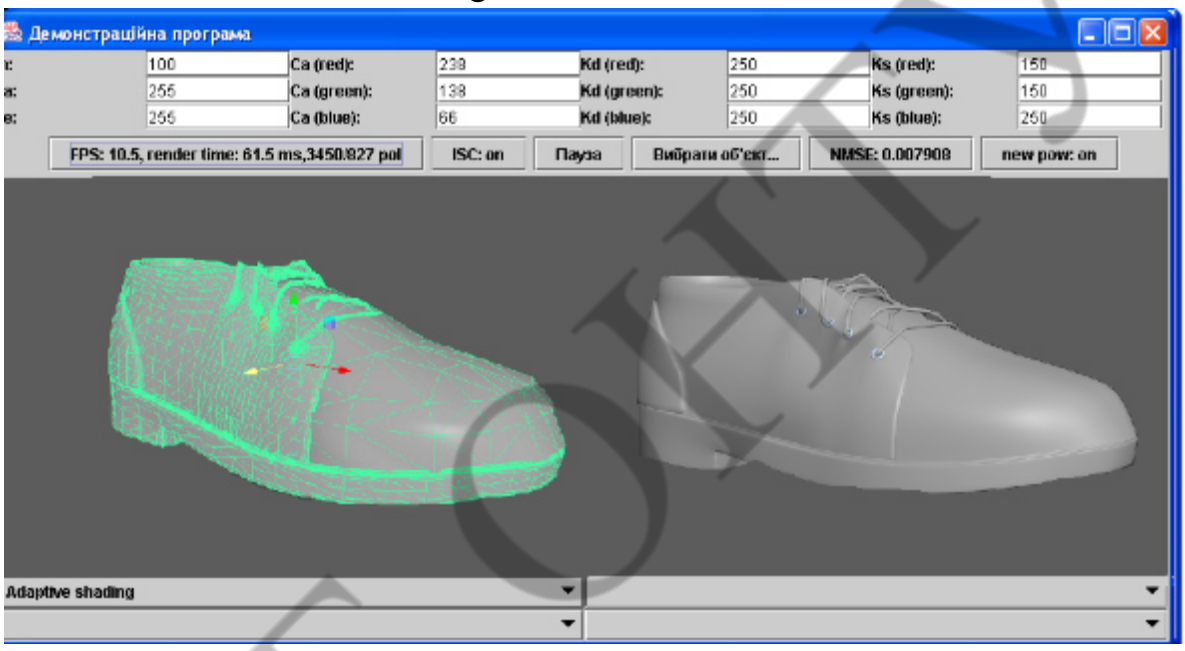

Figure 10 - Example of image formation using additional triangulation

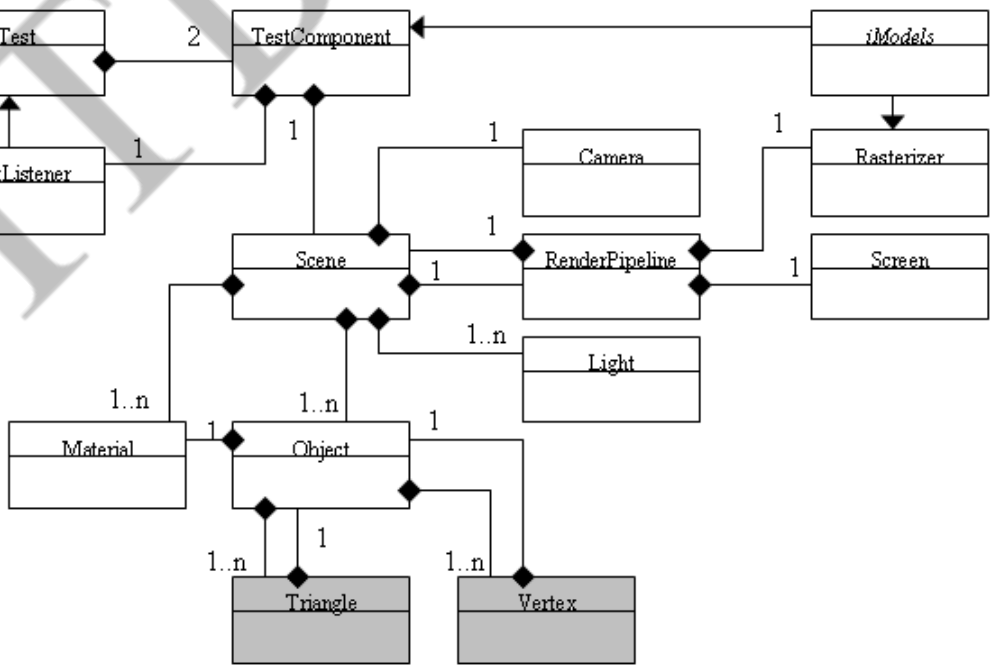

Figure 11 - Oriented model of the software module

Figure 12 - Example of triangulation

The simulation performed using the developed program confirmed the validity of the obtained theoretical positions.

Scientific novelty of the work.

1. An expression is obtained to determine the vector at an arbitrary point of the surface bounded by a triangle by the values of the vectors at its vertices and

the barycentric coordinates of the current point, which allows to detail the surface to increase realism.

2. The division of the output triangle into components with the same area is proposed, which allows to achieve a balanced loading of shader processors.
3. The obtained relations for detailing the surfaces of three-dimensional objects by Serpinsky triangulation makes it possible to increase the realism of image formation.
4. For the first time, it is proposed to perform triangulations of three-dimensional objects depending on the maximum values of color intensity on the edges of the triangle, which allows the use of adaptive triangulation.

The practical significance of the work is to develop on the basis of theoretical studies of algorithms and programs for triangulation and integrate them into a professional graphics engine idx3d.

8 scientific works have been published on the topic of research, including one article in a professional publication.

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A REAL-WORLD CASE STUDY OF A VEHICLE ROUTING PROBLEM

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Abstract. *The goal of this study is to create a route planning methodology. The created methodology assisgns cargo to a given set of vehicles in such a way that the profits would be maximized. When planning a route, the work hours of pick-up locations, are considered as well as when each cargo is ready to be picked up. Furthermore, cargo that is worth less than what it would cost to transport it, is removed from planning. Also, a unique feature to the original Pickup-and-Delivery problem with time windows is introduced. Namely, cargo can be redirected to depots for a fee, which lets drivers spend less time on the road and collect the redirected cargo in one place. The genetic algorithm method, proves to be a viable approach as it produces failry good results in relatively short time.*

Keywords: *Vehicle Routing, Optimization, Genetic Algorithm, Nearest Neighbour, Pickup-and-Delivery.*

I. INTRODUCTION

Road freight transportation is rapidly expanding in a competitive environment, hence logistics companies with limited transportation capacities are forced to look for more efficient solutions that concern the transportation of freight. One of the key indicators used to determine a company's efficiency is the profit generated by the transportation services provided, which directly depends on the route taken. Usually, a logistics manager ensures high-quality, fast transportation of a customer's cargo by striving to plan the best routes for truck drivers to take. In addition, the logistics manager has to take into account the available human resources, capacities of the vehicles, the order in which cargo is taken and the expenses that will accumulate during each planned route. All of this is considered to ensure efficient management of transportation services while minimizing the company's expenses.

Optimization of routes in regards to various constraints is known in scientific literature as the Vehicle Routing Problem (VRP). To create a methodology for road freight transport, optimization methods applied to the Pickup-and-Delivery (PDP) are analyzed. In this case, it is assumed that each load has a predefined delivery point (one-to-one) and that the goods can only be picked up and delivered at certain hours (time windows). Also, a feature is added to redirect cargo to depots that collect it for a fee. This allows a truck to spend less time deviating from its route. Such problems are often unsuitable to linear programming methods due to extremely long computation times, therefore a metaheuristic approach is used.

II. LITERATURE ANALYSIS

Vehicle routing problems originated from the generalization of the Traveling Salesman Problem (TSP). To solve it, the simulated annealing [1] and Tabu search [2-

3] algorithms were tested. However, experiments showed that these methods require large computational time resources. Also, a genetic algorithm method has been proposed to solve this type of problem. For example, a genetic algorithm has been used to create school bus routes [4]. This study revealed that fairly good results were obtained in a relatively short time.

The creation of transport routes with time windows (VRPTW) where customers can be served only for a specified time interval is analyzed in [5]. In this article, a genetic algorithm is used to determine how many cars are needed and a Tabu search algorithm – to reduce the total distance travelled by cars. The author notes that using both algorithms is more suitable for this (VRPTW) problem, rather than using a single of the aforementioned algorithms.

A study that is closer to ours, by having separate unique pickup and delivery points for each of the goods, is analyzed in [6]. In it, a Pickup-and-Delivery with time windows (PDPTW) problem is analyzed. The study has shown that dynamic programming is not suitable for solving this problem due to the long computation time, whereas the results obtained by a genetic algorithm were able to provide (sub)optimal solutions for problems bigger by up to 25% of the original problem.

In [7] study a PDPTW problem where not all goods are required to be transported is analyzed using a hybrid genetic algorithm. The genetic algorithm would take a few minutes to produce a good and stable result, whereas linear programming methods took more than two hours to reach these results. Also, the same problem was studied in [8]. Here, three metaheuristic methods were suggested, namely the Tabu search, the genetic algorithm, and the scatter search. Although all methods provided good results, the quality of the Tabu search results as well as the speed of convergence was notably better.

Taking everything into consideration, we can state that the problem solved in this case study belongs to the group of complex combinatorial problems. Linear programming methods take too long to solve such problems, so although they are suitable in theory, they are not implemented for solving real-world problems. Various scientists solve this problem using metaheuristic methods, of which the most popular were found to be the Tabu search and the genetic algorithm approaches.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

3.1. Object

In this study, we aim to create a route planning algorithm. The goal is to assign available cargo to a given set of vehicles in such a way that the profits would be maximized. When planning a route, the work hours of pick-up locations need to be considered as well as when each cargo is ready to be picked up. Furthermore, cargo that is worth less than what it would cost to transport it, should be removed from planning. Also, any cargo can be redirected to a depot which will collect the assigned cargo for a fee. In this study, we assume that the cargo would reach a depot at 7 p.m. the next day of when it would be ready (f.e., if a cargo is ready at 5 p.m. Monday, then it would reach the depot at 7 p.m. Tuesday). Redirecting cargo to a depot is usually done either to minimize the distance driven by a driver or to minimize the collection time of the cargo, as each cargo has a delivery deadline that when exceeded causes additional expenses. Furthermore, the mandatory breaks from driving must be

considered when assessing the time it takes to get from one location to another. The Hours of Service (HoS) used in this research state that: a 45 minute break must be done after 4.5 hours of consecutive driving, an 11 hour break after driving 9 hours per day and a 45 hour break after driving 56 hours per week.

To summarize, the object of this research is to create a route planning algorithm that would have these features:

- able to process large ammounts of data;
- ensure that the capacity of a truck will not be exceeded;
- assess which goods are not profitable and remove them from planning;
- able to redirect cargo to terminals when it is more convenient;
- take into account the work hours of each location;
- estimate the cost of delays and downtime (caused by reaching a pick-up location too early, as the goods are considered to be not ready for transport or a delivery location outside of its work hours);
- able to use different time zone data;
- ensure the drivers' hours of service are not exceeded.

3.2. Methods of research

3.2.1. Haversine distance

Haversine distance calculates the distance between two points on the earth's surface using longitude and latitude coordinates. This distance is also called the bird's flight distance as it does not take the terrain or road infrastructure into consideration.

Let earth be a perfect sphere with a radius of $r = 6367.45$ km, and points with coordinates (p_1, i_1) and (p_2, i_2) are at a distance of r kilometers from the center.

$$a = \sin^2\left(\frac{\Delta p}{2}\right) + \cos(p_1) \times \cos(p_2) \times \sin^2\left(\frac{\Delta p}{2}\right),$$

where $\Delta p = p_2 - p_1$ is the change in latitude, $\Delta i = i_2 - i_1$ is the change in longitude. Then the distance between two points d is calculated as follows:

$$d = r \times (2 \times a \tan^2(\sqrt{a}, \sqrt{1-a})).$$

3.2.2. Nearest neighbour algorithm

3.2.3. Genetic algorithm

IV. RESULTS

4.1. Problem formulation

A total of n transportation requests are represented as a directed graph $G = (V, A)$; where V is divided into nodes $P = \{1, \dots, n\}$ for pickup, $D = \{n+1, \dots, 2n\}$ nodes for delivery and $Term = \{Term^1 \cup \dots \cup Term^T\}$ for depot nodes, where T is the number of depots. Each cargo i needs to be transported from node $i \in P$ to a delivery node $n + i \in D$. The cargo three different dimensional characteristics, namely weight (w), volume (v) and loading meters (l) which we will denote as q_i^w, q_i^v, q_i^l accordingly. Let $q_{n+1}^w = -q_i^w, q_{n+1}^v = -q_i^v, q_{n+1}^l = -q_i^l$. Also, each cargo brings revenue e_i that are known beforehand. The terminals charge differently according to the weight and distance that needs to be driven, hence each terminal has different

transportation prices for the cargo $Term^j = \{c_1^j, \dots, c_n^j\}$, where c_i^j is the price of i-th cargo in the j-th depot. We then introduce a binary decision variable x_{ij}^k that equals 1 if cargo i of the vehicle k is redirected to a depot j. After redirecting the cargo into a terminal, the pickup location of the cargo i will change into the location of the depot j and the transportation price of the terminal $c_i = \min\{c_i^1, \dots, c_i^T\}$ is added to the total expenses. Furthermore, each node $i \in V$ must be visited within a time window $[a_i, b_i]$. A visit requires a certain time s_i to process. The time a truck k starts servicing node i will be denoted by T_{ik} and $Q_{ik}^w, Q_{ik}^v, Q_{ik}^l$ will denote the dimensions of the truck after servicing the i-th node. Another binary decision variable x_{ijk} will be equal to 1 if the truck k will drive from node i to node j. Each arc $(i,j) \in A$ has its price c_{ij} and travel duration t_{ij}.

The mathematical model can be formulated as follows:

$$\max \sum_{k\in K}\sum_{i\in V}\sum_{j\in V}(e_j x_{ijk}\mathbb{I}_P(j) - c_{ij}x_{ijk} + x_{ijk}\mathbb{I}_{Term}(j)\sum_{l\in P}(e_l - c_l)\, x_l^j)$$

$$\sum_{k\in K}\sum_{j\in V} x_{ijk} = 1 \qquad \forall i \in P \cup Term,$$

$$\sum_{j\in V} x_{ijk} - \sum_{j\in V} x_{n+1,jk} = 0 \qquad \forall i \in P, k \in K,$$

$$c_i = \min\{c_i^1, \dots, c_i^T\}, \qquad \forall i \in V,$$

$$T_{jk} \geq (T_{ik} + s_i + t_{ij})x_{ijk} \qquad \forall i \in V, j \in V, k \in K,$$

$$Q_{jk}^w \geq (Q_{ik}^w + q_j^w)x_{ijk} \qquad \forall i \in V, j \in V, k \in K,$$

$$Q_{jk}^v \geq (Q_{ik}^v + q_j^v)x_{ijk} \qquad \forall i \in V, j \in V, k \in K,$$

$$Q_{jk}^l \geq (Q_{ik}^l + q_j^l)x_{ijk} \qquad \forall i \in V, j \in V, k \in K,$$

$$T_{n+1,k} - T_{ik} - s_i - t_{i,n+1} \geq 0 \qquad \forall i \in P,$$

$$a_i \leq T_{ik} \leq b_i \qquad \forall i \in V, k \in K,$$

$$\max\{0, q_i^w\} \leq Q_{ik}^w \leq \min\{Q_k^w, Q_k^w + q_i^w\} \qquad \forall i \in V, k \in K,$$

$$\max\{0, q_i^v\} \leq Q_{ik}^v \leq \min\{Q_k^v, Q_k^v + q_i^v\} \qquad \forall i \in V, k \in K,$$

$$\max\{0, q_i^l\} \leq Q_{ik}^l \leq \min\{Q_k^l, Q_k^l + q_i^l\} \qquad \forall i \in V, k \in K,$$

$$x_{ijk}, x_i^t \in \{0,1\} \qquad \forall i \in V, j \in V, k \in K,$$

Constraints (2.2) and (2.3) ensure that each node is visited at most once. The smallest depot price is ensured in (2.4) constraint. (2.5) equation states that the departure time at node j must be later than the departure time at node i plus travel and processing time if route (i, j) is traversed. The consistency of load variables is ensured (2.6)-(2.8) constraints. Equation (2.9) introduces precedence constraints. Furthermore, (2.10) constraint impose time-window and (2.11)-(2.13) capacity constraints, respectively.

4.2. Experimental study of the method

In order to solve the problem formulated in the 4.1 subsection, a detailed route planning algorithm was made (Fig. 1). The realization of the algorithm was executed stepwise. A genetic algorithm approach was selected for further experimentation. At first, a simple shortest route-finding algorithm was developed. Then, the dimensions of vehicles and cargo were added. Next, depot locations as well as the possibility to redirect cargo to them were included. It was noticed that sometimes the route would go straight through water or the borders of neighbouring countries, hence the addition of a special zone was developed. To reach the starting country's border point, a vehicle in the special zone would have to first visit the special location from which the route to the border is undisturbed. Furthermore, the driving times and mandatory breaks of drivers were added. Finally, the work hours of each location as well as the time when each cargo is ready to be picked up were added.

To begin with, the available data set is prepared. Next, the initial population is selected. Selecting the initial population is crucial in using genetic algorithms as it directly affects the time it takes to converge. An initial population closer to the real solution leads to a faster (sub)optimal solution finding. For this study, the nearest neighbour (k-NN) algorithm is used for calculating the initial population. After finding the initial population, the genetic algorithm, depicted in Fig. 1, is initialized. The result, given by the genetic algorithm is later used to calculate the output values.

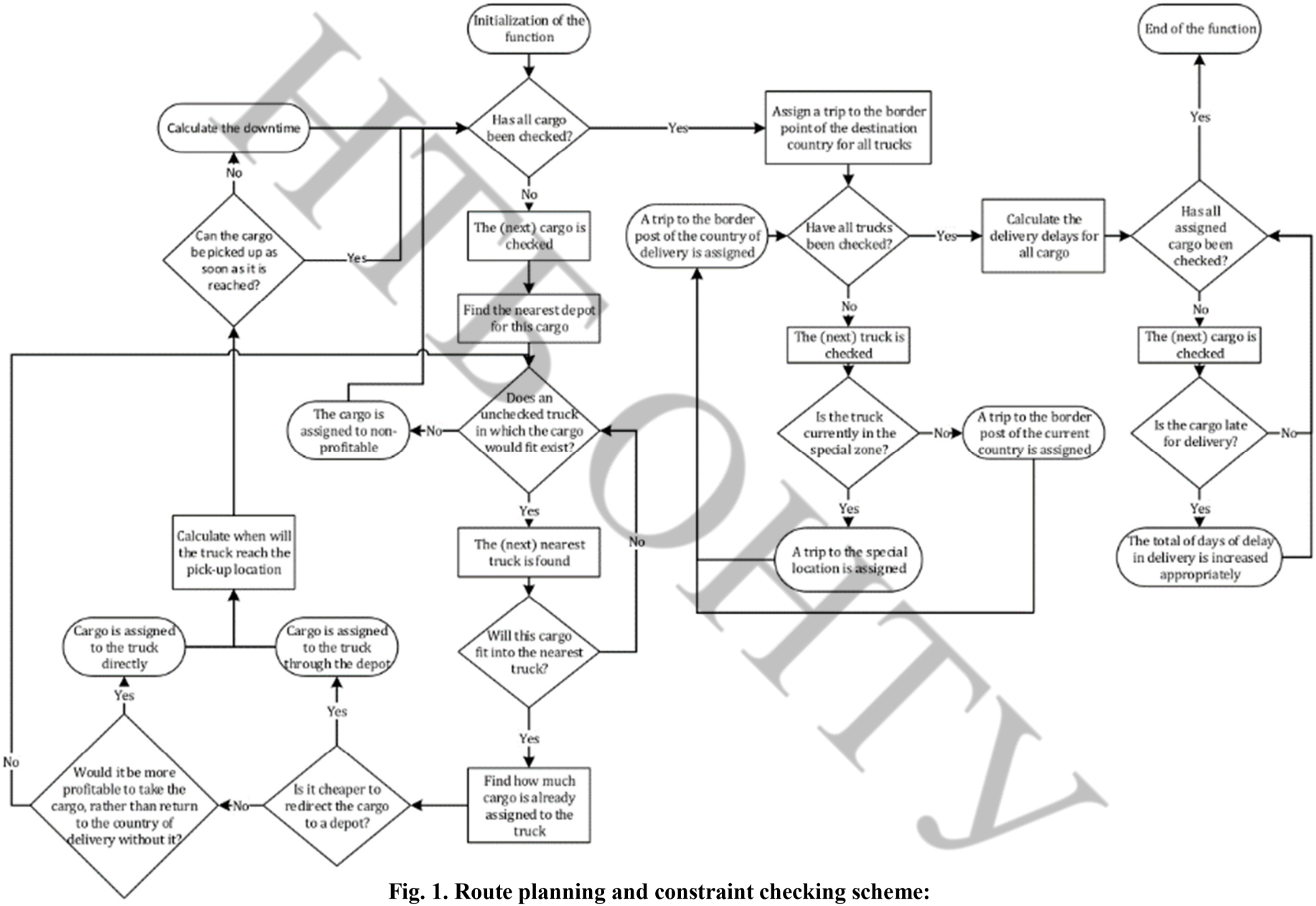


Fig. 1. Route planning and constraint checking scheme:

The effectiveness of the genetic algorithm is also affected by the selected model parameters. To increase the genetic algorithm's efficiency, the results of different operators of several components of the genetic algorithm were tested 50 times and their values were compared. For the selection component, the linear-rank (lr), the nonlinear-rank (nlr), the proportional/roulette wheel (rw) and the unbiased/tournament (tour) selection operators were compared. As for the crossover component, the cycle (cx), the partially matched (pmx), the order (ox) and the position-based (pbx) crossover operators were compared. What concerns the mutation component, the simple inversion (sim), insertion (ism), exchange/swap (sw), displacement (dm) and scramble (scr) mutation operators were compared. The comparison of these different operators (Fig. 2) revealed that the best results are achieved with the tournament selection, position-based crossover, and swap mutation operators. Also, experiments were performed to determine favourable probabilities between crossover and mutations pairs in the parental chromosome. The results presented in Figure 3 show, that using the probability of crossover p_k equal to 0.8 and the probability of mutation p_m equal to 0.5, yields the highest profits.

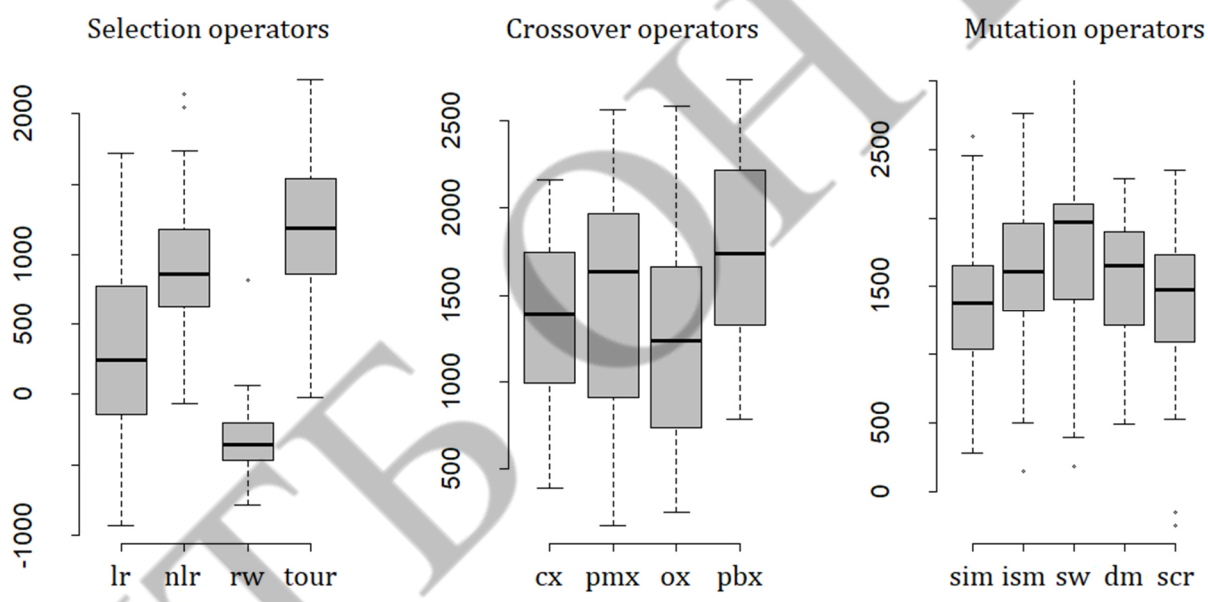


Fig. 2. Comparison of values generated with different genetic algorithm operators

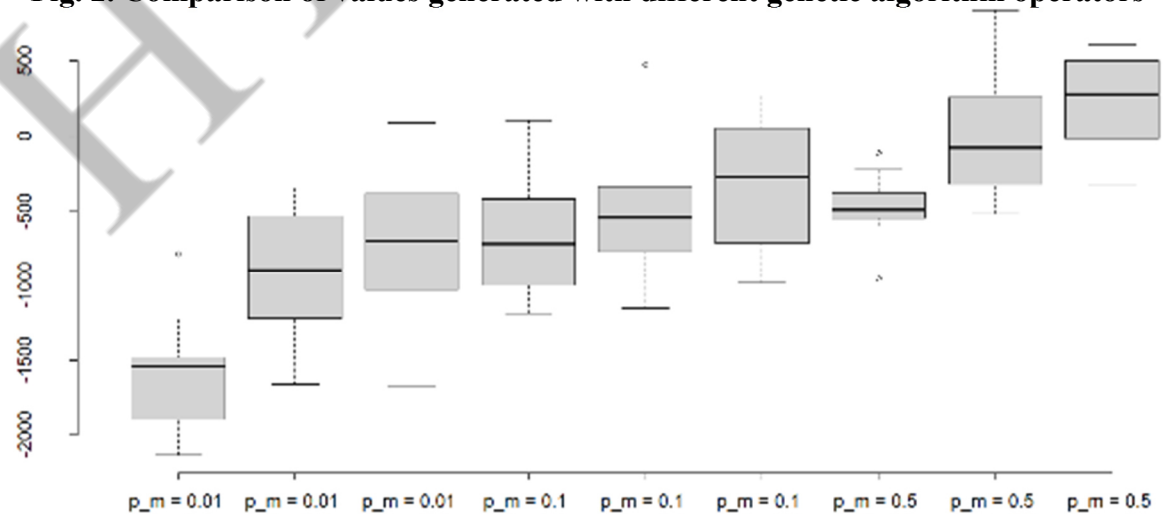
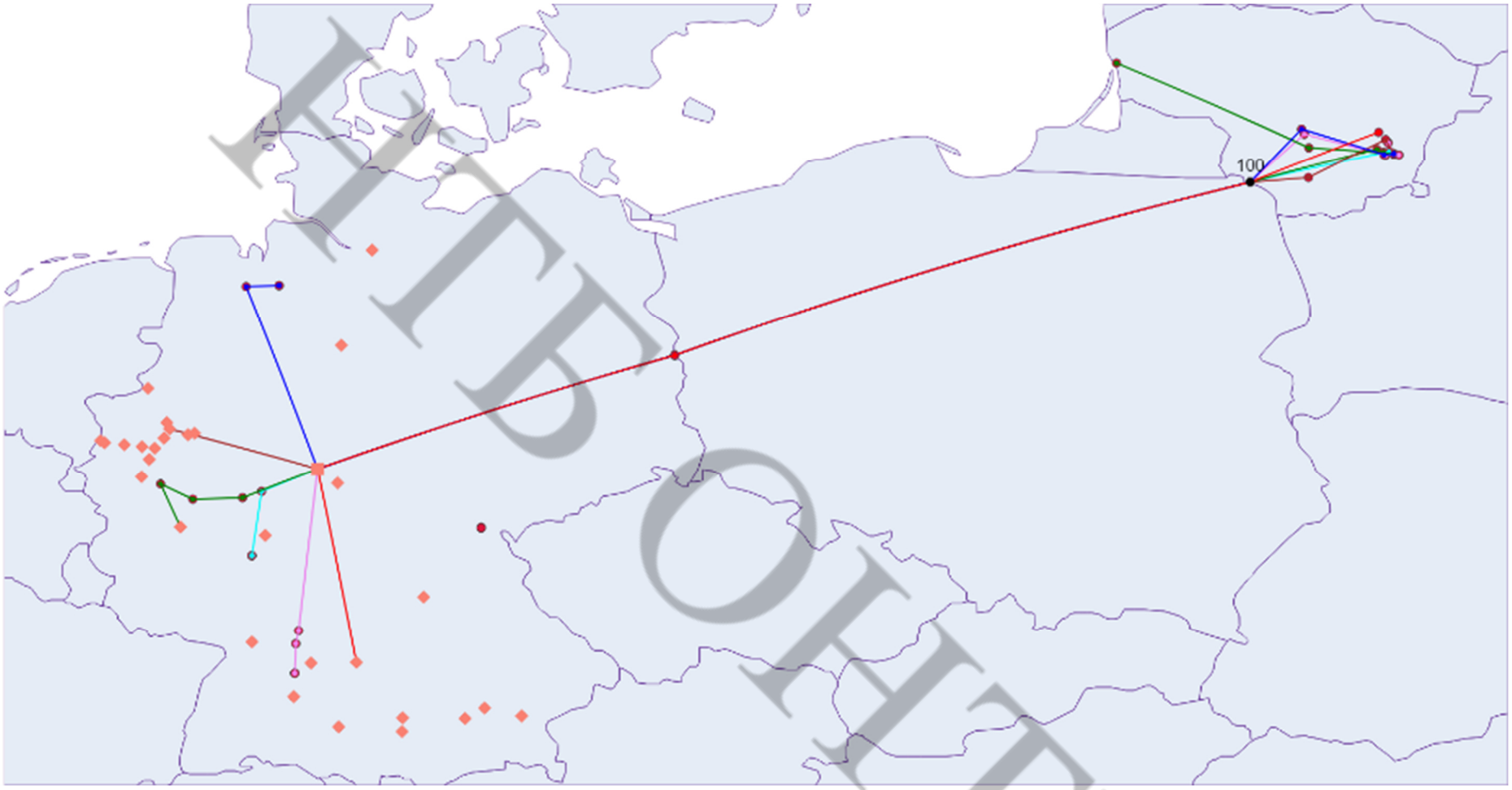


Fig. 3. Comparison of values generated with different crossover and mutation probabilities



In Figure 4, a visualization of the results after 100 iterations of the genetic algorithm are presented. It took about 10

Fig. 4. Visualization of the results

minutes of computing time to produce these results. Different colored lines represent routes of individual trucks. Diamond shaped locations are cargo redirected to the depot (a square of the same color). In this case, a special zone is constructed around the bottom of Germany as to ensure that the truck does not enter Czechia. The red dot near the west-most of Czechia is the special location that trucks would need to pass before continuing their drive to the border.

V. CONCLUSIONS

Taking everything into consideration, the literature analysis concludes that using metaheuristic methods is best for real-world applications. The most frequently used methods were the genetic algorithm and the Tabu search. In this study we confirm the viability of utilizing the genetic algorithm for route planning systems with various constraints.

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DECISION SUPPORT SYSTEM FOR FORECASTING THE NUMBERS OF THE TROOP IN THE MIDDLE AGES

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Abstract. *This work is devoted to solving the problem of predicting the number of troops in the Middle Ages. Three general tasks are formulated: forecasting the number of troops based on available factors; verification of the reality of the existence of troops of such a certain number; calculation of the size of the army after a certain time of the campaign. The main mathematical formulas necessary for carrying out calculations for each problem are given. The task of developing specialized software is formulated - a decision support system that allows you to test the hypothesis of the number of troops, dynamically simulate the number of troops at each moment of the campaign and calculate the number of troops using indirect data. An information model of the system is presented in the form of a set of UML diagrams (use cases, classes, sequence and components). Examples of using the developed system are described.*

Keywords: *medieval military history, forecasting, unified modeling language, Python, Eel.*

I. INTRODUCTION

Nowadays, the theme of medieval history is quite popular in popular culture. However, most of the historical media projects are quite far from the modern idea of medieval history. The reason for this phenomenon is a large number of historical myths roaming the Internet and the use of outdated historical literature. One of the most interesting moments of medieval history are wars and military campaigns.

One of the problems in studying military operations of a fairly distant past is determining the number of opponents on both sides. Medieval chronicles and some authors of fiction are tend to exaggerate the military events of the distant past, so it is very difficult to find more or less real facts among fantasies.

A more realistic understanding of the events of a very distant past will help us, the descendants, understand better the historical processes that took place more than half a millennium ago.

With the advent of the computer technology in historical science, various modeling systems are increasingly being used, as they allow visualizing and making visual and more understandable to the general public the information recorded in dry scientific articles, understandable only to specialists.

The purpose of the work is to find out non-combat losses in the medieval armies during marches.

The object of the study is the number of dead soldiers due to non-combat losses. The subject of the research is models, methods and information technologies for solving the task.

II. LITERATURE ANALYSIS

There are no open access applications for solving this problem, which is not surprising in view of a particularly narrow range of tasks to be solved. You can calculate the number of medieval troops using standard mathematical packages (SMatchStudio, MatchCad, etc.) or an Excel spreadsheet. But for each individual task, the Excel workbook will have to be redone and the database for each task will have to be created independently. In addition, it is impossible to create cycles in Excel, and this imposes additional restrictions on the accuracy of the calculations.

III. OBJECT, SUBJECT AND METHODS OF RESEARCH

Three general tasks can be identified. The main task: you need to predict the number of troops based on the available factors:

$$y = \{a_1, a_2, \ldots, a_n\}, y = \{a_1, a_2, \ldots, a_n\}, \quad (1)$$

where y is the total number of troops to be calculated;

a_i , i=1..n are factors affecting the number of troops (season, terrain, presence of epidemics, etc.);

n is the number of factors affecting the number of troops.

The total predicted number of troops can be divided into components:

$$y = y_1 + y_2 + \ldots, + y_m, y = y_1 + y_2 + \ldots, + y_m, \quad (2)$$

where y is the total number of troops to be calculated;

y_i , i=1..m are the numbers of a separate category of troops (cavalry, infantry, etc.);

m is the number of categories of troops.

The second task is to check the reality of the existence of troops of such a (given) number:

$$F(x) = \begin{cases} f_1(x, a_1) = y_1 \\ f_2(x, a_2) = y_2 \\ \ldots \\ f_n(x, a_n) = y_n \end{cases}, F(x) = \begin{cases} f_1(x, a_1) = y_1 \\ f_2(x, a_2) = y_2 \\ \ldots \\ f_n(x, a_n) = y_n \end{cases}, \quad (3)$$

$$Y = y_1 + y_2 + \ldots + y_n, Y = y_1 + y_2 + \ldots + y_n, \quad (4)$$

where x is the number of troops entered by the user;

a_i, i=1..n are factors affecting the number of troops (season, terrain, presence of epidemics, etc.);

n is the number of factors affecting the number of troops.

$f_n(x,a_i)$ is a function that calculates penalty points by checking x against the criteria {a};

Y is the total number of penalty points, indicating the correctness of the entered data.

Thus, by generating the number of a certain army and counting the number of penalty points, one can find the most probable value.

The third task is to calculate the size of the army after a certain time of the campaign. This can be done with the following function:

$$x_k = pood(x, d, \{a\}), x_k = pohod(x, d, \{a\}), \quad (5)$$

where x is the number of troops entered by the user;

d is the number of days of staying in the campaign;

{a} is a combination of other factors (season, location, presence of epidemics, etc.

xk is the number of warriors who reached the goal of the campaign.

The number of troops can still be determined by knowing the number of enemy troops in the battle and its result, but such a calculation can be implemented only using artificial intelligence methods, and in some cases only.

IV. RESULTS

The application has three usage scenarios: hypothesis testing (troop size), dynamic simulation of the troop size at each moment of the campaign, calculation of the troop size using indirect data. All of these use cases are shown in the usage diagram (Diagram 1). The information model of the new designed system was created in the unified modeling language UML - Unified Modeling Language [5].

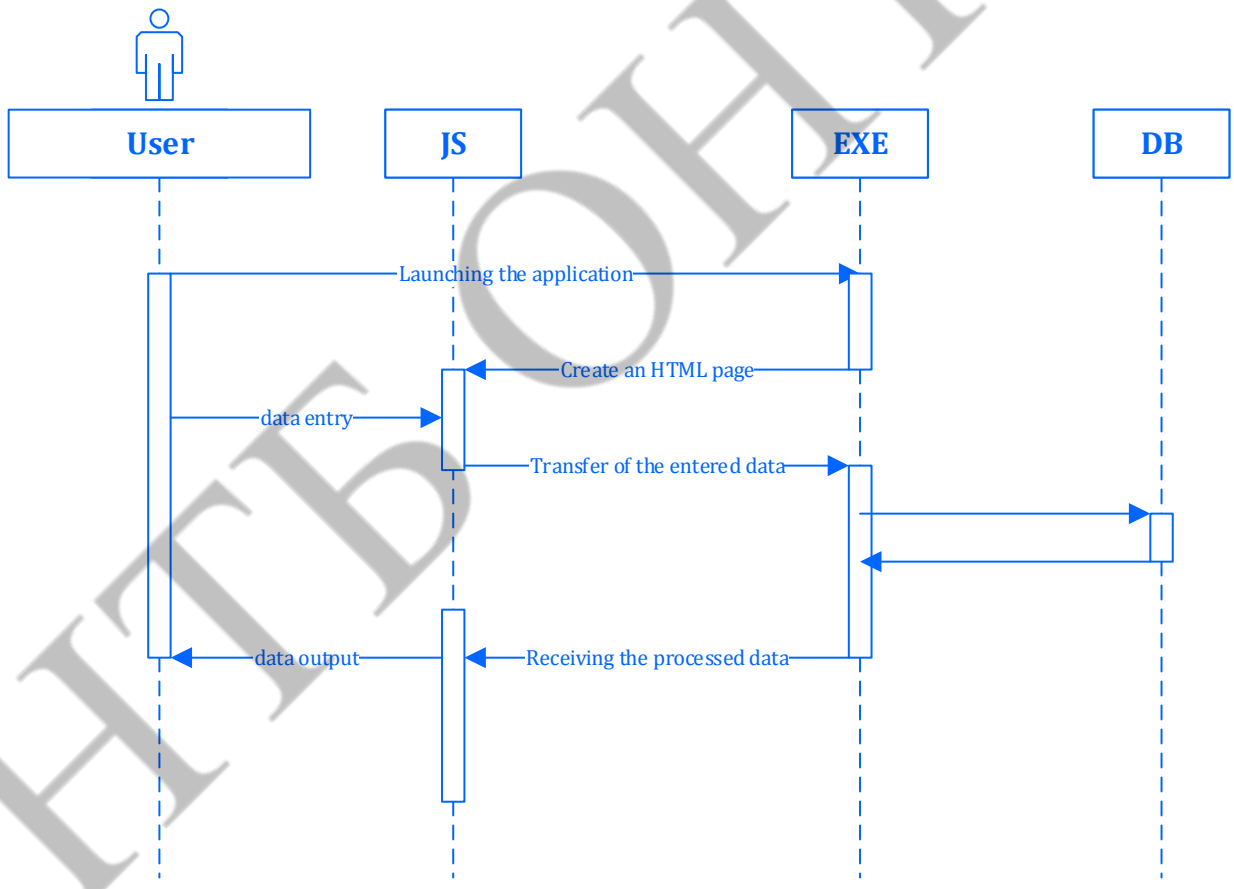

Fig. 1. Use Case diagram

The sequence diagram (Figure 2) shows the interaction between Python and JS while the application is running.

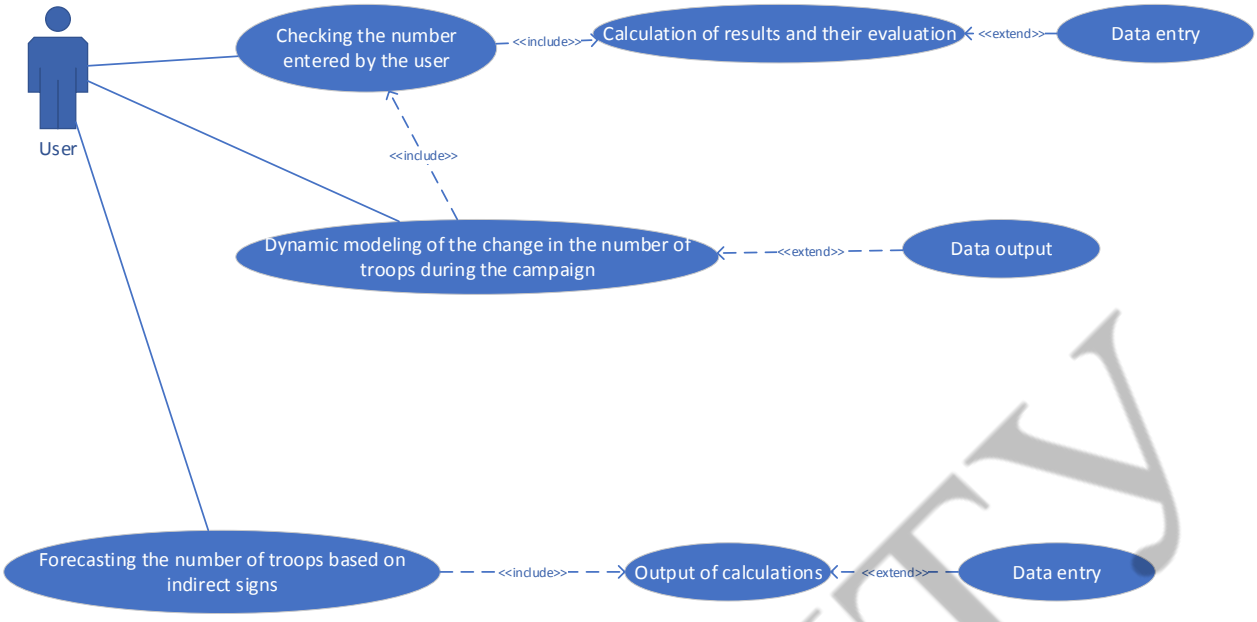

Fig. 2. Sequence diagram

The class diagram (Figure 3) shows JavaScript classes that display information to the user and receive it from him for transmission to Python, as well as two Python calculation classes for performing calculations according to the first and second scenarios.

To develop an information system, it is planned to use the Eel library for the Python programming language. Using this library allows you to develop an interface using standard web development techniques. This will allow you quickly to adapt the application to a large number of platforms, as well as transfer some of the functions for computing on the user's computer, reducing the load on the server (if the system is used as an online application). The detailed structure of the program files is shown in the component diagram (Fig. 4).

Having available UML diagrams, you can start the software implementation of the information system.

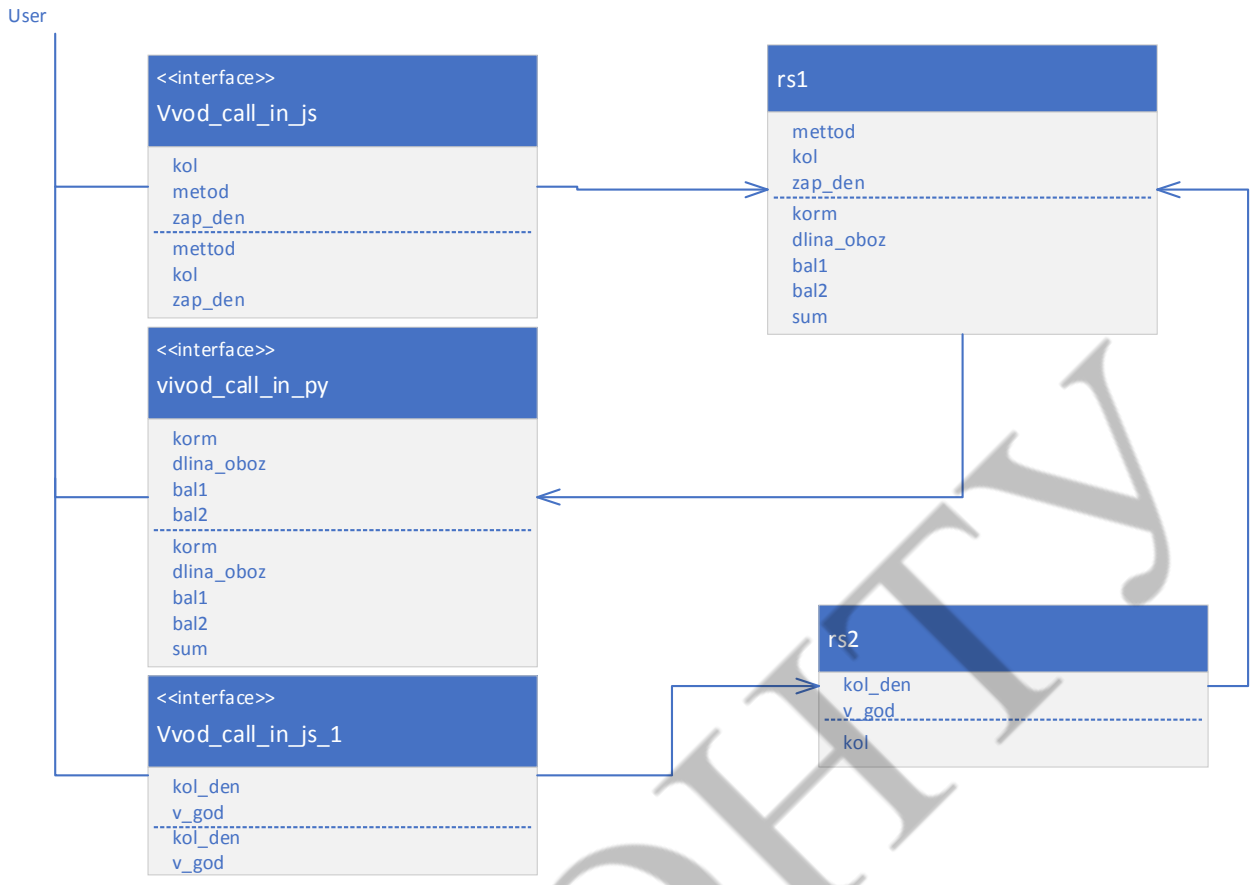

Fig. 3. Class diagram

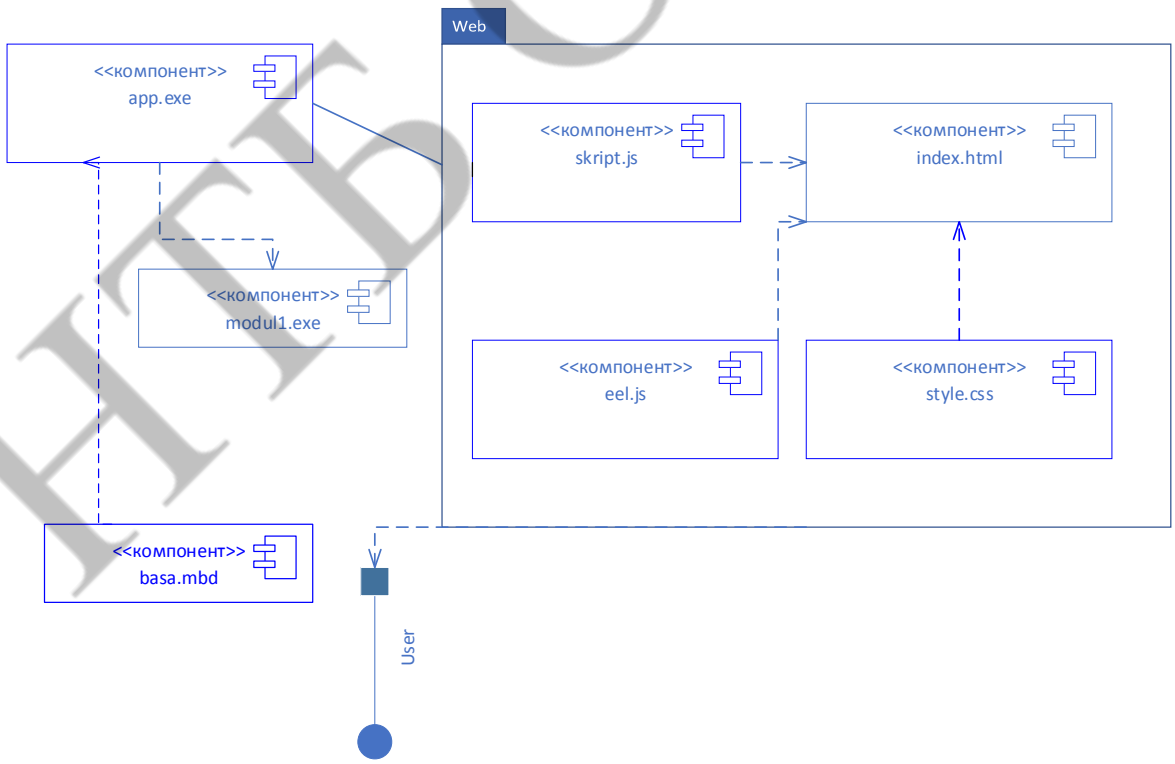

Fig. 4. Component diagram

Now some historians believe that the number of the Mongol army that came to Russia was no more than 40,000 [2]. Let's enter this value into the application (Figure 5).

Fig. 5. Application's work

The calculations show that during the six months of the campaign, non-combat losses will reach thousands of units. But even an army divided into three columns could

stretch for more than 100 km on the march, and a convoy with fodder for 10 days would stretch for more than 20 km.

Let's enter the data calculated by the historians from direct reading of the historical sources, for example 139,000 (Figure 6).

Fig. 6. Application's work

With the introduction of the initial value of the army at 139,000 for six months, non-combat losses will amount to almost 4,000 thousand units, but with this

calculation, the length of the convoy began to equal 69 km, so you need to reduce the number of days of army autonomy to 4 in order to at least slightly reach the value of up to 30 km, because a larger convoy cannot be controlled. The application warns that the autonomy parameter of the troops is greatly underestimated, because in real life the Mongol army would starve to death with an autonomy of less than four days.

The length of the column of soldiers on the march would stretch for 340 km, which would significantly reduce the efficiency of the army's advance compared to the first case.

V. CONCLUSIONS

A system was developed for modeling the number of the medieval troops during a campaign, which allows you to calculate the number of troops at every moment of their combat path.

All application components have been tested for correct operation and for incorrect user input, and those which did not work correctly have been disabled. Also, the study of literary sources made it possible to organize a hint system that would help the user while working with the application.

For software implementation, I have chosen the connection between Python and JS using the Eel library, because it makes it possible to make a nice graphical interface using the simple Python programming language.

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DEVELOPMENT OF SOFTWARE FOR AUTOMATION OF KNOWLEDGE TESTING

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Abstract. *Testing is one of the most effective and common ways to control knowledge. The process of taking the test, passing it and counting the results manually is quite time-consuming and monotonous. Modern means of information technology allow you to quickly create a variety of test and thus get rid of these shortcomings. However, despite previous developments in this area, research in this area is relevant. After all, modern technology allows you to perform intelligent analysis of test results, and make passing tests convenient on different devices.*

The ***purpose*** *of this work is to automate the process of testing knowledge.*

To achieve this ***goal****, the* ***task*** *was to create a universal testing system that would provide an environment for both test developers and test takers. Users will be able to create and edit test tasks, take tests on various devices and analyze test results.*

In the process of creating an automated system for testing knowledge, the following ***research*** *was conducted: analysis of analogous software, study of technical and methodological literature on the subject, work with technical documentation.*

To implement the task, the following technologies were used: Loosely Coupled Monolith; C# programming language; to implement data storage – SQL database.

The work consists of four chapter, conclusions, list of references. The total volume of the work is twelve pages. The work contains 13 drawings, 7 used scientific sources.

Keywords: *intelligent analysis of results, automated system, Loosely Coupled Monolith.*

I. INTRODUCTION

Today information technology has become an important part of human society. The development of the information society requires the existence of a modern education system.

The field of education, like any other, is constantly evolving. With it come new forms of learning and technology. One of the main areas of learning improvement is the development of an automated knowledge control system that allows you to effectively and quickly assess knowledge. Computer-based testing is a modern adaptive tool for testing student achievement. The development of information technology has allowed the introduction of modern computer technology in the process of monitoring and evaluating skills. Therefore, the main task is to study the process of testing knowledge and creating a modern program to automate this process.

The testing system should make it easy to create and edit the test. Based on the analysis of test results, the test creator is given the opportunity to improve the content of the test. Passing the test should be user-friendly, multi-platform and intuitive.

The C# programming language and Visual Studio 2022 development environment were chosen to implement the task. The Loosely Coupled Monolith

pattern was chosen to implement the system. The user has the opportunity to take the test both on the site and through a bot on social networking platforms such as Telegram.

II. LITERATURE ANALYSIS

Control of knowledge through testing is a topical issue today. Accordingly, there is a demand for the development of software to automate the testing process. During the development of technology in the field of software development, many products have emerged to automate the testing process.

Most software products may have similar basic functions. The systems have the functionality to create a test, as well as edit and analyze test results. Some services have authentication and storage of test results.

One of the most common services is Classroom [1]. In the service, you can leave comments on the work of schoolchildren and give grades, publish announcements, archive courses, share files from other applications, and have access to materials without an Internet connection. The teacher can monitor the process of completing assignments in real time [2].

Another popular ser vice is Quizizz, a world-famous service that provides distance learning through the creation of tests, control and homework assignments in the format of quizzes and tests, and the organization of competitions. It has millions of users in more than 100 countries around the world. The site contains a huge number of ready-made tasks in a variety of disciplines and industries, but the teacher can create new original quizzes and publish them in they profile. It shows the completion of tasks by the class in real time and the ability of the teacher to track the results of each student, to generate a report [3].

The systems listed above provide powerful functionality to meet the needs of the testing process. But this subject area is relevant, more and more people are working online, studying online, discussing work issues. Accordingly, this subject area is competitive in the market, and consumers are ready for new ideas and functions in the field of test automation.

After analyzing the functionality of the best products on the market, a plan was developed to create your own software product that will be competitive in the market, easy and convenient to use.

Firstly, the analysis of test results allows the test owner to control the knowledge better. For example, if there are questions in the test that most people answer incorrectly, it may be a problem of objective assessment of knowledge. Therefore, it was decided to add a statistics page to the software product, which will inform the test owner about potentially incorrect questions in the test.

Another need for a large number of users is the customization of content. Therefore, the software product has an API implemented so that developers can obtain data and customize it to their liking. An API is a system that enables data transmission between one software product and another [4]. It also contains the terms of this data exchange. Therefore, users with API skills have the ability to obtain test data, test results, export them to third-party analysis services, customize test results and the test itself for themselves and their audience.

It is very important that the software product is developed in sync with current user requests, taking into account their tastes. Today, messengers are the most common

way of communicating between people. So, we can conclude that almost everyone has a messenger installed on their phone, laptop and so on.

According to the AIN.UA poll, the most popular messenger in Ukraine is Telegram. It is chosen by 50.6% of respondents for communication [5]. Telegram provides an API for creating chatbots, which are predicted to have a great future in marketing and communications. This is a specialized application that is based on the messaging platform, allowing users to interact with third-party services through a familiar chat interface. Bots are third-party applications that run inside Telegram. Users can interact with bots by sending them messages, commands and inline requests. That is, in order to receive certain information, a person does not need to leave the messenger, it is enough to send a special command, which is interpreted accordingly by the bot [6].

At the moment, Telegram has a lot of bots that provide functionality for downloading music, searching for videos, viewing weather forecasts, etc. In this regard, one of the functions of the test automation system is to manage the functionality directly from within Telegram with the help of the chatbot. Thus, the user works with a familiar interface without wasting time getting to know the site interface [7].

As a result, after analyzing the most popular analogs of the test automation system, it was concluded that the products that are intuitive for the user, easy to use and have flexible functionality have gained the greatest success.

And, accordingly, to create a competitive software product, it is necessary to provide the user with functionality that will not be inferior to successful products in this area. A nice bonus that can attract users is a chatbot that will make life easier for users who do not like to get to know a new interface.

All this functionality is aimed at improving the quality of knowledge control.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The subject area of this work is test automation. Today there are several traditional methods of knowledge control:

• Oral examination - checks the quality of student training, consists of questions from the teacher. The quality of testing depends on the correctness and number of questions.

• Tests - allow you to test the possibility of applying theoretical knowledge in practice. It is more accurate than an oral examination, but requires more time to prepare and conduct.

• Practical and laboratory work - tests the ability to apply knowledge to solve practical problems.

All the above methods are created and carried out exclusively in manual mode, which is not effective. Routine operations for the preparation, printing, verification of tests and the formation of the assessment take a lot of time and, in addition, there are complications for the following reasons: the number and complexity of questions, the number of tests.

Tests are prepared by teachers to control knowledge of discipline modules, for session control or for state exams. Tests are provided to students in paper format. Students receive information on the rules of the tests. Test results are evaluated by processing answers using templates, comparing answers with correct answers. Such a system does not guarantee the quality and reliability of test checking. Based on the

results of testing, protocols are formed, which are the basis for assessment of knowledge in the discipline. The student does not always have the opportunity to adjust the answer when performing tests. As a result of the analysis of existing testing processes, a decision was made to automate these processes.

The development of scientific and technological progress has made it possible to create a new, better and less time-consuming way to control knowledge - machine testing. The use of computers during testing makes it possible to improve the quality of control, reduce complexity and cost. In addition, the human factor, which can negatively affect the quality of evaluation of results, is limited as much as possible. In general, the method of testing can quickly and effectively control the knowledge of a significant number of people in a short period.

The software product involves the design of tests by the user. The system should ensure convenient creation and storage of the tests. After testing, the results should be displayed on the screen. There is also a security system that will not allow users to view and edit tests without access rights.

The target users of the software product are students and teachers. The system also provides an opportunity for users who want to test their knowledge, take tests that are in common access, see their position in the rankings.

The main modes of the program are test taking and test design.

Software features in the test taking section:

1. Registration of the user who passes the test. This is necessary in order to save the tests created by the user and store the results of the tests they have taken.

2. Navigation between test questions. Transitions between questions make taking the test more convenient. The user has the opportunity to leave a question to which they do not know the answer, and return to it later.

3. Forming the answer to the question. Choosing the answer that the user thinks is correct. The user has the opportunity to change the answer.

4. Generating test results. After passing the test, the user sees the page with the test results. The results are saved, and the registered user after login sees the history of the tests, their results and their place in the ranking.

Software functions in the test design section:

1. Creating and editing a test. In their account, the user can create a test. The created test can be edited or deleted.

2. Test planning. Assigning test status. Each test has a private or public status. A public test is visible to all users of the system. Users who have been granted access by the test owner can take a private test. You can set a time frame for the private test for when it is available for passing.

3. Preliminary testing. The owner of the test can take the test to check its operability: how clear the questions are, the answers, whether they are displayed correctly, whether the user will have enough time to pass all the test questions.

4. Report. The user can see the statistics of the tests created by them. How many people passed the test, how successful the test results are.

Based on the requirements of modern users, the following functionality was created:

1. API for developers. The user can use it to configure tests or use test data in

their system.

2. Telegram chat bot. Ability to view a list of your tests, results, without leaving Telegram.

All the described functionality is aimed at meeting the needs of the user in the field of test automation.

Most other software products in this area work in such a way that the user has to register as a teacher or student. Accordingly, the teacher cannot take the test, and the student has no right to crate the test.

However, our software product is aimed at synthesizing user rights. There is no role assigned to the user. Each user has the opportunity to both create tests and pass them. For example, a teacher creates a private test for students. In addition, the same user has the opportunity to take a public test, which they find interesting.

Thus, the system provides a wide range of functions to meet user requrements and lead to their satisfaction with the product.

IV. RESULTS

4.1. Overview

After analyzing the literature, defining the object, subject and methods of work, a software product with the functionality described above was developed. The system is called “Test Your Brain”.

4.2. Authorization

To control the full functionality of the system, you must log in (Fig. 1.a.). Users who do not have an account yet have the opportunity to register in the system (Fig. 1.b.).

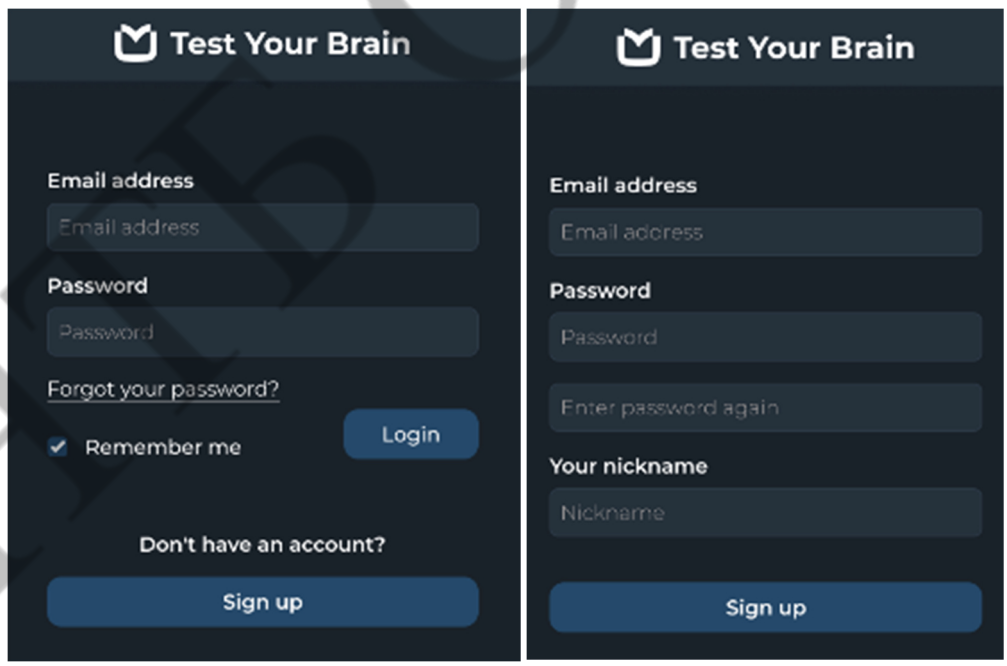

Fig. 1. Authorization:
a – login form, b – sign up form

After registration, the system user has the opportunity to specify additional information on the account page - name, surname, country. It is also possible to add an avatar, change the nickname and password (Fig. 2.).

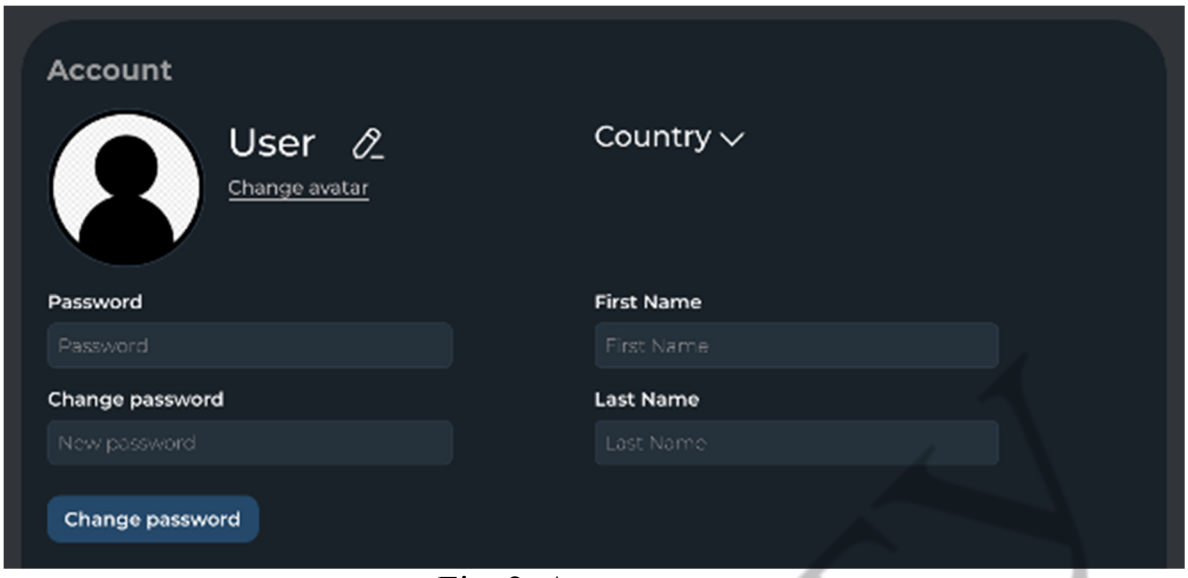

Fig. 2. Account page

This data will be useful for users for whom it is important to see information about those taking the test.

4.3. Navigation bar

After logging into the system, the user has the opportunity to use the full features of the system through the navigation bar (Fig. 3.).

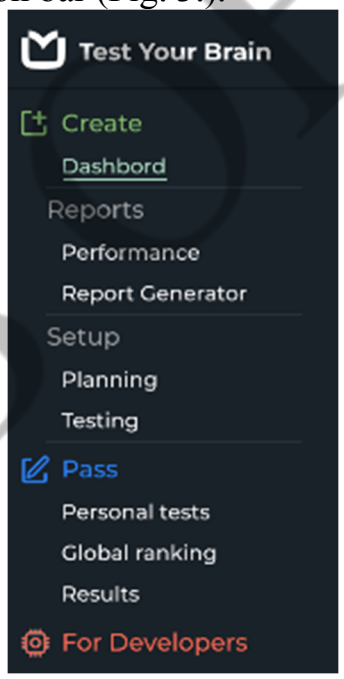

Fig. 3. Navigation bar

The panel is divided into three sections.

1. Test creation section. Through this dashboard tab you can create a test, edit and delete the test, see a list of created tests. The reports unit provides data on the results of users who have passed the test. The setup unit manages the status of the test, plans the time of the test, previews the test to test the convenience of passing.

2. Test taking section. The personal tests tab shows information about the tests the user was given access to. The results tab contains information about the results of the passed tests, and the global ranking tab shows information about the most accomplished users by the number and quality of tests passed.

3. Section for developers contains API for developers to customize tests.

4.4. Dashboard tab

The tab is used to view and manage the data of the created tests (Fig. 4.).

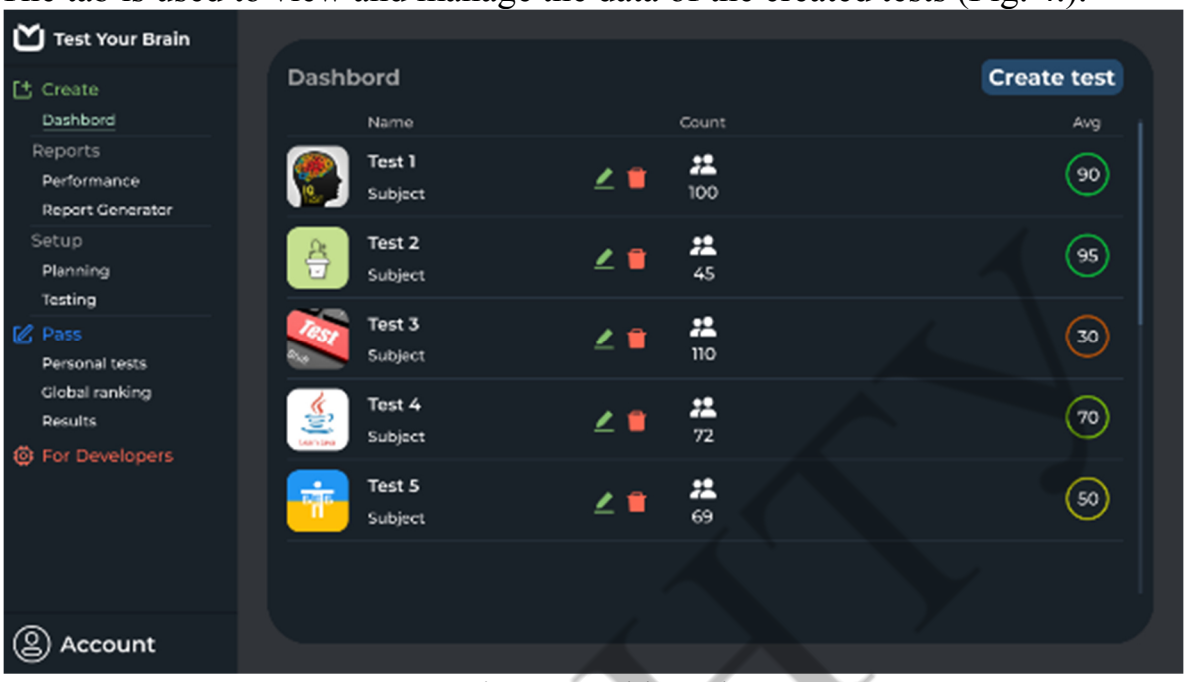

Fig. 4. Dashboard

Through the dashboard the tests are managed: the tests can be created edited or deleted. This page provides tabular information on the number of people who took the test and the average score of those who took the test.

4.5. Create test page

Creating and editing the test is performed through the following page (Fig. 5.).

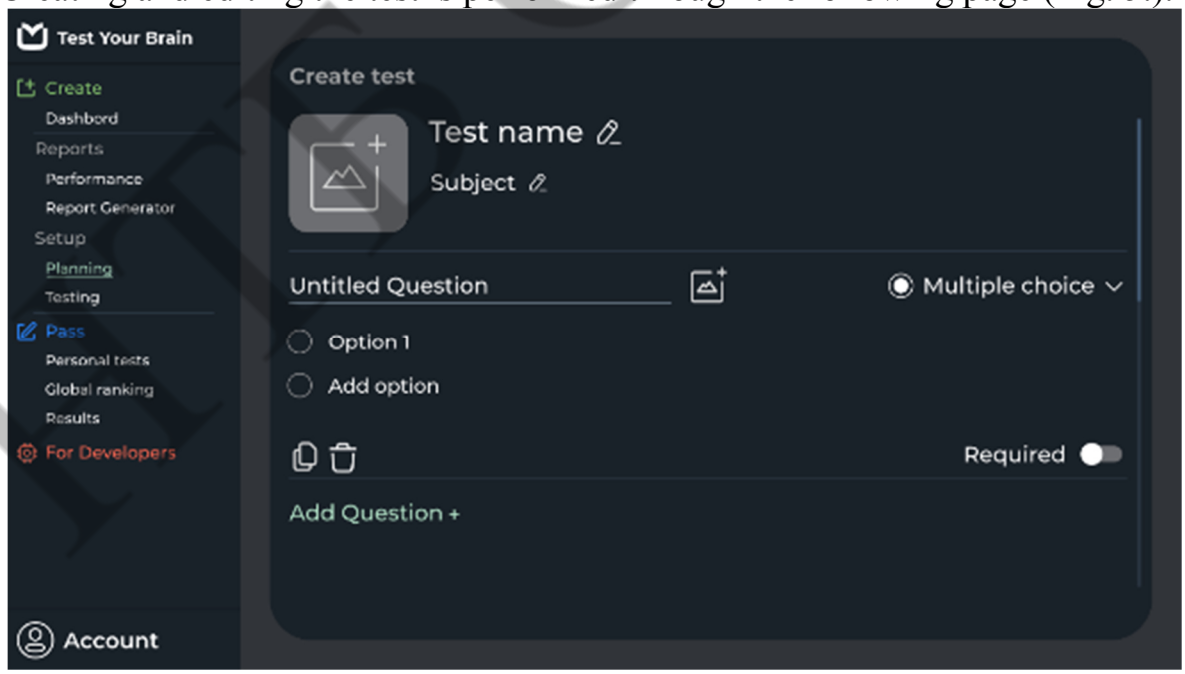

Fig. 5. Create test page

The test has the following properties: title, subject, icon, and list of questions. Each question has its own properties. It can be mandatory or not, have one or more correct answers. This page provides functionality for creating and editing test questions and information.

4.6. Reports section

This tab allows you to view the statistics of the results of those who passed the test graphically (Fig. 6.).

Fig. 6. Performance

An analysis of the effectiveness of the created tests is conducted through the reports section. It is possible to filter by time, view information on a specific test, and the tests overall, view the number of users who passed the test broken down by day, see the average score for the tests and compare them with each other.

4.7. Setup section

This section provides functionality for editing the test status and preview of the test.

The planning tab looks as follows (Fig. 7.).

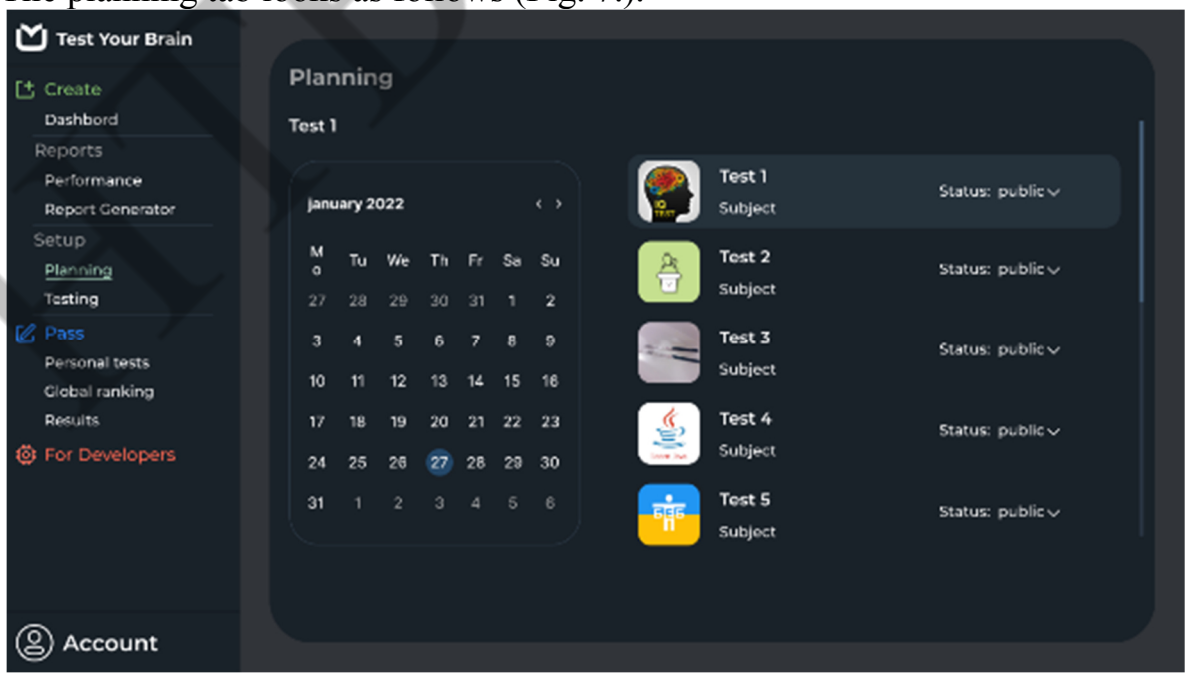

Fig. 7. Planning page

This tab presents a list of tests with their status: public or private. A public test

is visible to all users, a private one - only to those who have been granted access. Each test is assigned a time frame for when the test is available.

The test tab is designed to check the quality of the test by passing it (Fig. 8.).

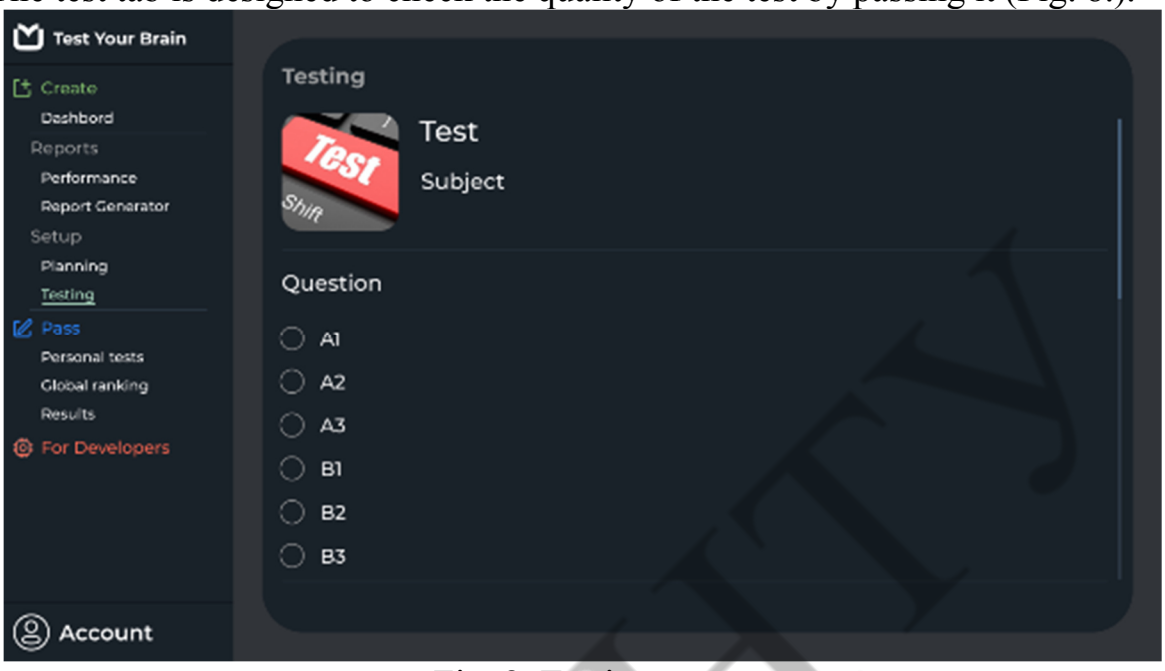

Fig. 8. Testing page

A test page is identical to the passing page, but without saving the test results. The user answers the questions, choosing the options that they consider correct, after confirming the answers, the test result is formed.

4.8. Personal tests page

This page shows a list of tests that are available for the user to pass (Fig. 9.).

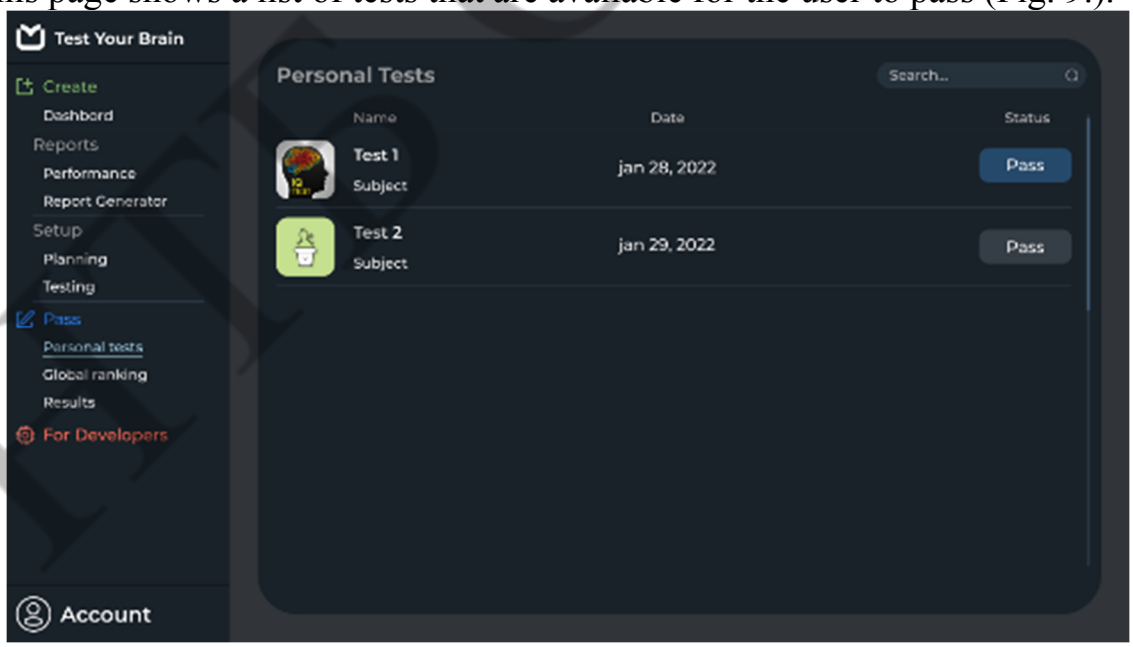

Fig. 9. Personal tests page

The user sees a list of tests that they will be able to pass later, and tests that are already available for passing.

4.9. Results page

The results page provides the user with information about the tests they have passed (Fig. 10.).

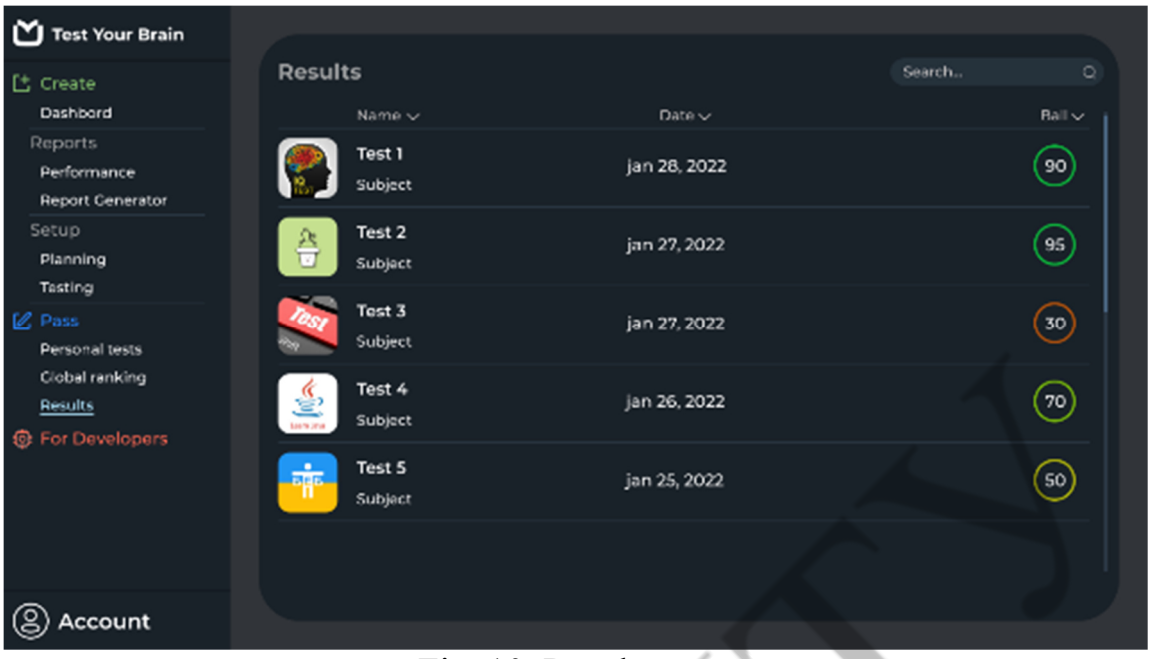

Fig. 10. Results page

This page contains information about the passing date and the percentage of correct answers to each test. It is possible to sort data by name, date, and score.

4.10. Global ranking page

This page shows information about the most successful users of the system, and shows a list of the most popular tests.

The Top Tests panel shows information about the tests that have been taken the most times and the average percentage of correct answers from users who have taken the test (Fig. 11.).

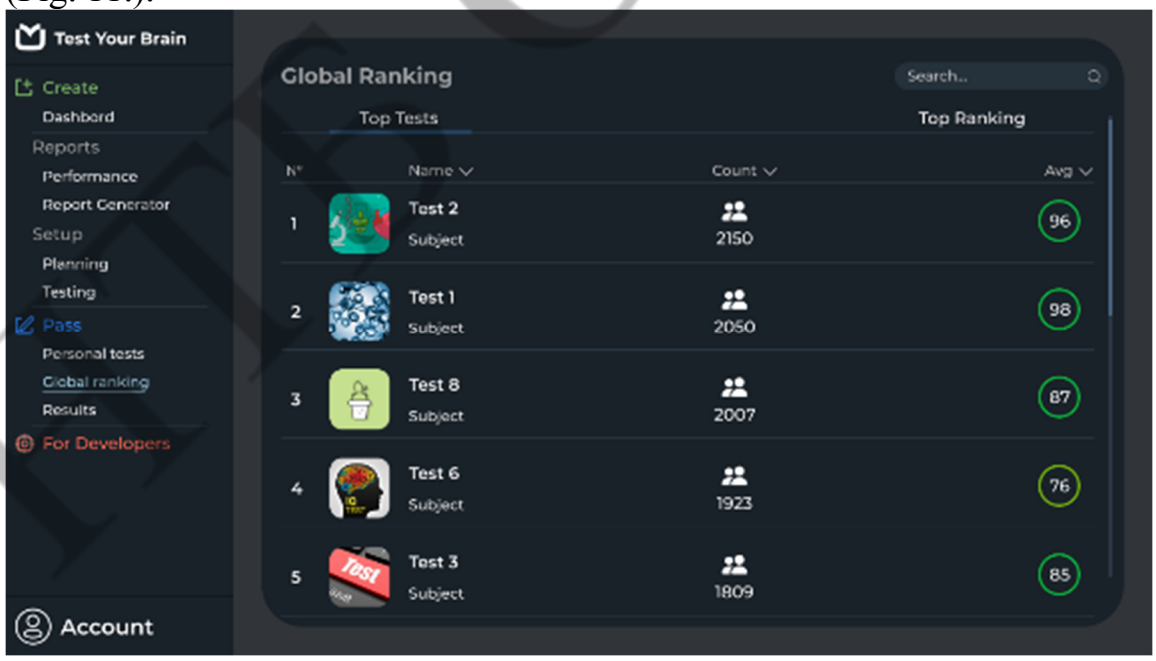

Fig. 11. Top tests panel

The Top Ranking panel shows information about the users who passed the most tests and who passed the tests with the maximum percentage of correct answers (Fig. 12.).

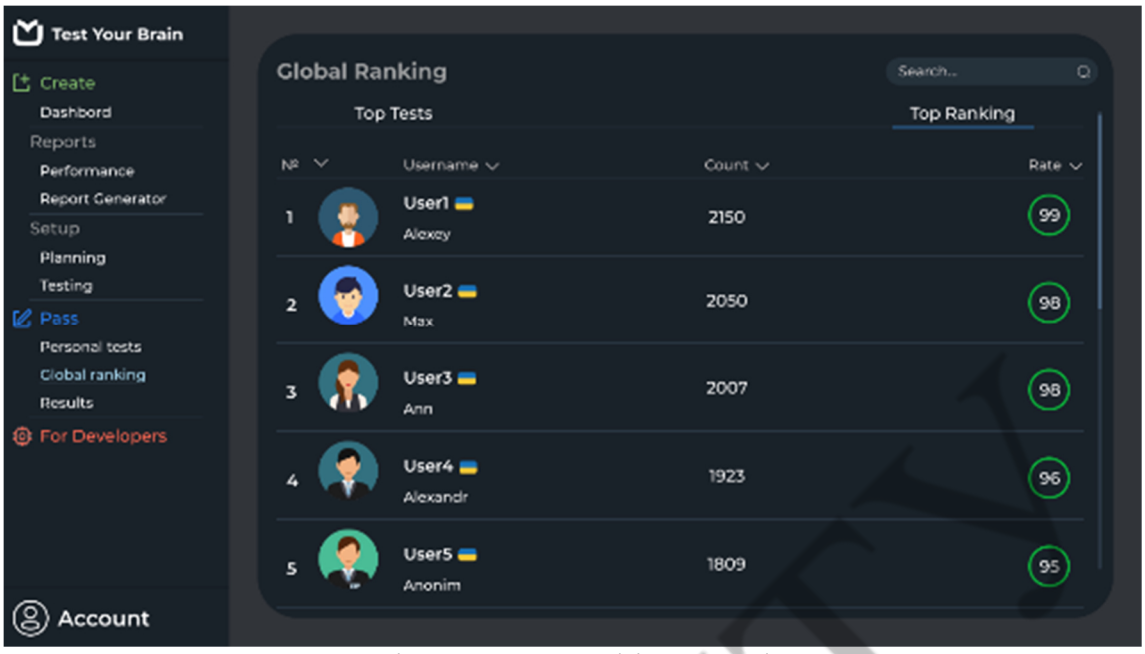

Fig. 12. Top ranking panel

Data can be sorted by number of tests, or by average score. Thus, it is possible to view your place in the global ranking of users, and to see how popular the tests created by a user are among others.

4.11. Telegram bot

The telegram bot looks as follows (Fig. 13.).

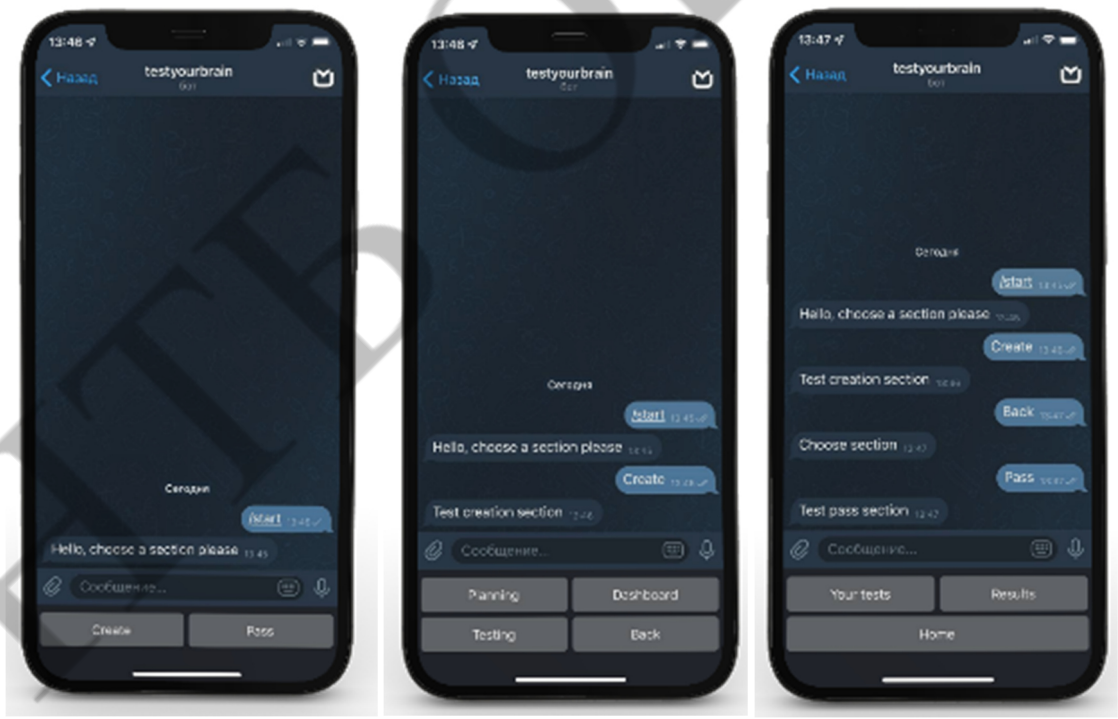

Fig. 13. The telegram bot:

a – start bot, b – test creation section, c – test pass section

The interface of the bot is intuitive and repeats the functionality of the site.

V. CONCLUSIONS

The field of education, like any other, is constantly evolving. An automated knowledge control system has been developed that allows for efficient and fast assessment of knowledge.

Computer testing has the following capabilities:
- creating a test with questions;
- editing the test;
- saving the test;
- viewing statistics of created tests;
- passing the test;
- viewing the results;
- viewing the leaderboard.

The software product provides greater accuracy and speed in the process of conducting and designing tests than in manual testing. The test design process is universal and the user can compose individual questions in tests, quickly edit test questions, view the list of leaders, take public tests that they like or private tests that are made available to them.

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A COMPILER OF DOMAIN-SPECIFIC LANGUAGE FOR "SMART-HOME" APPLICATIONS: DESIGN PRINCIPLES AND IMPLEMENTATION ISSUES

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Abstract. *The actuality to use of a domain-specific language (DSL) concept in such complex problem areas as the Internet of Things systems and "Smart-Home applications (SHA)" is motivated. The overview of the main methods and software tools for DSL design and implementation is done, and one possible scheme for their classifications is proposed. The approach to DSL compiler designing for SHA is proposed which is based on a configurable grammar rules system. All main functional blocks for the proposed DSL compiler are developed using such programming tools as Python and C++, and the first testing results of this implementation are obtained and analyzed. The effectiveness assessment for this compiler prototype is provided in the way to calculate of two quantitative metrics, and this one allowed to get the approximated weighted efficiency value of the compiler's usage about 16.75%. It shows the acceptable quality of the elaborated DSL compiler's prototype, allows to make the positive conclusions about the proposed approach, and to formulate some further work to be done in this research.*

Keywords: *compiler, domain-specific language, IoT, smart-home, design, software, effectiveness, metric*

I. INTRODUCTION

An efficient software development in such modern and high-tech application domains as the Internet of Things (IoT) system, and especially, for 'Smart-Home' applications (SHA) [1-2], supposes the usage of such new sophisticated and advanced design methods as a domain-driven development, a model-driven architecting, and some knowledge-based software tools and technologies [3].

SHA systems have some specific features and options which influence the appropriate problems for their design and implementation [2], see the Figure 1.

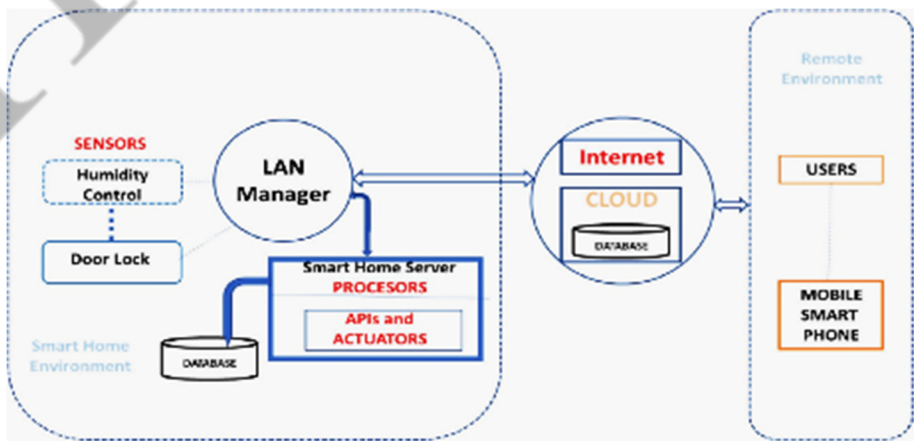

Fig. 1 – A reference conceptual architecture of IoT / SHA [2]

Some SHS specific features are:

- includes a lot of interconnected hardware and software components;
- any such a component has a lot of specific features and parameters;
- all components operate in real-time mode;
- operation environment is dynamic and changeable.

According to these issues the following main challenge for SHA-developers are facing with: how to design and to implement configurable and adaptable complex software and hardware solutions, taking into account different user's needs and requirements?

One of the recognized ways to achieve this aim is the usage of concepts and technologies of domain-specific languages (DSL) [4], which have to be created for a given application area, that finally allows to provide more effective and cheaper programming techniques in system development. One very important reason to use DSL is an opportunity to support variability and adaptivity of appropriate software solutions due to the elaboration of flexible grammar rules and building of correct domain dictionary (or a set of tokens).

The purpose of this study is to analyze some existing models, tools, design principles for DSL construction, to propose an approach to create DSL compiler for adaptive software development in SH applications, to provide compiler components prototyping and testing, and to get first results of effectiveness estimation for the proposed approach in the subject area 'Smart-Home' application.

II. MAIN DESIGN PRINCIPLES FOR SHA / DSL

2.1. Basic design approaches for DSL

There are 2 main types of domain-specific languages: external DSL and internal DSL (or also known as embedded DSL) [3]. External DSLs have their own syntax, which is, in most cases, separated from the application programming language. On the other hand, all internal DSLs use some general purpose language (GPL), but in fact, they just expend a specific subset of the functionalities of this language. One of the most important problems in the creation and future use of DSL is the availability of special language workbench (tools). These tools can be known as the specialized integrated development environments (IDEs) for defining, designing and creating DSL for specific needs.

The process of creating external DSLs consist of three key steps:

1. Definition of the semantic model;
2. Definition of the syntactic mode (abstract and concrete syntax);
3. Definition of rules of transformation (in other words, how abstract is translated to actual).

To determine the specific syntax of the language and to create the specific transformation rules by building a language translator there are some ready-made tools, which can be helpful. For example, ANTLR [5] allows generating lexical and syntax parser, language translator. To determine the semantic model of language, which describes a particular aspect of the system there are no special tools. To do so, every

DSL developer must independently describe the metamodel of the language by using GPL or, maybe, other DSL.

When creating an internal DSL, the most straightforward way is to select one of the GPL as a base (e.g. Java, Kotlin, C# etc.) and create a special library, based on the grammar of the chosen language. This custom library then could be used in a certain style, usually to manage particular aspects of the software system that is being developed [5]. Unlike external DSL, using the grammar of the selected language could lead to some obvious constraints. Thus, the less flexible the constructions of base language are, the less usable and effective the internal DSL is going to be. It means, when choosing the language, the capabilities of one have to correspond to the scope and use of the internal DSL which will be created on its basis. Last, but not least, with all of the functionality of the selected language as a base, the developer receives a ready-made set of development support tools, such as modern IDEs, plugins, documentation and so on. So, the developer loses complete freedom of definition of the grammar, remaining within the grammar of the base language, but at the same time gets the opportunity to use all the already available benefits of this language.

Another approach to creating internal DSL is the use of programming languages with configured syntax, i.e., languages focused on metaprogramming techniques. This approach is called "Extensible programming", which is a programming style focused on the use of mechanisms for expanding programming languages, translators, and execution environments [6]. The examples of these languages could be the follows: Forth, Common Lisp, Nemerle, and Racket.

As the syntax of all GPL is based on a text grammar, such grammars have one essential disadvantage: when it comes to expanding, it could become ambiguous [6]. In other words, there may be a situation when the same lines of source code will have several interpretations, and it’s really unknown, which one it is meant to be. This problem is especially visible when the developer is trying to combine several different grammar extensions into one language. Of course, separately they are absolutely unambiguous, but when combined together, it may lead to serious problems and further use of the language will be impossible. The refusal to use text grammar may be a possible solution. In this case, the program could be considered as an instance of the active syntactic metamodel. Usually, the metamodel of programs is presented in the form of an abstract syntactic tree. The examples of these ones could be follows: Scheme, Clojure, etc.

2.2 Software tools for DSL development

All language support tools, in fact, are the tools that not only help to create DSL, but also provide its elaboration as modern intelligent development environments, providing opportunities to build modern IDEs for the created languages. Such DSL development environments will be able to provide some essential capabilities, without which modern software development is impossible:

- Code auto-completion;
- Default automatic code generation;
- Tools for easy and flexible refactoring;
- Debugging of DSL scripts or scenarios;

- Integration with version control tools (git, cvs, svn);
- Unit and integration testing.

There are some frameworks for already existing popular editors, e.g., IntelliJ IDEA, however, it can't provide an appropriate level of support and integration with DSL. So, one of the most suitable solutions for this problem may be use of JetBrains MPS [7]. This is a metaprogramming system that implements a paradigm of language-oriented programming. It can be both an environment for language development and at the same time IDE for the developed languages.

In order to maintain the compatibility of language extensions with each other, MPS deal with the programs not as text, but as a syntax tree. This allows editing to take place directly. As a result, instead of specific language syntax, the MPS defines an abstract syntax (syntax tree structure) for the DSL, which is currently developed. MPS offers a special projection editor to work with the trees. It means for each node of the syntax tree, IDE creates the part of the screen, with which user can interact.

Summarizing the overview results given below it is possible to propose the classification scheme of the methods and tools for design and support of DSL compilers which are shown in Figure 2:

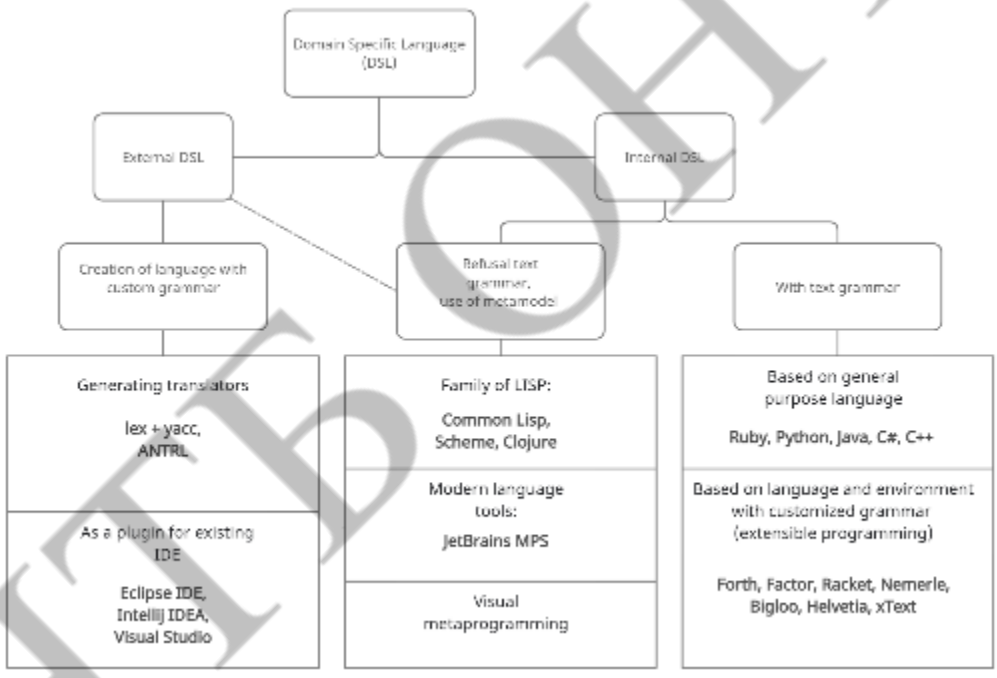

Fig. 2 – The proposed classification of methods and tools for creation and support of DSL

III. IMPLEMENTAION OF THE PROPOSED DSL COMPILER FOR ADAPTIVE SHA DEVELOPMENT

Taking into account this elaborated classification scheme we decided to elaborate the target DSL compiler for adaptive SHA development as an internal DSL with textual grammar using GPL Python and C++.

3.1 Grammar rules for the DSL

Any programming language (GPL or DSL) is a subset of the real (natural)

language and is created to facilitate and support the process of human communication with the computer. The compilation theory is built on the fact that any language can be described formally. Formally means that such a language consists of a set of finite words and their grammatical constructions. The syntax of a programming language, or an appropriate grammar is a collection of structure-corrected and pre-determined combinations of characters, which can be simply called as rules. The syntax of programming languages is usually defined with using of a combination of some regular expressions for its lexical structure and the Backus – Naur notation [8].

So, to define the syntax of DSL grammar rules for SHA, it is necessary to apply some special notation symbols, namely:

- {} – zero or more than zero,
- [] – zero or one,
- + – one or more than one from the left part,
- () – for grouping purpose.
- | – logical OR.

Some predefined words in the grammar rules can be whether links for other grammar rules or appropriate tokens [14].

Further, it is important to define the main grammar rule, without which there is no further grammar development possible. So, in this example, it will be dome as follows:

program :: {statement} (1)

The expression (1) means, that there is a grammar rule with the name “program”, which consists of zero or more than zero “statements”. In this case, a “statement” is another grammar rule, and it can be structured as the following set of the basic rules (see the expressions (2)-(6) respectively):

statement :: “DISPLAY” (expression | string | array | object) nl (2)

| “IF” comparison “THEN” nl {statement} “ENDIF” nl (3)

| "DECLARE" ident "=" expression nl (4)

| "INPUT" ident nl (5)

| ident "=" expression nl (6)

where “DISPLAY”, “IF”, “THEN”, “ENDIF”, “DECLARE”, “INPUT” are the appropriate keywords of the proposed DSL grammar rules with respect to typical process control algorithms used in SH applications; “string|”, “array”, “object”, “ident” are some variables of the different data types; “nl”, “expression”, “comparison” are other grammar rules, see below the definitions (7)-(12).

Other defined DSL grammar rules look like as follows:

nl ::= '\n'+ (7)

comparison ::= expression (("==" | "!=" | ">" | ">=" | "<" | "<=") expression)+ (8)

expression ::= term {("-" | "+") term} (9)

term ::= unary {("/" | "*") unary} (10)

unary ::= ["+" | "-"] primary (11)

primary ::= number | ident (12)

As it may be seen from the set of DSL grammar rules given in (1) - (12), a tree-like grammar structure will be generated using these ones sequentially. It provides an ability to construct the DSL expressions correctly, and the main implementation issues for the DSL compiler for these grammar rules are presented in the next subsection.

3.2 Software implementation of the main compiler' blocks

The first module of the compiler, which is the lexical analyzer (Lexer), will produce a stream of tokens. To do so, first what needs to be done, to implement the ability to track the current position in the input DSL text and character, which corresponds to this position. It will allow the compiler to analyze every symbol or set of symbols separately and find out which token it is. Of course, it is also needed to move the current position further and update the symbol on this position accordingly. In some cases (it will be explained later), it will be needed to know the next symbol without updating the current position. The code examples of these functions are shown in Figure 3:

```
def nextChar(self):
    self.curPos += 1
    if self.curPos >= len(self.source):
        self.curChar = '\0'
    else:
        self.curChar = self.source[self.curPos]

def peek(self):
    if self.curPos + 1 >= len(self.source):
        return '\0'
    return self.source[self.curPos + 1]

def abort(self, message):
    sys.exit("Lexing error. " + message)

def skipComment(self):
    if self.curChar == '#':
        while self.curChar != '\n':
            self.nextChar()

def skipWhitespace(self):
    while self.curChar == ' ' or self.curChar == '\t' or self.curChar == '\r':
        self.nextChar()
```

Fig. 3 – Python code fragment for lexical analysis

One of the main steps in creating a lexical analyzer is defining tokens, which will be allowed in the proposed compiler. A list of available tokens for adaptive SHA was received from the FODA model description (see in Figure 3). However, there are some tokens given by default:

- Operator – one or two characters: + - * / = != > >= < <=;
- String – quotation marks followed by zero or more characters;
- Number – one or more numeric characters followed by optional decimal part;
- Identifier – alphabetic character followed by zero or more alphanumeric characters;
- Keyword – some set of characters reserved by programming language.

There is a possibility of lexical errors in input DSL code, so it's needed to define a mechanism of handling such situations. So, in case if the lexical analyzer can't determine which token the current character is, it will prematurely complete the compilation process and notify the user about the lexical error. It is also important to skip all comments and non-used whitespaces, which may be present in the input text.

For example, for a mathematical operator recognition, it may be enough to analyze the current character and, if it is matched, the token is successfully identified. However, this approach can't recognize operators, which consist of 2 symbols, such as !=, >=, <=. So, for this type of operators, if the current operator could be 2-symboled, it's needed to check the following symbol (see in Figure 2).

The second module of the compiler is a Parser, which is directly connected with language grammar, so, the main goal is to implement language rules in the programming language. It means, that each rule in the formal grammar must have an appropriate handler in the parser. The input of the Parser is a stream of tokens, which were generated in the previous step. As well as in Lexer for symbols, for the Parser to work properly it is needed to track the current token and move to the next one after processing it. So, basically, the program will iterate on the token list and call the appropriate handler on each token match. The code examples of these handlers are shown in Figure 4:

```
def nl(self):
    self.match(TokenType.NEWLINE)
    while self.checkToken(TokenType.NEWLINE):
        self.nextToken()

def expression(self):
    self.term()
    while self.checkToken(TokenType.PLUS) or self.checkToken(TokenType.MINUS):
        self.emitter.emit(self.curToken.text)
        self.nextToken()
        self.term()

def term(self):
    self.unary()
    while self.checkToken(TokenType.ASTERISK) or self.checkToken(TokenType.SLASH):
        self.emitter.emit(self.curToken.text)
        self.nextToken()
        self.unary()

def unary(self):
    if self.checkToken(TokenType.PLUS) or self.checkToken(TokenType.MINUS):
        self.emitter.emit(self.curToken.text)
        self.nextToken()
    self.primary()
```

Fig. 4 – Python code fragment for parser`s handler of the rules (7-11)

It is important to understand that to achieve different levels of priority it is needed to consistently organize grammatical rules. In other words, operators with higher priority must be lower in grammar in order for them to be lower in the parsing tree, which is the output of the parser. Thus, operators, which are the closest to the tokens in the parsing tree (i.e. closest to tree leaves) will have the highest priority. Since binary operators "+" and "-" are lower in grammar rules, they will have higher priority than * and /. For a better understanding of this concept, let's consider simple math examples, which are 1 + 2*3 and 4 / -5. The generated parsing trees for these examples are shown in Figure 5:

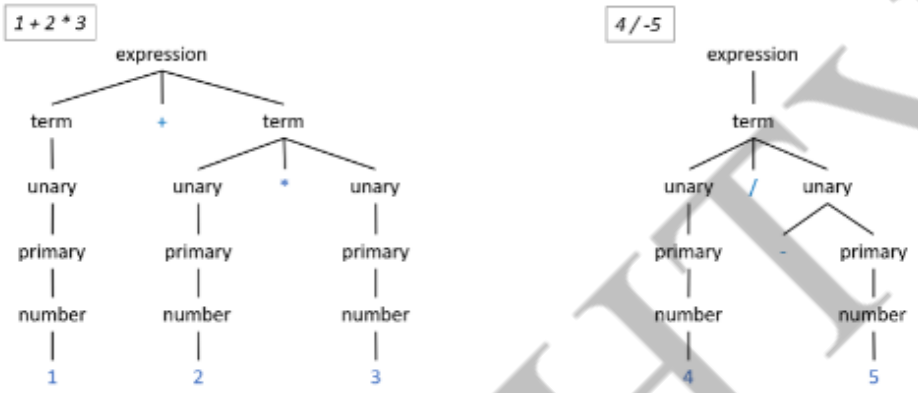

Fig. 5 – Generated parsing trees for some simple math expression examples

It means, that the multiplication operator will always be lower in the tree than the plus operator. The single negation operator (!) will be even lower. If there is more operators with the same priority, then they will be processed from left to right.

The last module of the compiler is a Code emitter. It will iterate along a parsing tree and for each handler function generate the corresponding C++ code. The generation of machine-executable code can be achieved by using any standard C ++ compiler. The usage of such an approach does not require to provide a code optimization by the created DSL compiler, as, in fact, this will be handled by the compiler of the source programming language. The code examples of generating target code are shown in Figure 6:

```
def program(self):
    self.emitter.headerLine("#include <stdio.h>")
    self.emitter.headerLine("#include <iostream>")
    self.emitter.headerLine("#include <string>")
    self.emitter.headerLine("using namespace std;")
    self.emitter.emitLine("int main(void){")

    while self.checkToken(TokenType.NEWLINE):
        self.nextToken()

    while not self.checkToken(TokenType.EOF):
        self.statement()

    self.emitter.emitLine("return 0;")
    self.emitter.emitLine("}")
```

Fig. 6 – Python code fragment of generating target C++ code

In Figure 6 proposed compiler emits base C++ file structure and some additional required libraries.

IV. RESULTS OF WORK IN A FORM OF PROPOSED QUANTITATIVE METRICS

To prove an effectiveness of the elaborated compiler for SHA development, it is needed to choose the specific quality metrics of software development. In this case, it was chosen the method of estimating the number of lines of code (LOC). Thus, one of the possible metrics of efficiency of the DSL compiler Kef (1) can be calculated by the formula:

$$Kef(1) = \frac{LOC_{DSL}}{LOC_{GPL}} * 100\% , \quad (13)$$

where LOC_{DSL} – the number of DSL lines of code; LOC_{GPL} – the number of generated GPL lines of code.

For the described specific use case, this value by formula (13) is calculated as 13/39*100% = 33%.

Another way to evaluate the quality of the created compiler is to compare the amount of C++ code generated by DSL compiler with the amount of C++ code that was created manually, for the same example of air conditioner controller. This example was found in the public code repository on the GitHub service [9].

Therefore, the second possible metric of the efficiency of the DSL compiler Kef (2) can be calculated by the formula:

$$Kef(2) = \frac{LOC(C++)_{GPL} - LOC(C++)_{DSL}}{LOC(C++)_{GPL}} * 100\%, \quad (14)$$

where $LOC(C++)_{DSL}$ – is the number of LOC generated by DSL compiler; $LOC(C++)_{GPL}$ – is the number of LOC in the C++ program written in a manual mode. For the described specific test case, this value calculated by the formula (14) is equal: (25-23)/25*100% = 8%.

It is to mention that the Kef (1) determines the advantage of the use of the DSL compiler from the point of view on cost reduction for the implementation of the resource management system of SHA. The Kef (2) determines the advantage of the use of the DSL compiler from the maintenance, support, and refactoring code point of view in the target SHA system.

In order to calculate the estimated weighted average efficiency score of the developed DSL compiler, it's needed to choose some so-called software development and maintenance importance factors. Let's consider them, e.g. as 0.35 for the Kef (1), and as 0.65 for the Kef (2) (in more correct way it can be done using one of the expert estimation methods, e.g, the Analytic Hierarchy Process [10]). Therefore, the final average value of the estimation metric K_avg can be calculated with the following formula:

$$K_{avg} = \left(0.35 * Kef(1) + 0.65 * Kef(2)\right) * 100\% = 16.75\% \quad (15)$$

where Kef(1) and Kef(2) are the values of the compiler efficiency metrics calculated using the formulas (13) and (14) accordingly.

So, as a final result, the approximated weighted average efficiency score of the developed DSL compiler is equal to 16.75% that corresponds with some data about these issues already published (see, e.g. in [11]).

The additional ideas and more specific issues of this research can be found in [12].

V. CONCLUSIONS

In this paper we have motivated an actuality to apply a concept of domain-specific language (DSL) in such modern and complex problem domains as Internet of Things (IoT) systems and "Smart-Home" applications. The performed overview of the main methods and software tools for DSL design and implementation allowed us to elaborate their possible classification scheme and choice the appropriate way for our DSL development. The main functional blocks for the proposed DSL compiler are designed and implemented using Python and C++, and the effectiveness estimation for this compiler is done with calculation of two quantitative metrics that allowed to get the approximated weighted average about 16.75%. These results show the acceptable quality of the elaborated DSL compiler, and it allows to make the positive conclusions about the proposed approach.

Further work in this research is supposed to expand the grammar of the DSL compiler with special rules that will support effectively the variability of software components in "Smart-Home" systems, and to develop a comprehensive methodology for a performance evaluating of a prospective DSL compiler, taking into account the possible costs of its construction and usability for its end users.

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DEVELOPMENT OF SOFTWARE MODULE FOR ANALYSIS OF IT SPECIALISTS' LABOR MARKET

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Abstract. *The paper describes how software module was developed to analyze the labor market of IT professionals using the Python programming language in the integrated programming environment. The software module screens, crawls, parses and exports data from specialised sites. The software module allows to find, structure and export data to CSV and TXT files. The sample of key parameters was investigated by means of business analytics.*

The developed program can be expanded with additional functions, supplemented by a graphical interface, uploaded to the web hosting.

The software module provides processing of a large array of unstructured information from vacancy announcement sites, reduces the amount of routine manual operations and provides an opportunity to focus stakeholders' attention on key priorities.

The aim of the work is to develop a parsing software module for automated collection and analysis of open position data to determine which knowledge and skills are most important for employers in the IT industry.

Keywords: *web-scraping, data mining, business intelligence, programm module, Python programming language.*

I. INTRODUCTION

Collection and analysis of information about the labor market is necessary constantly, and especially relevant in modern conditions. The economic crisis as a result of the spread of COVID-19 has affected entire industries, the number of employees has decreased in almost all countries. As of the beginning of 2022, the unemployment rate in France is 7.5%, Sweden – 8%, Ukraine – 10.4%, Turkey – 11.5%, Spain – 14.1%, Georgia – 18.5%, South Africa – 34.9% [1-3].

The information technology sector is able to bring the world economy out of the crisis and ensure social development. The situation in the IT sector is characterized by a parallel staff shortage (lack of highly qualified specialists) and the influx, and consequently, the difficulty of employment for junior beginners. Also, today the amount of information in general, and about the labor market in particular, causes both congestion in the number of sources, and the omission of important elements for individuals and organizations.

The aim of the work is to develop a parsing software module for automated collection and analysis of open position data to determine which knowledge and skills are most important for employers in the IT industry.

Stakeholders of such a project are:

1) active job seekers – for a more efficient and rational search (review of more vacancies); for faster selection of positions that correspond to the available

qualifications; to reduce mental stress and resource-intensive search operations, to improve the psychological state;

2) employers – to determine competitive salary, understanding of popular technologies;

3) institutions of higher education, centers of advanced training, trainers – for the formation and adjustment of training programs in accordance with market requirements;

4) students and graduates – to get acquainted with the existing requirements, choose the right disciplines, prepare relevant research topics; to study what is needed and relevant in the labor market;

5) IT specialists – to determine career opportunities (it is usually considered that every two years you should learn a new programming language to maintain competitiveness and improve professional level);

6) professionals who plan to change the field of activity – to understand the demands of the industry, focus retraining on the necessary skills;

7) government – increasing the number of employees reduces social tensions (the population becomes more self-sufficient, does not rely on social benefits), provides economic growth (potentially more employees provide more payments to the budget and GDP growth);

8) investors – as in a promising direction in specialized search portals, data aggregators, startups of analytical services, etc. invest in venture capital organizations, media holdings, recruitment firms, etc.

These parties are potential users of the software module.

The results of the work – a systematic list of vacancies and summary in tabular and graphical form of employers' requirements for a position (knowledge and skills of specialists, programming languages, years of experience, education, etc.) – can be the basis for creating a resume tracker, cover letters and interviews; formation of a (self) training plan, which will organize an effective job search and acquaint a wide range of people with popular requirements, increase the level of education, provide an understanding of trends in the IT industry.

II. LITERATURE ANALYSIS

2.1. Basic concepts of web scraping

Web scraping technology is best suited to fulfill the task set in the paper – the development of a software module for the analysis of the IT professionals' labor market, from the initial collection of information to its processing and analysis.

Web scraping (also scraping, web collection, data retrieval from the web) is:

1) automated collection of information from the World Wide Web;

2) technology, when a computer program extracts data;

3) the practice of data collection in any way other than the program that interacts with the API. This is most often achieved by writing an automated program that sends a request to a web server, reads the data (usually in the form of HTML and other files that make up web pages), and then analyzes it to extract the necessary information.

Web scraping can be a stand-alone tool for targeted information retrieval, as well as a component of web development used for web indexing, web mining and data mining, online monitoring of price changes and their comparison, to monitor competition, collection of other data. It is also used for web automation.

Automated data gathering from the Internet exists almost as much as the Internet itself. Although web scraping is not a new term, in the past this practice was better known as screen scraping, data mining, web miner, web harvesting or similar variations. In general, the term web scraping is now more popular, although programs that go through multiple pages are usually called web crawlers, spiders, spiderbots, and scraping programs themselves are bots [4, c. ix preface].

The topic of scraping is complex, as it is not possible to be limited to one language or technology, you need knowledge of databases, web servers, HTTP, HTML, Internet security, image processing, data science and other tools. Data management is especially relevant in the context of big data, when only a small part of them is structured.

In practice, web scraping covers a wide range of software techniques and technologies, such as data analysis, natural language parsing and information security [4, p. x preface].

Scraping usually involves the use of two tools: a crawler, which navigates the website to extract (extraction, fetching, collecting, capturing) HTML from the page; and a parser that finds an HTML tag in pages to extract relevant information.

Parsing (from the Latin pars – part of speech) – the study of a predetermined sequence of characters (from natural or computer language or data structure), for further grammatical analysis of the structure.

Parser is a full-fledged program or part of it designed for parsing.

In the process of parsing text components are brought into a coherent form, design the data structure, most often – in the tree of the syntactic structure of a given sequence, which can be further processed. As a rule, the work of parsers goes through two stages: the identification of meaningful tokens (lexical analysis), and then a parsing tree is formed.

A token is an object formed from a lexeme (a word as an independent unit of meaning) in the process of lexical analysis. In applied programming, the concept of token and its lexeme may not differ [5].

The parser is an extension or part of the scraper.

Websites consist of 3 main components: HTML, which contains the content of the website; CSS, which contains its style, and Javascript, which contains elements that update themselves without refreshing the page, or that you can interact with (such as a drop-down menu).

For scraping each individual site requires its own code [6]. The general process of web scraping is shown in Fig.1. For each new resource, you need to go through the whole process from start to finish to get specific data.

After collecting data in the set, you can search, change the presentation format, copy to a table or database (DB).

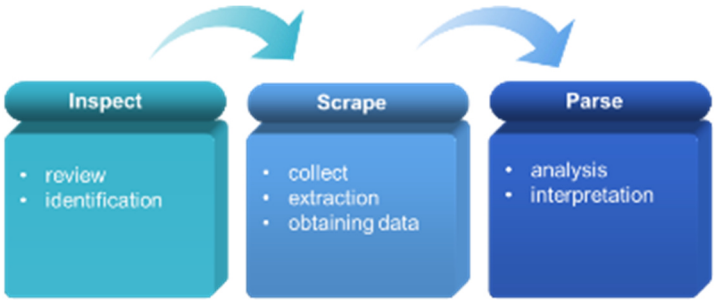

Fig. 1. Process of data-mining

Source: author's design

2.2. Usage

Web-scraping (web / data / text content mining, text analytics) is needed for research, analysis; formation of personal collections, personal or organizational knowledge bases; information retrieval, knowledge discovery, etc. [7, p. 33].

Common applications are collecting data from public users of social networks as potential customers, comparing prices, aggregating news, collecting ads for rent or sale of housing, weather, outlets, tracking competitors or reviews of their own brand, systematization of internal documentation (email, PDF files etc.); analysis of consumer sentiment, machine learning, search for cheap hotels / tickets, creation of additional or main content (blog posts, creation of own aggregator). In the table 1 we give specific examples.

Table 1. Examples of using web scraping

Company / product	Description
Wandex (World Wide Web Wanderer)	the first web robot; for measuring the size of the WWW (established in 1989), worked since June 1993, in 2011 resumed work
JumpStation	the first search engine based on crawler, not on the work of administrators (December 1993)
WebCrawler	the first full-text search engine (1994)
Salesforce, eBay	first Web API and API Crawler (2000)
Google Search	indexing the Internet with crawlers and later AI
Google Knowledge Panel	pulling up query data from Wikipedia, the official site, and other sources
Facebook Telegram	when you insert a URL into a message or post, the title and thumbnail of the linked page is pulled up
Google Alerts Visualping Wachete Service	monitoring changes on sites, new articles on request
Beautiful Soup	library for scraping in Python (2004), is considered the most complex and advanced

Source: author's summary

2.3. Alternatives

Sources of structured data are:

1) official APIs – limited, expensive. Amazon AWS and Google (API Discovery service) provide end users with free tools, services, and publicly available parsing data.

As for the sites-virtual bulletin boards (Indeed, Work.ua, Rabota.ua), the API is available only to employers (i.e., for registered organizations, for a fee and have restrictions). Part of the functionality is not available for ua.indeed.com, and dou.ua does not have an API. In addition, APIs can be closed at any time;

2) ready-made databases – such kits are available in various formats (SQL, Excel, JSON online forms, log files of automated systems, etc.). But data is rapidly becoming obsolete and needs constant updating. In the case of vacancy announcements, a number of sites do not even publish the archive, removing already inactive publications from public access;

3) RSS or Atom feeds – subscriptions to site updates using XML formats, consists of full text or part and metadata, is read by special programs-readers / aggregators (such as Feedly, Feedbro, Inoreader, TinyTinyRSS, closed in 2012 Google Reader). Atom or RSS feeds save a lot of time tracking updates, and readers allow you to view content changes centrally without going directly to the sites themselves. The most common uses are frequently updated sites, blogs, news sites, web magazines, podcasts, etc. RSS is actually an XML document and belongs to the sources of structured data.

One reader allows subscriptions to many sites or sections (however, services often set a free usage limit above which a fee is charged). Also, depending on the settings, RSS usually displays only the last 20 articles, depending on the date of subscription to the feed. StackOverflow Jobs states that RSS is their API [8], but the page displays only the last 1001 posts, while jobs.dou.ua displays the latest 51 posts in RSS.

The format helps to disseminate information without e-mails or personal messages through bots, etc., and also helps to distribute publications on a “post once-syndicate everywhere” basis, when publications appear on a single official resource individuals or organizations and then distributed to all platforms used.

As this reduces the site traffic in some way (users do not come many times to check for updates), and the number of views / conversions decreases, the format is not very popular, many users do not know about it at all, and for notifications about news sites they subscribe to their pages at social networks. In addition, parsing RSS is often not appropriate, as it usually does not display the news archive, but only the last 20 posts.

In general, the advantages of using web scraping compared to these methods are:

- data structured according to queries;
- the owners of the sites pay considerable attention to data management and maintenance, and the work is done more carefully than with the API documentation;
- there is practically no limit of use, the main thing – not to overload servers;
- anonymous access;
- data is visible immediately – without separate requests to the organization or waiting to open access to the API.

We analysed existing tools (30 the most used and the like) and defined that they have a number of limitations: they are often proprietary, paid (or freemium), the settings are limited by the functionality of services or applications. As often in such cases, the best solution in modern conditions is to develop your own software product of a certain specification.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of research is the process of collecting, processing and analyzing data on the labor market of IT professionals.

Subject is software tools for labor market analysis of IT professionals.

Research methods used in the paper are the following: comparative analysis, web scraping, structuring and organization of data, parsing of texts, statistical methods of analysis of poorly structured data of large volume, tabular and graphical.

To solve the problem, we choose the Python language with the appropriate libraries for scraping, parsing and visualization.

In 2021, 38% of the developers who identified Python as one of their three main programming languages used it to develop web parsers / scrapers / crawlers (survey [9]). In general, being the most popular language, Python is also the most popular for web scraping, because it:

- is well designed, considered easy to learn;
- is well documented on official resources;
- has good support, including due to popularity, there are a large number of publications, forums, tutorials;
- is suitable for rapid development;
- is free;
- has an active community;
- contains a large number of tools in the standard package and additional libraries;
- creates code that is readable, easy to further support, can be reused [10, p.13-17].

Python is a powerful automation tool, contains a rich collection of libraries, has an intuitive syntax. The 3 best known approaches to processing web pages in Python are regular expressions, BeautifulSoup and lxml modules [11, p.39-45]. All of them were used in this research to gain the most complete data.

Python is usually able to avoid various scraping restrictions by using multiple proxies, retrying downloads, and configuring a user agent. It is able to read data from web pages with dynamic content, which is downloaded not from the internal database of the server, but through Javascript. Uploading / exporting data can be done in a database or table (SQL, CSV, XLS, JSON, other formats).

IV. RESULTS

4.1. Project structure

For the project it is decided to choose 3 sites, the total number of ads – 500-1000, geography – the world, time period – April 19 – May 20, 2021.

In the process of preparation, an alternative approach was considered – scraping of those already employed with Linkedin, but the profiles may not be complete, not updated, freelance or the wrong sector is indicated. Vacancy announcements are more reliable.

The project methodology is similar to the general scheme in Fig.1, but supplemented in accordance with the tasks (Fig.2).

The process of developing a software module corresponds to such steps:

- open the file, on the site with a web scraper collect links from the list from one page to individual pages of announcements, and using pagination – from the rest;
- collect data on the pages of the ads themselves, reading HTML-tags;
- using loops "for", go to full descriptions;
- extract data for each tag and save to the table;
- analyze key parameters;
- determine the frequency of use of key terms;
- create elements of information panel by visualization with business analytics tools.

Having decided on the sequence of work, we move on to the next stage.

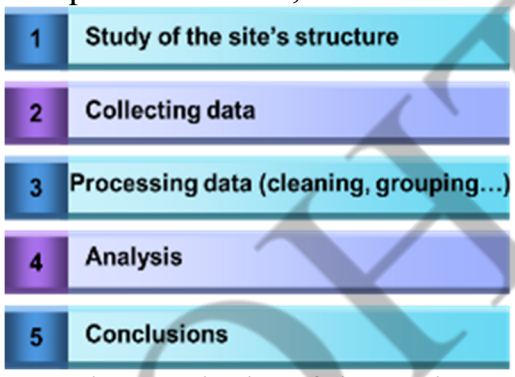

Fig. 2. Blocks of the project

4.2. Selection of sources

At this stage, it is important to consider the internal documentation of the sites. Scraping is absolutely legal, if it does not contradict the rules of site owners [4, p. ix, 263-277]. In the lawsuits that actually took place (plaintiff Linkedin), the decisions were in favor of the defendants: what is visible to users on the sites can be collected and automatically [12]. However, the number of Linkedin ads in the IT sector as of May 4, 2021 in the United States alone for the last 24 hours is 5,792 positions, last week – 35,196, month – 115,436, any time – 159,340. The quality of such information is not very high – too many duplicate results, and information cannot be fully filtered at the collection stage on the site itself. Therefore, given these two factors, Linkedin will not be included in the analyzed sites.

The terms of use of the largest aggregator of vacancies in the world – Indeed – explicitly prohibit the scraping of any information from the site with an indication of the possibility of appropriate lawsuits [13].

Considering other options, the choice is summarized in table 2.

Selection criteria are availability of data and a sufficient number of publications for analysis.

Table 2. Site selection and number of job ads

Site	Number
Rabota.ua	8 647
Rabota.ua – other countries	119
StackOverflow Jobs	1 337
Dou.ua	10 800
Усього	20 903

Source: author's summary based on data from [14-16]

4.3. Project implementation

To obtain the most up-to-date set of vacancy announcements, we used scraping for all pages with categories "Information Technology" on selected sites: Rabota.ua, Dou.ua, StackOverflow Jobs by:

- code planning;
- inspect HTML;
- scrape – the first function – to collect links;
- pagination and
- export (data storage)

We saved the results (export data) in the CSV file, because it can be opened in both text and spreadsheet editors and has no line limit [17].

All pages with a list of links and relevant available information were successfully collected from three sites (Fig. 3).

title	company salary	location	link
Tools Lead	kwalee	Royal Lea	https://stackoverflow.com/jobs/527954/
Senior Java Engineer - Remote	wallethub	No office	https://stackoverflow.com/jobs/527950/
(Senior) Full-Stack Web Develope	wunder mobility	Hamburg,	https://stackoverflow.com/jobs/527937/
(Senior) Software Engineer (Pyth	delivery hero se	Berlin, Ge	https://stackoverflow.com/jobs/527921/
Blockchain Rust Developer	komodo platform	No office	https://stackoverflow.com/jobs/527914/
PHP Software Engineer	trivago nv	Düsseldor	https://stackoverflow.com/jobs/527910/
Solution Engineer (m/f/d)	relayr	Berlin, Ge	https://stackoverflow.com/jobs/527907/
DevOps Engineer (AWS) Require	montash	No office	https://stackoverflow.com/jobs/527882/
DevOps Engineer (m/f/d) Cloud I	covestro deutschland ag	Leverkuse	https://stackoverflow.com/jobs/527878/

Fig. 3. Fragment of the intermediate table

To collect a complete description of vacancies, we must go to each of the collected links and take data from the relevant fields.

Proceeding with project is to use:

- crawl – the second function – to collect complete descriptions of requirements
- cleaning data and merging descriptions (the next step is post-processing, data cleanup – removing duplicates, non-necessary spaces, posts that appear several times and so on);
- parse – the third function – the parsing of the text.

For convenience, we summarized all job descriptions in one text file. In the process of parsing job descriptions, we performed tokenization, deleted stop words (a, the, etc.), create n-grams (stable phrases) and identified the words that are used most often.

First, a function to remove punctuation marks (including different types of quotation marks) was created.

In order for such connections as .net, pixi.js and the like not to be broken, it is necessary to build n-grams – a sequence of n elements [18, p.176]. We have formed 2 grams in the amount of 102 elements. Having performed parsing and defined the most common words, we built a tag cloud.

4.4. Visualization of results

Definition of key requirements

We created a tag cloud to identify the keywords that have the highest frequency in open position ads (Fig.4). As we can see, the most commonly used are “experience, software, development, knowledge, engineering, data, product, team”.

Fig. 4. “Cloud of words” for vacancies

Source: formed by the author according to the sample [14-16]

This list is a summary of the database, but it is oversaturated with general words. For a more detailed analysis, we used the search for specific languages and frameworks. For further visualization we used the Microsoft Power BI tool.

First, we determined the *level of education*, which one is the most often requested in publications (Fig.5). The master’s degree is found in almost 4% of advertisements and is the most popular educational degree, while the bachelor’s degree is found in 3.1%; PhD – less than 1%, MBA is not requested at all. The popular belief that a bachelor’s degree is sufficient for gaining a job and succeed in career is not supported by this sample.

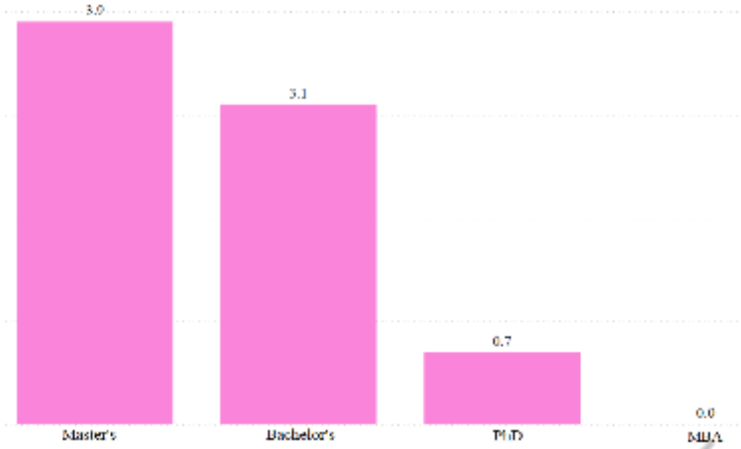

Fig. 5. Prevalence of degrees in announced vacancies, %

Source: author's design according to the sample [14-16]

We calculated the coincidences of the dictionary in the same way for the *majors* (fields of knowledge in Ukrainian system of higher education). Engineering and software engineering together occur in more than 60% of ads, computer science – in 14, the second group in prevalence – in a much smaller range of 1% or less – "hard sciences" and those that use quantitative methods.

Job titles

Fig. 6 shows which positions were most often open – they are IT Product Manager, System Administrator and IT Recruiter.

Fig. 6. Number of vacancies announced by position, %

Source: author's design according to the sample [14-16]

To determine the *years of experience*, we used regular expressions: for analysis, the requested years of experience are grouped by natural numbers: 3-, 3+ and 3-5 years are taken as 3, etc. The most popular experience is 2 years – it is found in almost 11% of ads. In second place – 3 or 5 years, 7%. The least frequently announced is the search for specialists with 0 and 10 years of experience – 0.7 and 0.1%, respectively.

The most popular *programming languages* was defined by comparing the dictionary (built on the basis of TIOBE – the largest list of programming languages with more than 8000 thousand elements [19], selected 375 first) with the texts of vacancies. The most common are Python, Javascript and Java (Fig.7).

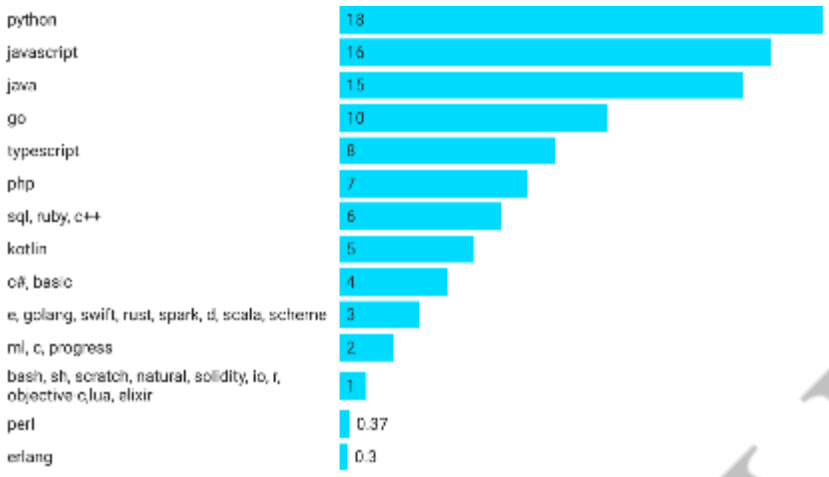

Fig. 7. Programming languages prevalence, %

Source: author's design according to the sample [14-16]

The level of positions is shown in Fig. 8. In 44% of cases, Senior positions are open.

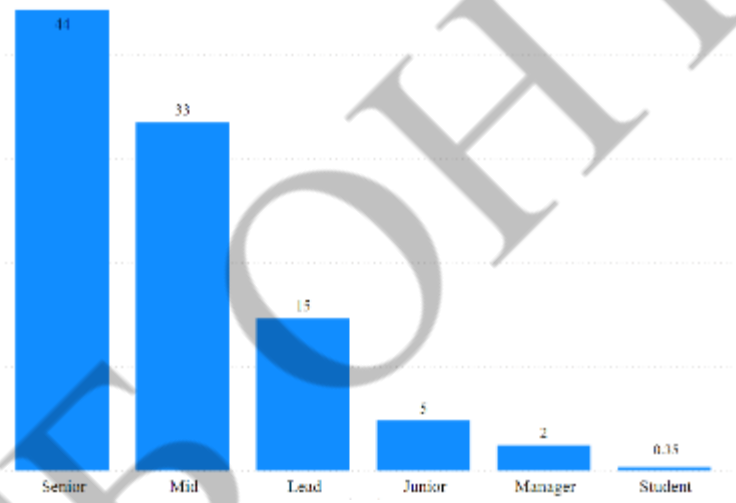

Fig. 8. Level of vacancies, %

Source: author's design according to the sample [14-16]

Location

In Ukraine, most vacancy announcements in the IT sector were in Kyiv, Kharkiv, Lviv, Odesa and Dnipro (Fig.9).

In the distribution *by country*, the leaders in the number of open positions are Germany, Great Britain, the Netherlands, the United States, Austria and Japan (Fig. 10). It is worth noting that so far, most vacancies have been marked "remote" or "no office location". This is due to both external (COVID-19) and internal factors (traditionally greater loyalty of employers in this sector to work remotely).

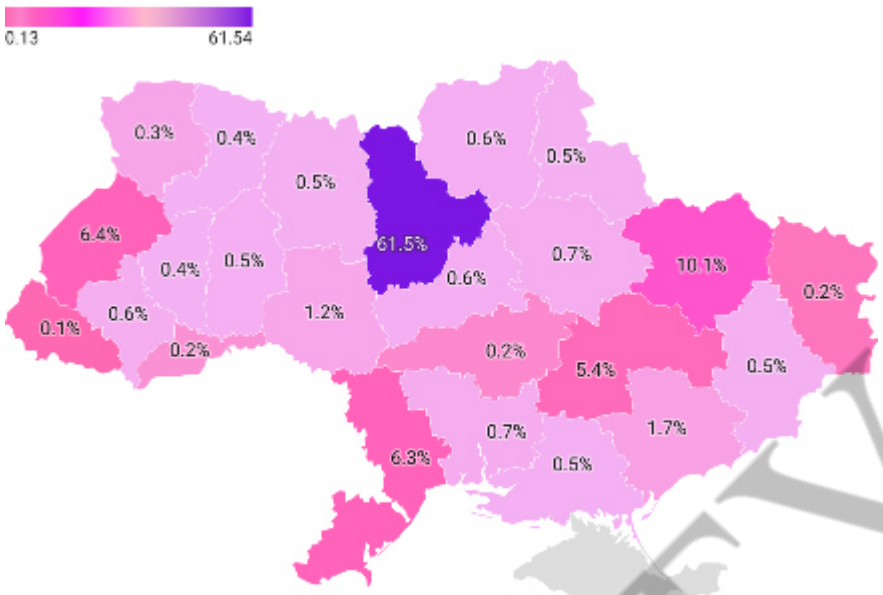

Fig. 9. Cities and regions of Ukraine, distribution by number of IT vacancies
Source: formed by the author on the basis of data [14-16]

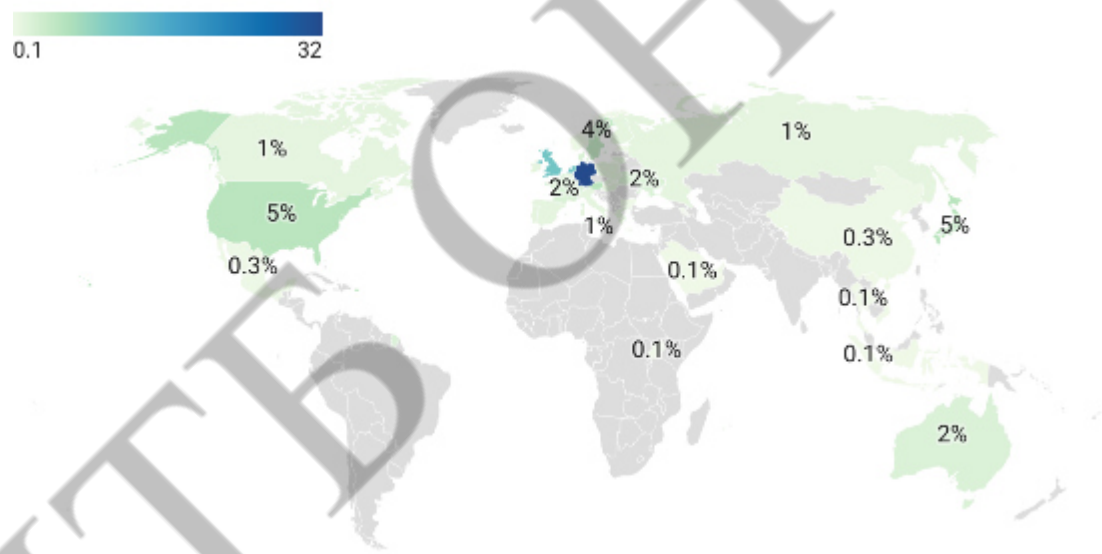

Fig. 10. Distribution by number of vacancies in the world
Source: formed by the author on the basis of data [14-16]

Considering what percentage of ads mentioned *other tools* (Fig.11), the data of the ads' texts are compared with the dictionary of Tech Stack terms. In addition to the already mentioned Python and Javascript there are used React, Linux, Apis, Rest, PHP, MySQL.

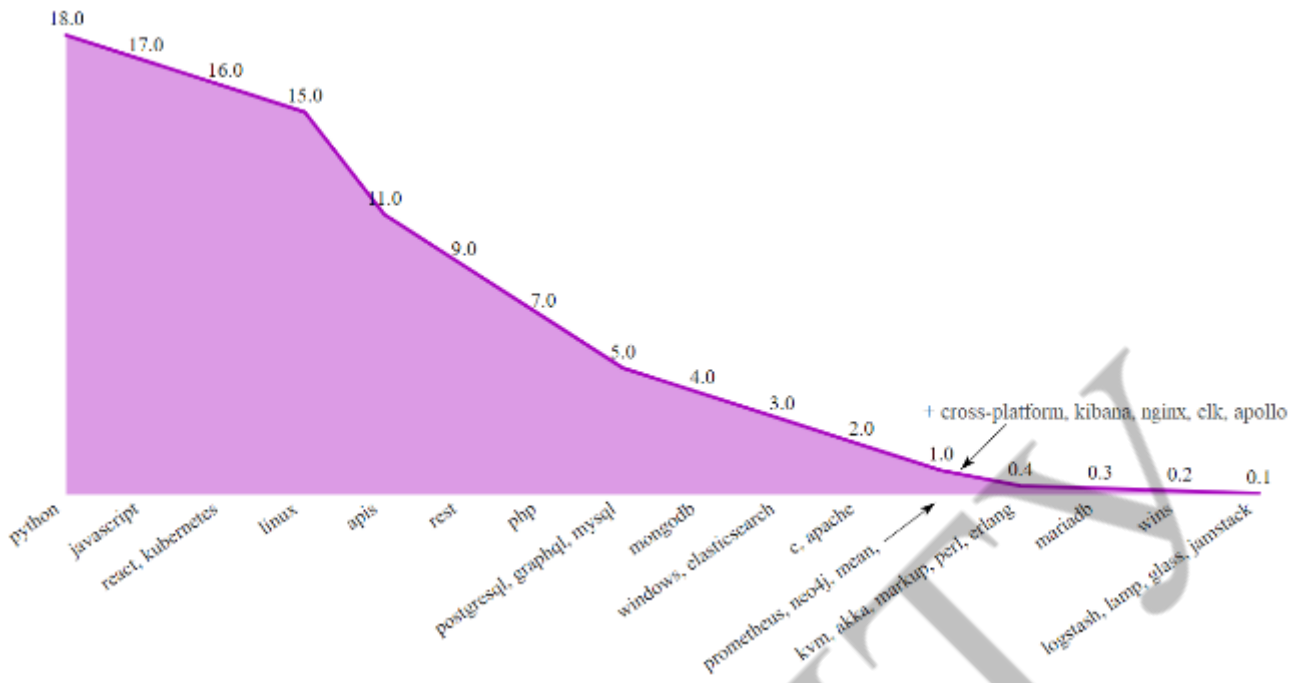

Fig. 11. 35 techstack tools, %

Source: formed by the author according to the sample

The key areas (specialization) in ads are machine learning, software as a service and artificial intelligence (Fig. 12).

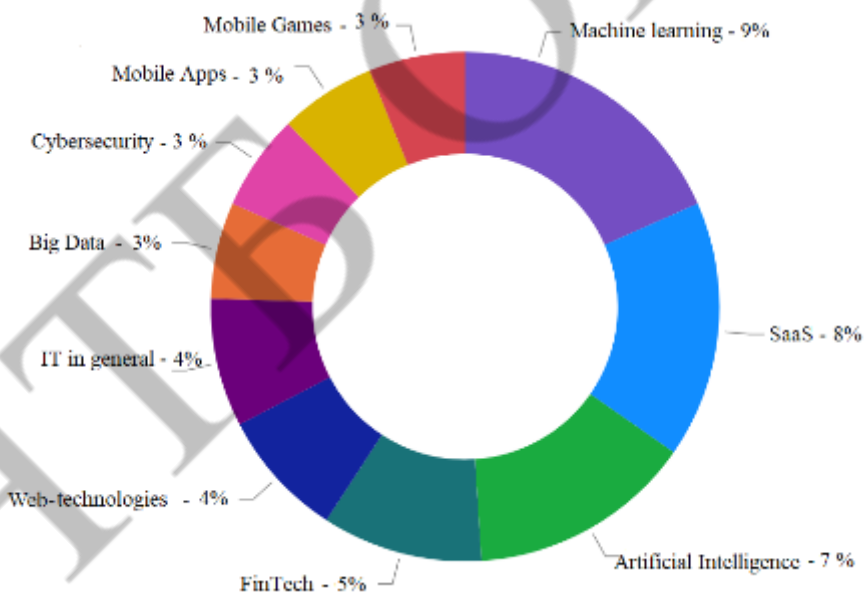

Fig. 12. Subsectors

Source: created by the author according to the sample

Soft Skills

Among the "flexible" skills in the ads there were not mentioned problem solving, public speaking and hard work (0 matches with the dictionary). Instead, sociability, leadership skills and creativity are leaders in demand (Fig. 13).

Salary for the unification of conclusions was analyzed in dollars. The exchange rates of the sampled currencies (Australian and Singapore dollars, Swiss francs, Danish

and Swedish krona, euros, British pounds, Japanese yen and Polish zlotys) to the dollar were taken from Google Finance [20].

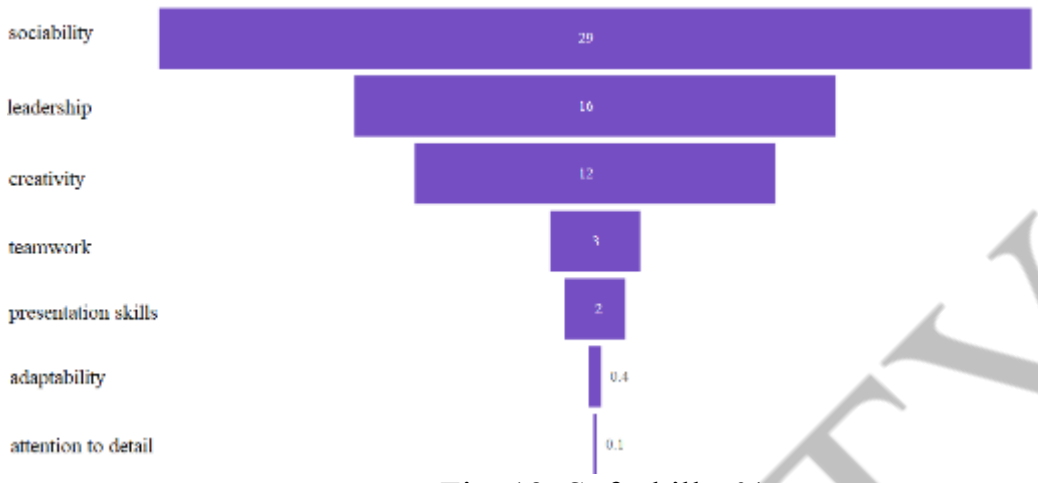

Fig. 13. Soft skills, %

Source: created by the author according to the sample data

After resolving recruiters mistakes, we saw that the minimum salary offered by employers to IT professionals on rabota.ua was $90 (for the position of "Teacher for C ++ courses"), a maximum – of $48,600 (Golang Developer), the most common minimum salary was $540 (10.5% of ads), the most common maximum – 720-1080 dollars (4.6%). At dou.ua, the minimum salary was $300 (Senior PHP Engineer) and the maximum salary was $70,000 (in the "Abroad" section for Senior Frontend Developer).

At StackOverflow Jobs, the minimum salary per month was $4,500, the maximum was $18,300, and the average was in the range of $5,750-8300. It is noted that almost 11% of companies provide non-preferred shares.

Thus, after receiving, storing, organizing and analyzing data, we see that the most popular are the following:

- programming languages: Python, Javascript, Java;
- tools: React, Kubernetes, Linux;
- areas: machine learning, software as a service, artificial intelligence;
- soft skills: sociability, leadership and creativity.

V. CONCLUSIONS

As a result of the research paper, the task of developing a software module for the analysis of IT specialists' labor market was performed.

To analyze the labor market of IT specialists, it was decided to take the primary source – job vacancies from employers themselves, rather than information from various reports, statistics, surveys. The Python programming language was chosen for the software implementation. The final product is a module that performs scraping, crawling, parsing and exporting data from 3 sites.

The study examined *more than 20,000* vacancy announcements in the IT sector from Rabota.ua, Dou and StackOverflow Jobs in order to summarize the requirements of employers for knowledge and skills of specialists, programming languages, years of

experience, education, etc. Vacancy announcements were collected from the indicated sites, transferred to tabular form, and conclusions were analyzed and visualized. The software implementation facilitated the structuring of information and systematization of these requirements.

The most popular characteristics for positions are defined. The results are formalized with graphs, charts, summary tables, and other elements of visualization.

Software module allows to find, structure and export data to CSV and TXT files.

The final product meets all the specifications defined in the paper. The developed program can be extended with additional functions, supplemented by a graphical interface, uploaded to the web hosting.

The software module provides processing of a large array of unstructured information from vacancy announcement sites, reduces the amount of routine manual operations and provides an opportunity for stakeholders to focus on key areas.

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CONTROL SYSTEM OF CONDENSING DRYING PROCESS WITH ENERGY RECOVERY USING HEAT PUMP

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Abstract. *The purpose of the work is to develop a system of automatic control of the drying process, which would support adjustable variables in the regulatory zones in both steady and transient modes of operation.*

Research methods and tools - in identifying the properties of the object of control used methods of imaginary active and passive experiment with further processing of their results; control object models and control systems were developed in Simulink / Matlab environment; parametric synthesis of the control system is carried out by the method of optimizing the quality of its operation; the development of the advanced system was carried out analytically using the apparatus of transfer functions.

The obtained results - the received system of the increased dynamic accuracy which supports adjustable variables in regulatory zones both in steady, and in transient operating modes

Scope - the system can be used to modernize the process of production of dried fruits.

Significance of work and conclusions - the developed system has advantages in comparison with traditional ACS which are used in practice.

Key words: *heat pump, drying unit, heater, mathematical model, simulation model, channel model, perturbation model.*

I. INTRODUCTION

In the last decade, heat pump technologies are increasingly used not only in the field of heat supply to heat consumers, but also in heat technology processes, one of which is the drying of various materials and, in particular, food raw materials. For example, fresh fruits contain about 75-90% water and 5-15% sugar, so they spoil easily, wither quickly, rot. If you reduce the moisture content in fresh fruit to 10-20%, they become resistant to microorganisms, do not spoil, in appropriate conditions can be stored for a long time quite suitable for consumption for a long time. But due to the high heat capacity of water, drying processes are very energy-intensive, so the use of energy-efficient modes of drying processes is an urgent task.

The introduction of the condensing drying process with energy recovery through the use of a heat pump can provide a significant increase in its energy efficiency. However, existing heat pump drying control systems are usually not able to maintain energy-efficient modes, the required dynamic accuracy of reproduction of the set temperature and moisture content of the drying agent, which reduces energy efficiency and may reduce the quality of finished products.

One of the most effective and proven ways to achieve this goal is to increase the intellectual level of key process control algorithms (TP).

One of such processes is the process of condensation drying of raw materials with energy recovery through the use of a heat pump. This process is crucial in shaping the quality of finished products, so increasing the requirements for the quality of regulation of mode parameters is quite natural.

The paper presents studies of the process of condensation drying of raw materials with energy recovery through the use of a heat pump as a control object (OK), which resulted in mathematical models (MM) of the main control channels and perturbations. Based on the obtained models, process control algorithms have been developed that provide high quality control of regulated variables. Simulation modeling of the behavior of the control system, which implements the developed control algorithms, is performed, and its operability is confirmed.

II. ANALYTICAL REVIEW OF LITERATURE

There are various methods of automatic control of the drying process, which differ in technological schemes, the number of adjustable parameters and control methods.

There is a method of automatic control of the grain drying process in a mine grain dryer, including measuring and regulating the grain temperature and drying agent temperature in each zone of drying, measuring and regulating grain moisture at the exit of the grain dryer and compensating for delays in this control channel [Патент України № 35801. Спосіб автоматичного управління процесом сушіння зерна в шахтній зерносушарці F26B 25/22 / Степанов М.Т., Ловчев О.М.; Заявл. 02.04.2008. Опубл. 10.10.2008. Бюл. № 19]

The disadvantage of this method of automatic control is the low quality of the finished product due to the harmful mutual influence of the control circuits, which is quite significant.

III. OBJECT, SUBJECT AND METHODS OF RESEARCH

3.1. Selection of the object for modernization of the automation system, description and analysis of the technological process and the corresponding equipment implemented by him.

The essence of the technological process of condensation drying of raw materials with energy recovery through the use of a heat pump is to remove moisture from the raw material and convert it into a dry product. The technological process is implemented in the drying chamber. The technological scheme of the process is given in Fig.1.

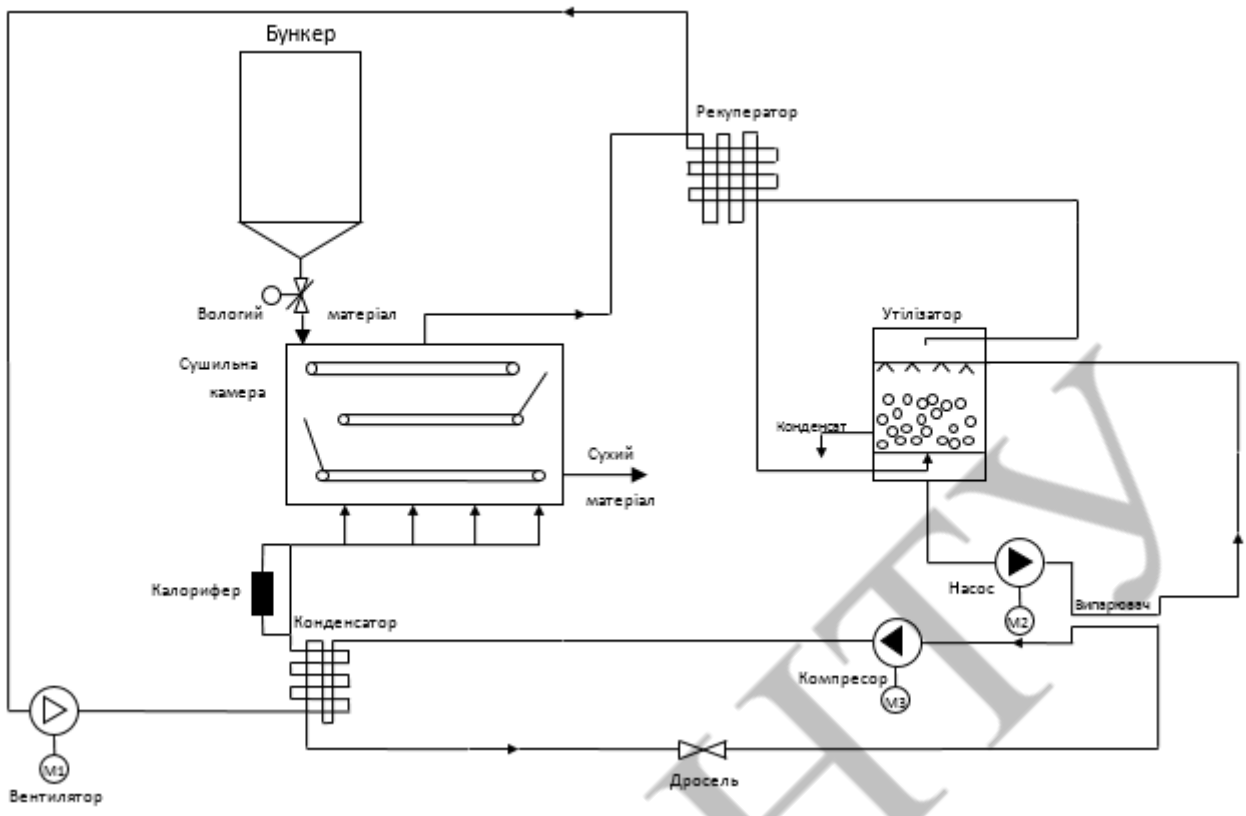


Fig.1.– Technological scheme of the drying process

In the stationary mode of operation of the installation, the flow of drying agent with a temperature of 60 ^{0}C is fed into the drying chamber. After passing the material, the stream enters the recycler, where excess heat is disposed of. After passing the recycler, the flow of drying agent passes through the recuperator. After passing through the recuperator, the flow of drying agent enters the condenser of the heat pump, while heating, and, heating up in the heater, enters the drying chamber. The cycle repeats.

The drying unit, which was developed in the laboratory of the Department of ATP and RS ONAFT is a drying chamber with a heat pump.

The nominal consumption of the installation is 40 kg / h. The equipment also includes a heat pump, the electric drive of the compressor of which has a capacity of 5 kW.

The purpose of the drying process is to obtain a product with specified quality indicators. In industrial production, the achievement of the goal can be justified only when the technological process makes sense to implement, when a number of requirements for the technological process are met.

It is expedient to realize technological process of drying if:

- there is a sufficient supply of raw materials for work, ie, if the stock is not less than 1 ton;
- there must be electricity in the power supply circuits of the heat pump compressor with average network parameters;
- There should be a place to ship the finished product.

The technological process of drying is a thermal process associated with the transfer of heat from the drying agent to the wet material through their interaction in the drying chamber. An important condition for the normal functioning of the technological

process is the filling of the drying chamber with the product. We will parameterize the technological scheme. The results of parameterization are shown in Fig.2.

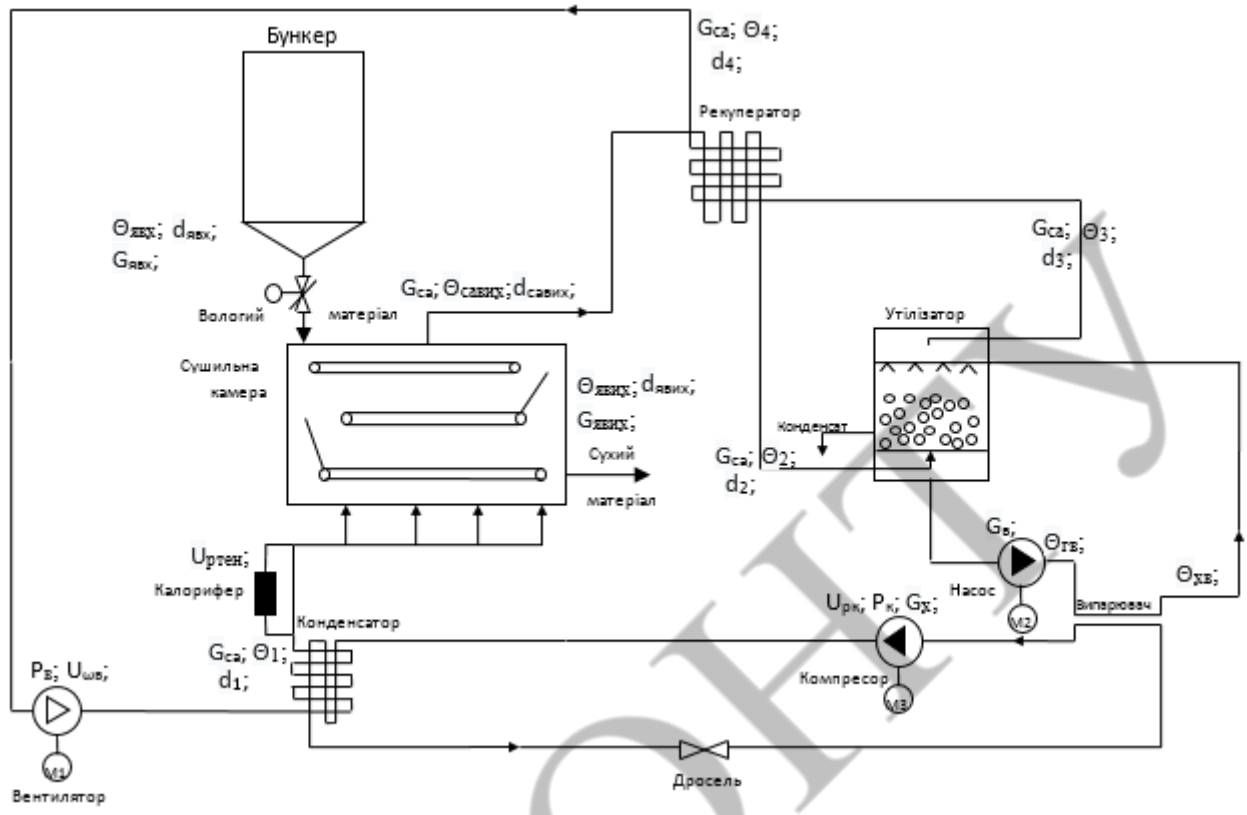


Fig. 2. – Parameterized technological scheme of the drying process

Designation on the parameterized technological scheme:

G_{ca} – consumption of drying agent, м^3/с ;

$\Theta_{савх}$ – the temperature of the drying agent at the entrance to the drying chamber, set by the drying technology, ^oC ;

$d_{савх}$ – moisture content of the drying agent at the entrance to the drying chamber, g/кg ;

$\Theta_{савих}$ – the temperature of the driving agent at the outlet of the driving chamber, ^oC ;

$d_{савих}$ – the moisture content of the drying agent at the outlet of the drying chamber, g/кg;

Θ_0 – the temperature of the drying agent at the inlet of the condenser, ^oC ;

d_0 – the moisture content of the drying agent at the inlet of the condenser, g/кg;

Θ_1 – the temperature of the drying agent at the outlet of the condenser, ^oC ;

d_1 – the moisture content of the drying agent at the outlet of the condenser, g/кg;

Θ_2 – the temperature of the drying agent at the inlet to the recycler, ^oC ;

d_2 – the moisture content of the drying agent at the inlet to the recycler, g/кg;

Θ_3 – the temperature of the drying agent at the outlet of the recycler, ^oC ;

d_3 – the moisture content of the drying agent at the outlet of the recycler, g/кg;

Θ_4 – the temperature of the drying agent at the outlet of the heat exchanger, ^oC ;

d_4 – moisture content of the drying agent at the outlet of the heat exchanger, g/кg;

$G_в$ – water consumption, м^3/с;

$\Theta_{хв}$ – cold water temperature, ^oC ;

$\Theta_{гв}$ – hot water temperature, ^oC ;

$G_х$ – refrigerant consumption, м^3/с ;
$G_{явх}$ – consumption of wet material, м^3/с ;
$\Theta_{явх}$ – temperature of wet material, ^{o}C ;
$d_{явх}$ – moisture content of wet material, g/кg;
$G_{явих}$ – consumption of dry material, м^3/с ;
$\Theta_{явих}$ – temperature of dry material, ^{o}C ;
$d_{явих}$ – moisture content of dry material, g/кg;
$P_к$ – heat pump compressor power, кWт;
$P_в$ – fan power, кWт;
$U_{рк}$ – heat pump compressor speed, % х.р.о
$U_{ртен}$ – power of the electric heater, % х.р.о
$U\omega_в$ – fan speed, % х.р.о

Table 1. – Table of regulations

Name of parameters	Marking	Unit of measurement	Nominal value of the parameter	Permissible deviations from face value		
				Long ($t\to\infty$)	Short-term ($0<t<<\infty$)	
				size	size	time, sec
1	2	3	4	5	6	7
The temperature of the drying agent at the inlet of the drying chamber	$\Theta_{савх}$	^{0}C	60	±1	±5	200
Moisture content of the drying agent at the outlet of the drying chamber	$d_{савих}$	g/kg	45	±1	±5	200
The temperature of the water entering the recycler	$\Theta_{хв}$	^{0}C	24	±0,5	±3	100c

3.2. Development of a conceptual model of the object of regulation

For the drying process, the control actions include the power of the heater, which changes the temperature of the drying agent at the inlet to the drying chamber ($U_{ртен}$), the speed of the heat pump compressor ($U_{рк}$) and the fan speed that controls the flow rate of the drying agent ($U_{\omega в}$). For the drying process, it is expedient to include the temperature of the recirculating drying agent $\Theta_{рса}$ in the controlled disturbances. All other input actions are classified as uncontrolled disturbances. The deterministic component of these perturbations is additively applied to the control actions, and the stochastic component is applied to the adjustable coordinate.

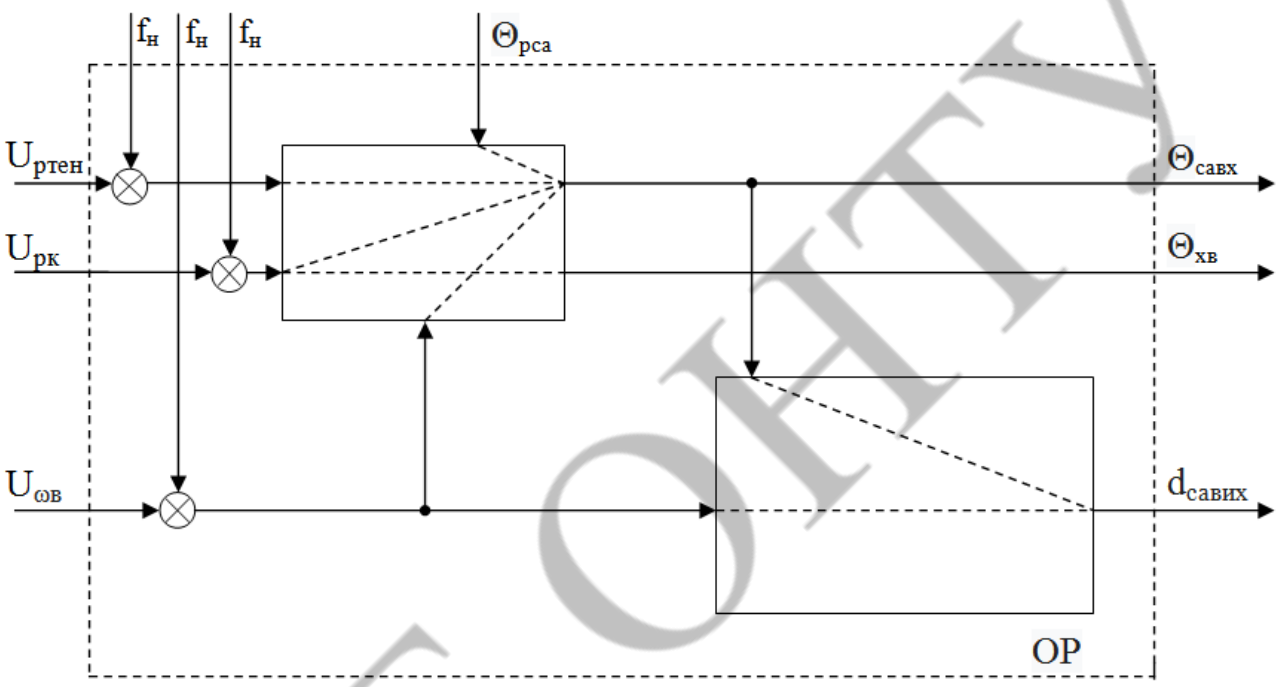


Fig. 3.– Block diagram of the drying process as an object of regulation

3.3 Identification of models of channels of transformation of object of regulation

Before starting the experiments, it is advisable on the basis of a priori data, based on the physical nature of the object, to pre-evaluate the properties of the channels whose models are to be identified.

For the technological process of drying both on the control channel and on the channel of controlled perturbation OK has the property of self-alignment, because the technological process is thermal. Increasing the control action (power of the electric heater) will increase the drying temperature.

To identify the models of OK channels, we plan and conduct an active experiment.

Active experiment plan

1. By changing the control action, we achieve the value of the adjustable coordinate, which would be in the vicinity of its nominal value. For our OK value $U_{ртен}$ = 60% x.p.o. , $U_{рк}$ = 60% x.p.o. and $U_{ωв}$ = 60% x.p.o. will correspond to the values of the adjustable coordinates $\Theta_{савх} = 60^0C$, $\Theta_{хв} = 24^0C$,

$d_{савих}$ = 45 g/kg.

2. We are waiting for the end of the transition process in the channels and the onset of a stable mode in which the original variables will stop changing.

3. Let's change control actions step by step on 10% x.p.o., noting the moment of the beginning of their change.

4. Register the change of output variables before the onset of new stable modes, the input action in this case may not be registered.

The results of the active experiment are shown in Fig. 4 – 6

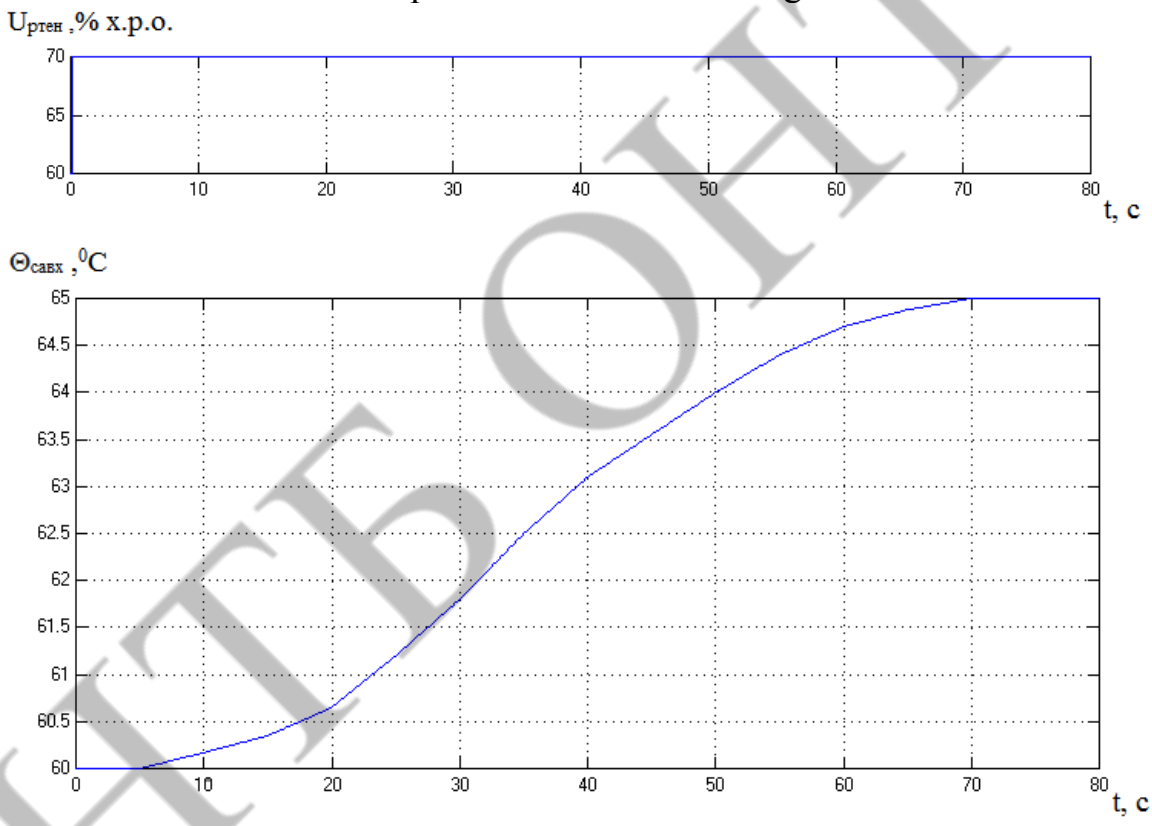


Fig. 4. – The results of an active experiment on the channel «$U_{ртен}$ - $\Theta_{савх}$»

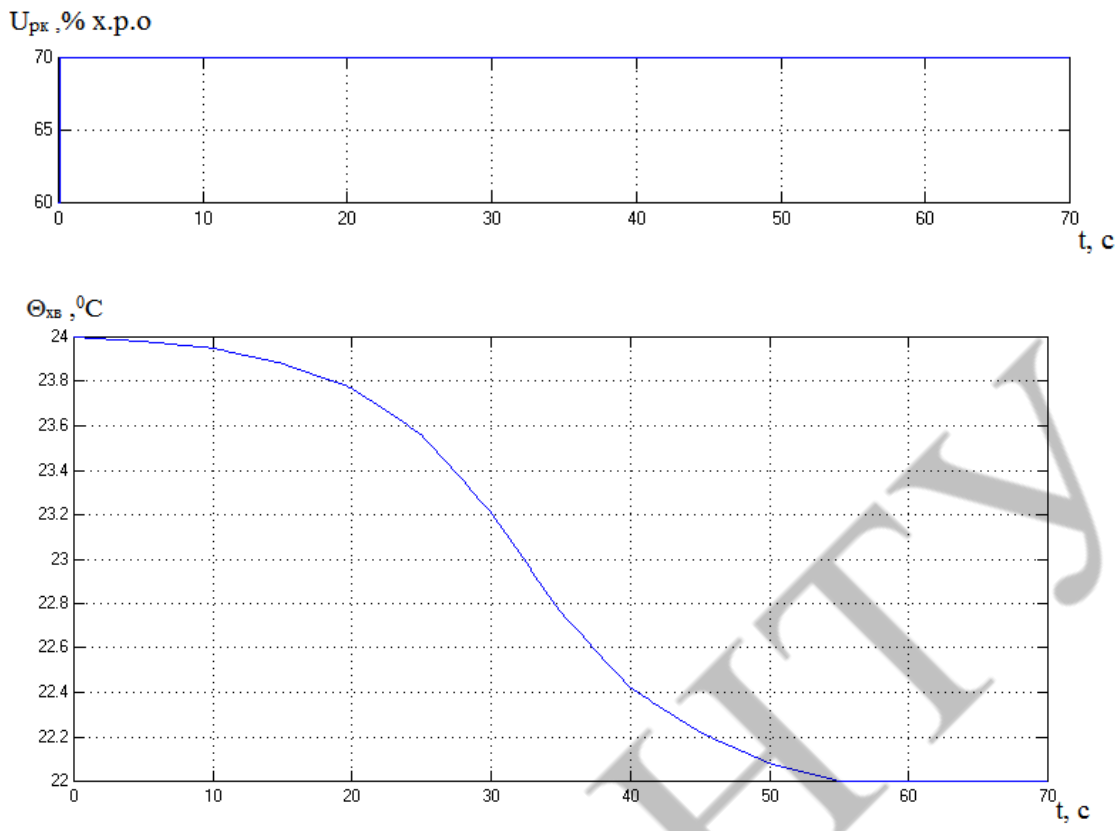


Fig. 5. – The results of an active experiment on the channel «$U_{рк}$ - $\Theta_{хв}$»

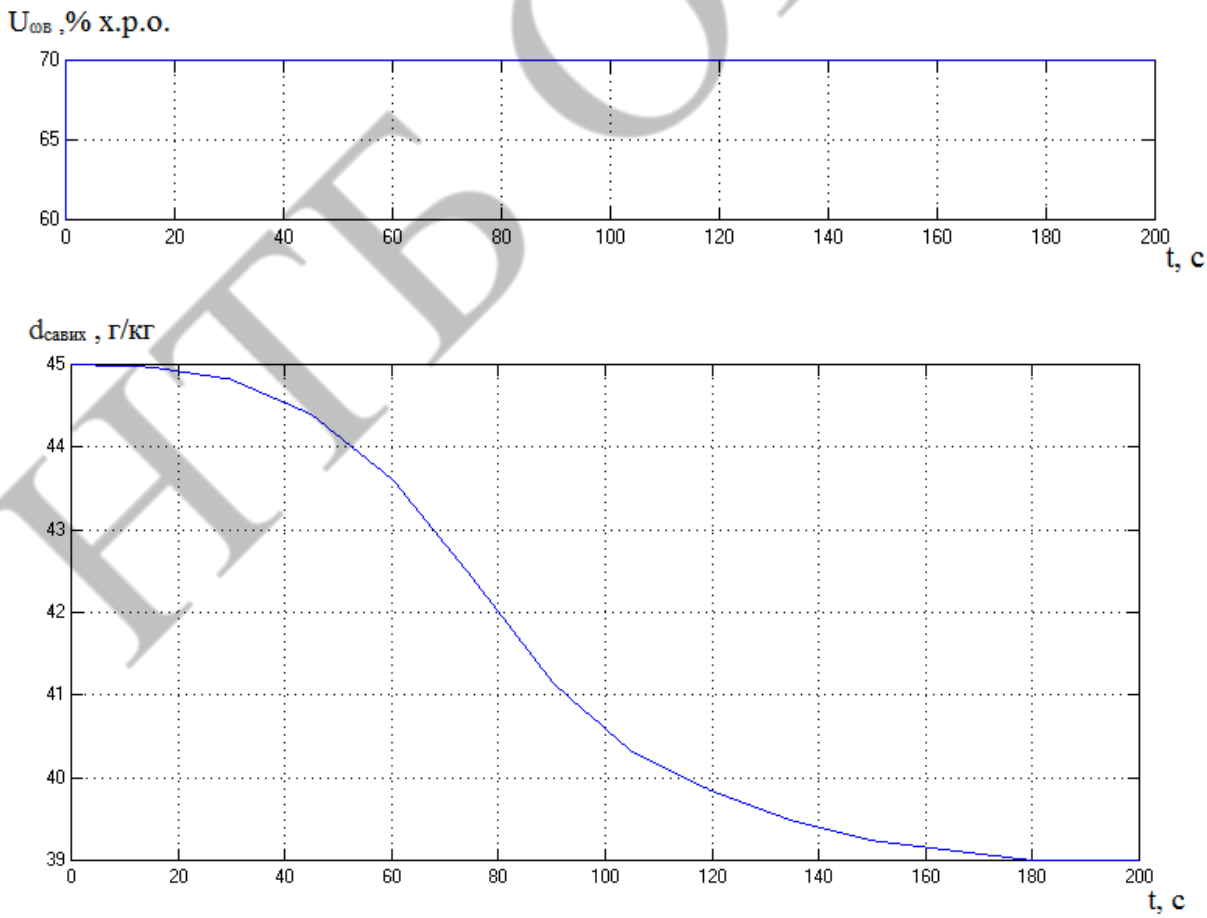


Fig. 6 – The results of an active experiment on the channel «$U_{ωв}$ - $d_{савих}$»

The following are the transfer functions for the 1st and 2nd order models for all OK channels.

Transfer function of the 1st order channel model «$U_{ртен}$ – $\Theta_{савх}$» looks like:

$$W_0(p) = \frac{0,5 \cdot e^{-20,9p}}{19,6p+1} \quad (1)$$

Transfer function of the 2nd order channel model «$U_{ртен}$ – $\Theta_{савх}$» looks like:

$$W_0(p) = \frac{0,5 \cdot e^{-11,85p}}{(13,6p+1)^2} \quad (2)$$

Transfer function of the 1st order channel model «$U_{рк}$ – $\Theta_{хв}$ » looks like:

$$W_0(p) = \frac{-0,2 \cdot e^{-23,54p}}{11,5p+1} \quad (3)$$

Transfer function of the 2nd order channel model «$U_{рк}$ – $\Theta_{хв}$ » looks like:

$$W_0(p) = \frac{-0,2 \cdot e^{-16,68p}}{(8,61p+1)^2} \quad (4)$$

Transfer function of the 1st order channel model «$U\omega в$ – $d_{савих}$» looks like:

$$W_0(p) = \frac{-0,6 \cdot e^{-53,04p}}{36,16p+1} \quad (5)$$

Transfer function of the 2nd order channel model «$U\omega в$ – $d_{савих}$» looks like:

$$W_0(p) = \frac{-0,6 \cdot e^{-34,86p}}{(25,65p+1)^2} \quad (6)$$

Static properties of OK are described by static characteristics (models) of channels. They reflect the relationship between the input and output coordinates (variables) of the OK channels in statically constant modes, ie after the attenuation of all transient components of these variables.

To identify models of static characteristics of the OK, we will conduct an active experiment. The results of the experiment to determine the static characteristics of the channels are summarized in tables 2-4 and in Fig. 7 - 9.

Table 2

The results of the experiment to determine the static characteristics of the OK channel «$U_{ртен}$ – $\Theta_{савх}$ »

$U_{ртен}$, % x.p.o	$U_{рк}$, % x.p.o	$U_{\omega в}$, % x.p.o	$\Theta_{савх}$, °C
60	60	60	60
70	60	60	65
80	60	60	70
50	60	60	55
40	60	60	50
0	60	60	30

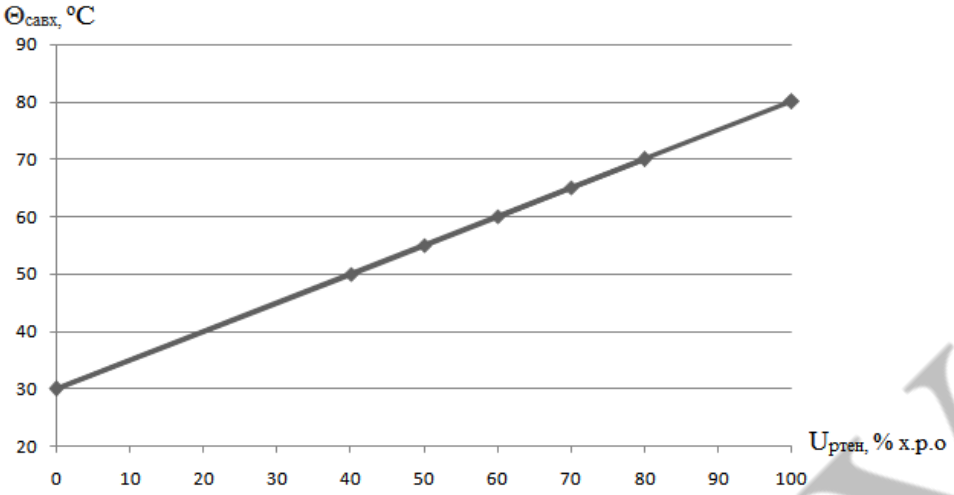


Fig. 7 – The results of the experiment to determine the static OK channel characteristics «$U_{ртен}$ – $Θ_{савх}$ »

Table 3

The results of the experiment to determine the static characteristics of the OK channel «$U_{рк}$ – $Θ_{хв}$ »

$U_{ртен}$, % х.р.о	$U_{рк}$, % х.р.о	$U_{ωв}$, % х.р.о	$Θ_{хв}$, °C
60	60	60	24
60	70	60	22
60	80	60	20
60	50	60	26
60	40	60	28
60	0	60	40

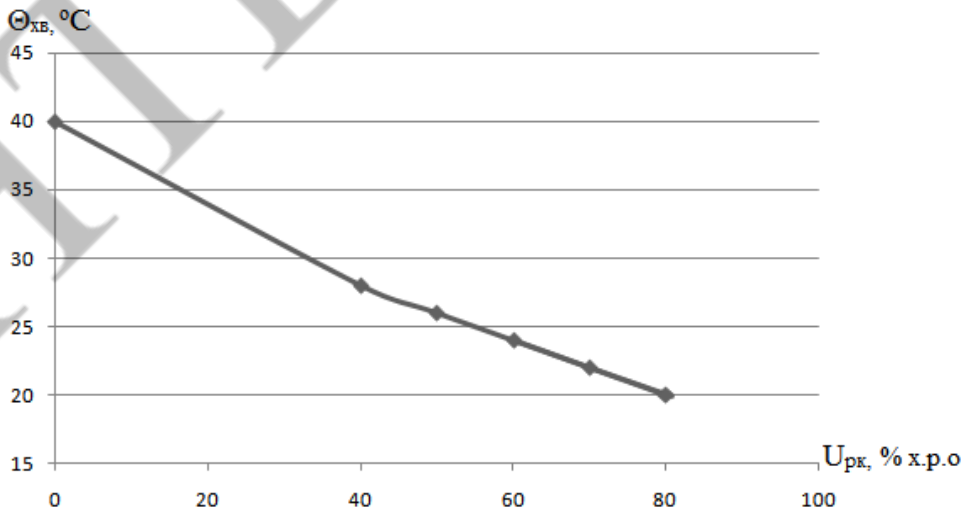


Fig. 8 – The results of the experiment to determine the static OK channel characteristics «$U_{рк}$ – $Θ_{хв}$ »

Table 4

The results of the experiment to determine the static characteristics of the OK channel «$U_{ωв}$ – $d_{савих}$ »

$U_{ртен}$, % x.p.o	$U_{рк}$, % x.p.o	$U_{ωв}$, % x.p.o	$d_{савих}$, g/kg
60	60	60	45
60	60	70	39
60	60	80	34
60	60	50	50
60	60	40	57

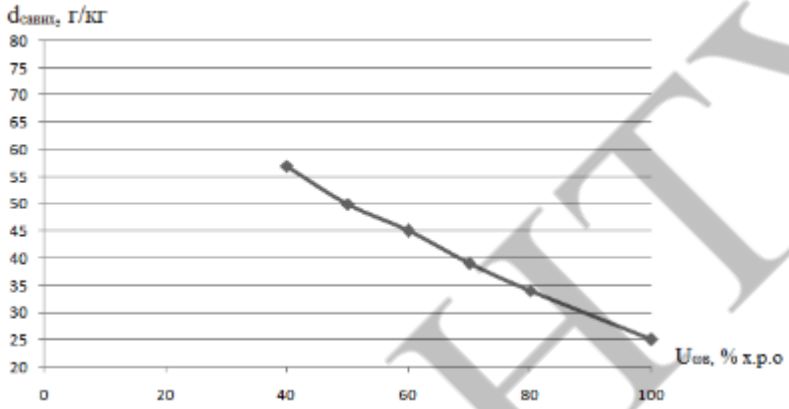


Fig. 9 – The results of the experiment to determine the static OK channel characteristics «$U_{ωв}$ – $d_{савих}$ »

3.4 Identification of deterministic and random models components of uncontrolled disturbances

Models of uncontrolled perturbations should be represented as the sum of four components. Moreover, the deterministic component ($f_{НД}$) it is expedient to lead to a controlling action, and quasi-deterministic and stochastic components ($f_{НС}$) it is advisable to bring to an adjustable coordinate (look. Fig. 10).

The model of controlled perturbation by analogy with the model of uncontrolled perturbations can be represented by four components that will be applied to the input of the channel of controlled perturbations.

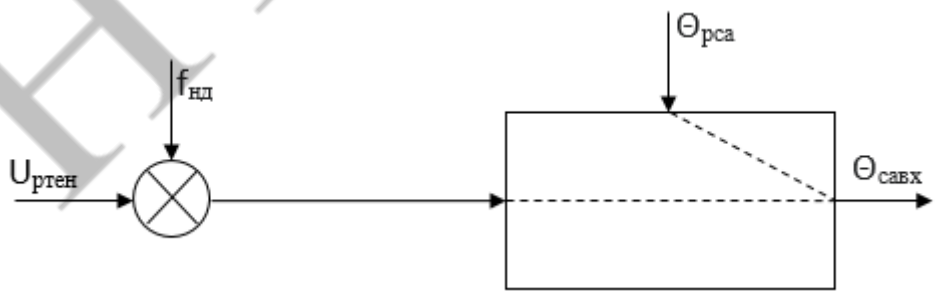


Fig. 10 – Block diagram of adding coordinate perturbations

Since it is not possible to obtain real experimental data, you can use a data generator for educational purposes.

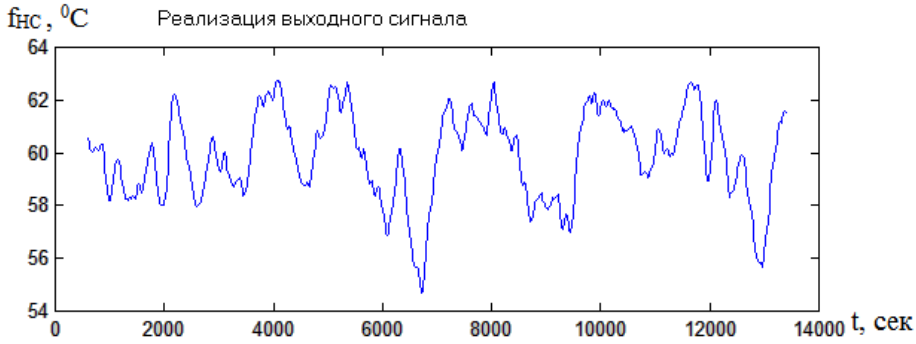


Fig. 11 – The results of generating a random process corresponding to the signal of uncontrolled perturbation for the studied OK

You can use the IdSoft environment program to identify models of controlled and uncontrolled coordinate perturbations.

The results of estimating the probabilistic characteristics of a random process corresponding to uncontrolled perturbations are given in Fig. 12, a corresponding to controlled perturbation – in Fig. 13.

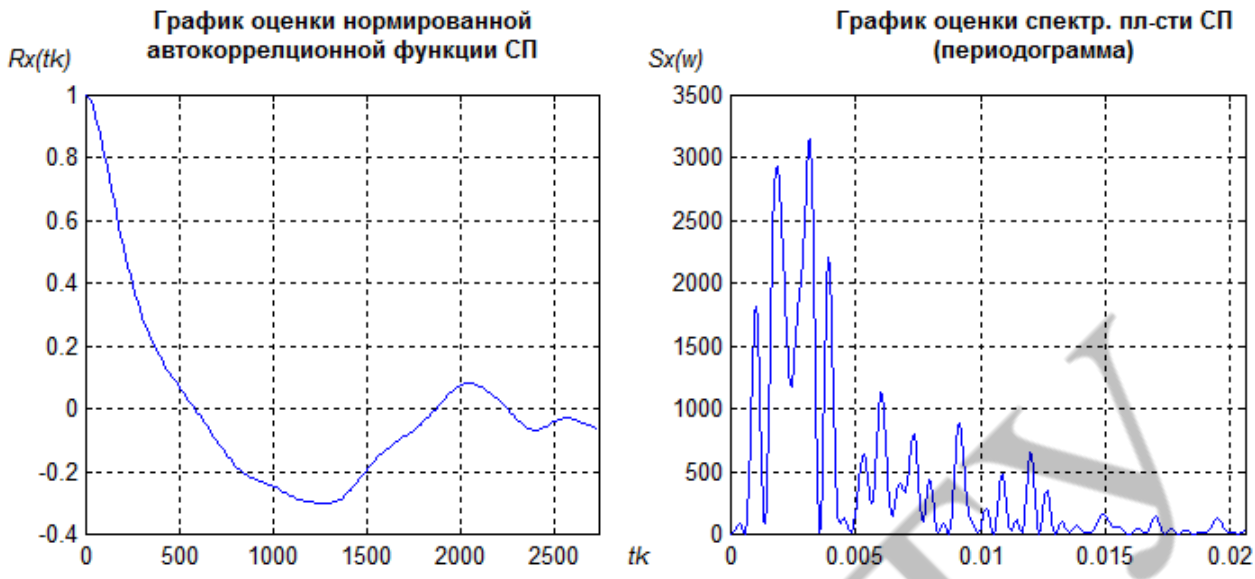


Fig. 12 – The results of estimating the probabilistic characteristics of a random process corresponding to uncontrolled perturbations

Fig. 13(1)– The results of estimating the probabilistic characteristics of a random process corresponding to controlled perturbations

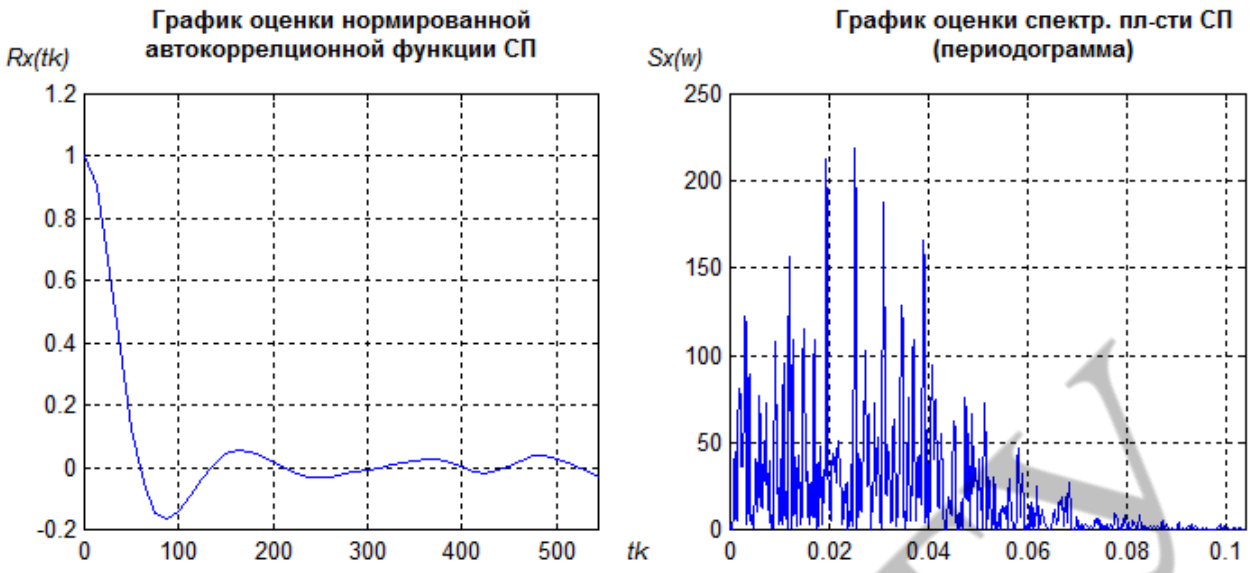


Fig. 13– The results of estimating the probabilistic characteristics of a random process corresponding to controlled perturbations

As can be seen from the simulation results, the OK model fairly accurately reflects the experimental data. This means that the resulting OK model is adequate.

To reproduce the model of perturbations as stochastic processes with given properties, we will use the method of forming a filter. It can be represented as such a structural scheme of modeling (Fig. 14).

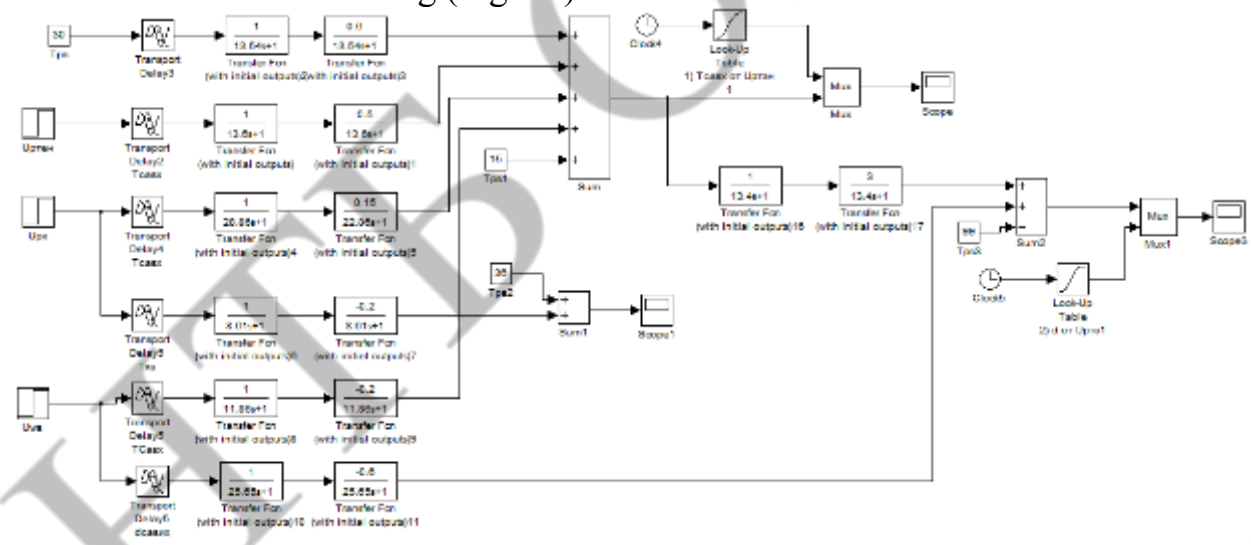


Fig. 14 – Model modeling scheme OK

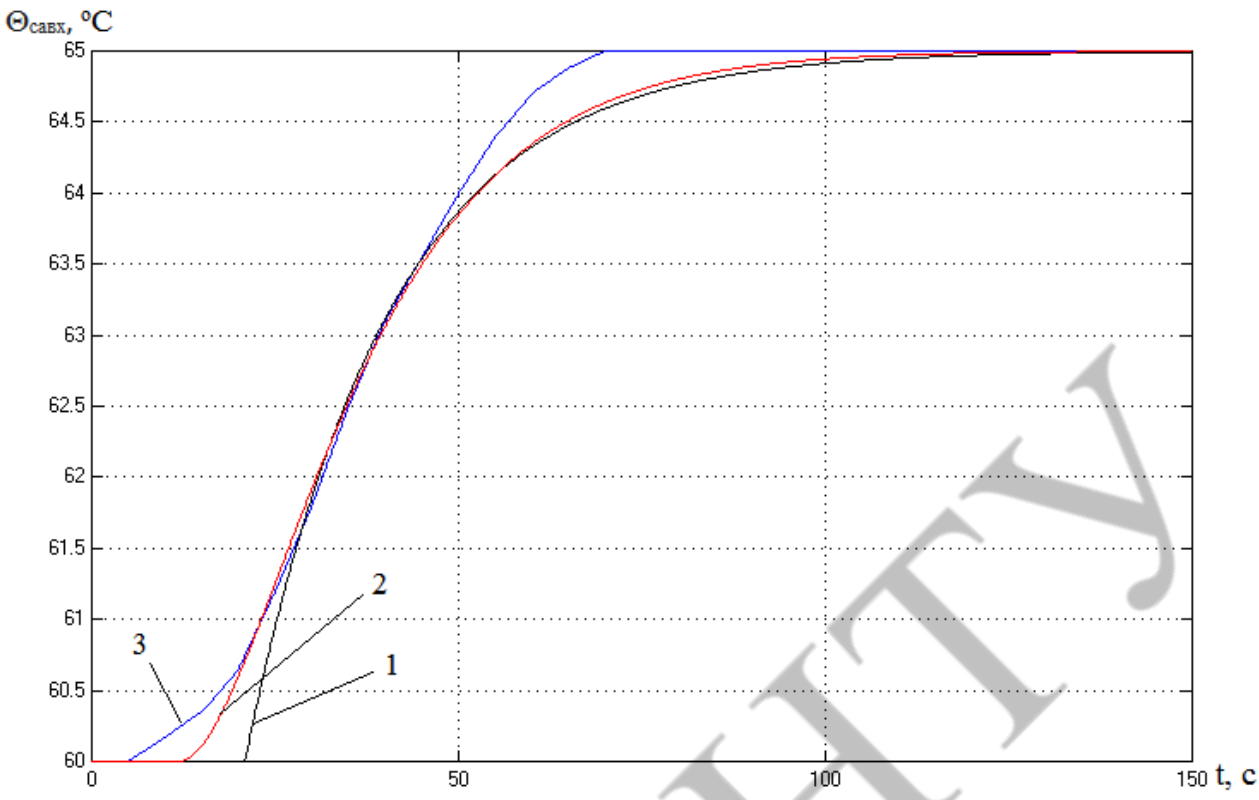


Fig. 15 – The result of channel simulation «$U_{ртен}$ – $\Theta_{савх}$», where 1 is a model of the 1st order; 2- 2nd order model; 3- experimental data.

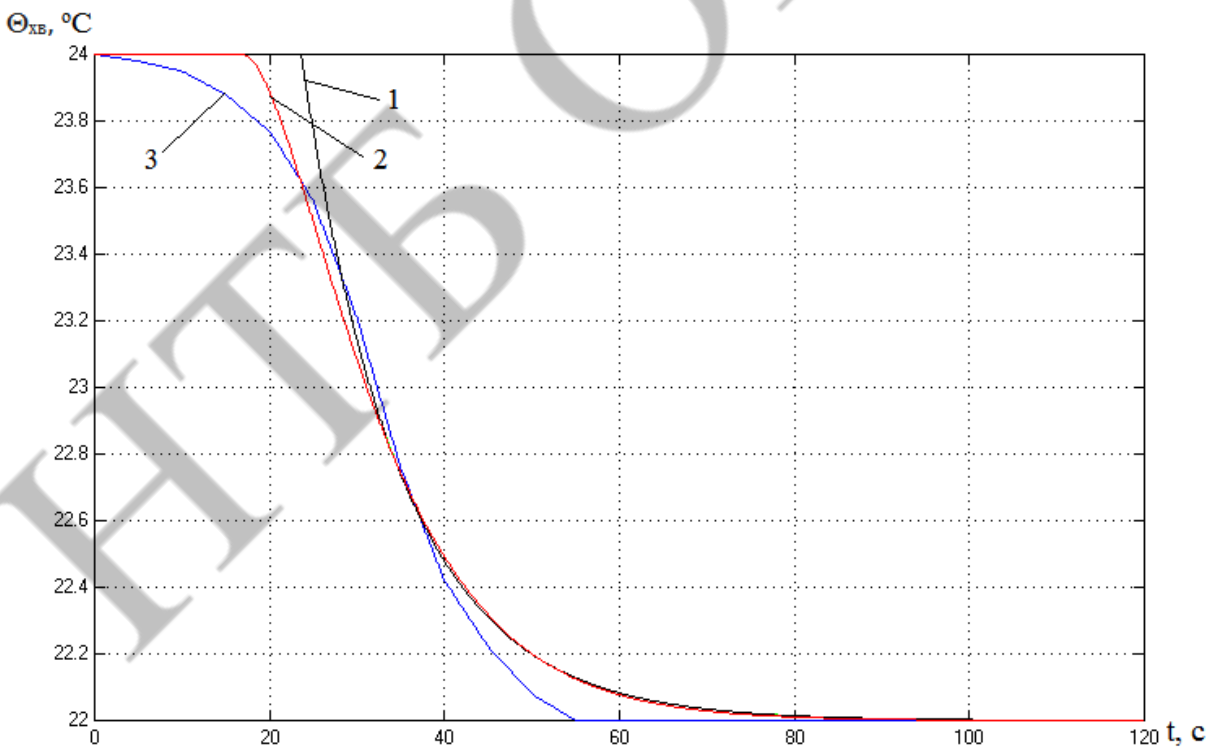


Fig. 16 – The result of channel simulation «$U_{рк}$ – $\Theta_{хв}$», where 1 is a model of the 1st order; 2- 2nd order model; 3- experimental data.

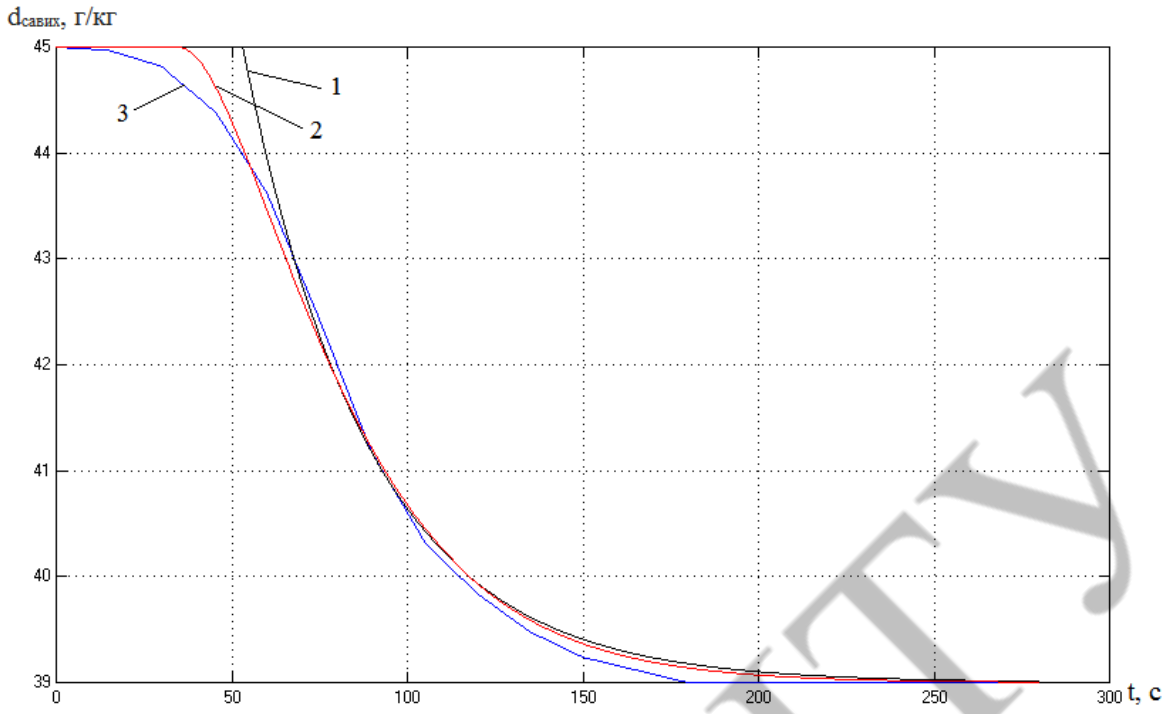


Fig. 17 – The result of channel simulation «$U_{ωв}$ – $d_{савих}$», where 1 is a model of the 1st order; 2- 2nd order model; 3- experimental data.

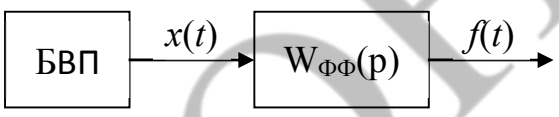


Fig. 18 – Block diagram of the model of stochastic processes

Forming filter parameters: : k = 3,5; T = 187 c; ξ = 0,6. The scheme of modeling the final forming filter is shown in Fig. 19, and the simulation results - in Fig. 20.

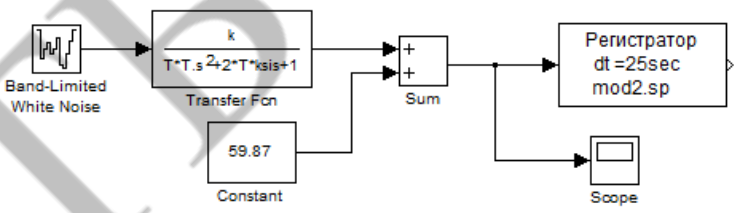


Fig. 19 – Uncontrolled perturbation simulation scheme with generating filter having adjusted parameters

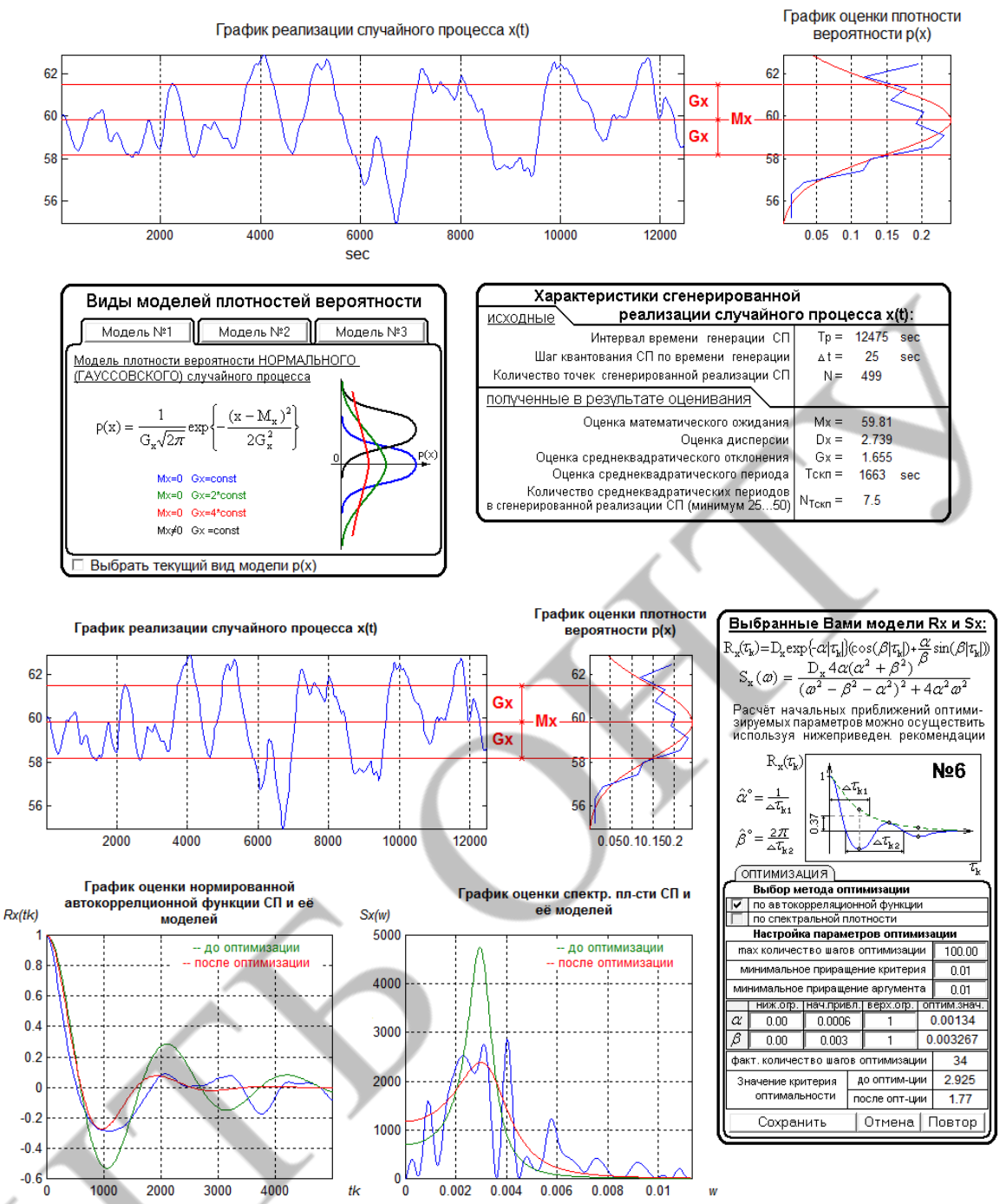


Fig. 20 – The results of modeling uncontrolled perturbations with the calculated parameters of the forming filter

Let's estimate accuracy of reproduction of parameters in model. The results show that the reproduction error σ_f, α i β less than 5%, hence the accuracy of the model of uncontrolled perturbations is sufficient.

3.5. Parametric synthesis and analysis of ACS base structure

The coordinate diagram of the drying process in the drying chamber is shown in Fig. 3. According to it, the block diagram of the ACS will look like Fig. 21.

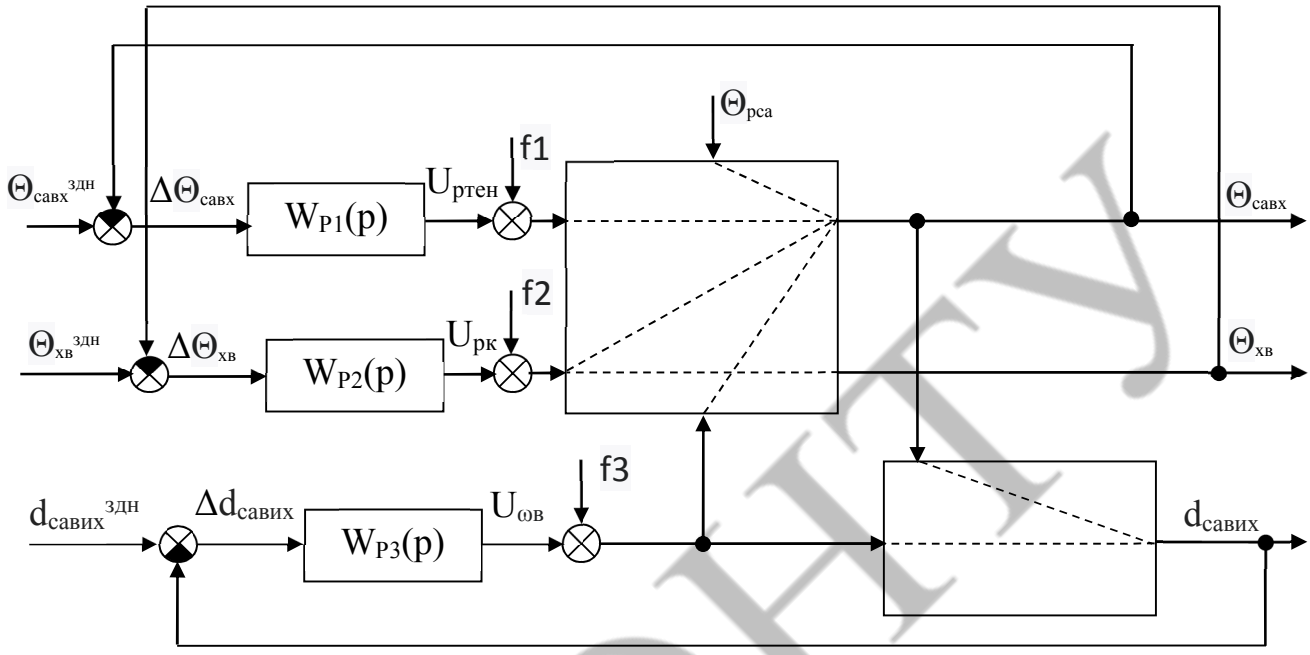


Fig. 21 – Block diagram of the ACS control of the moisture content of the drying agent of the basic structure

In the picture:

$U_{хв}$ – the position of the cold water temperature regulator;

$U_{ртен}$ – the position of the temperature regulator of the drying agent;

$U_{ωв}$ – the position of the regulator of the moisture content of the drying agent;

$Θ_{савх}$ – the temperature of the input drying agent, ^{0}C ;

$Θ_{хв}$ – chilled water temperature, ^{0}C ;

$d_{савих}$ – moisture content of the drying agent, g/кg;

f1, f2 and f3 – vectors of uncontrolled perturbations;

$W_P(p)$, $W_{P2}(p)$ and $W_{P3}(p)$ – transfer functions of temperature controllers for the preparation of the drying agent ;

$Θ_{савх}^{здн}$ – the set temperature of the input drying agent, ^{0}C;

$Θ_{хв}^{здн}$ – the set value of the cooled water temperature, ^{0}C;

$d_{савих}^{здн}$ – the set value of the moisture content of the drying agent, g/кg;

$Δ\ Θ_{савх}$ – error in adjusting the temperature of the input drying agent;

$Δ\ Θ_{хв}$ – cooling control error;

$Δd_{савих}$ – error in adjusting the moisture content of the drying agent;

As a control algorithm we choose proportional-integral-differential (PID) control algorithms.

Transfer function of the PID controller

$$W^P(p) = K_p \cdot \left(1 + \frac{1}{T_{ІЗ}\,p} + \frac{T_{УП}\,p}{0{,}2 \cdot T_{УП}\,p + 1}\right) \qquad (7)$$

The block diagram of the ACS modeling with the PID controller is shown in Fig. 22, and the structural scheme of modeling OK - in Fig. 23. The results of optimizing the settings of the PID controller are shown in Fig. 24-26.

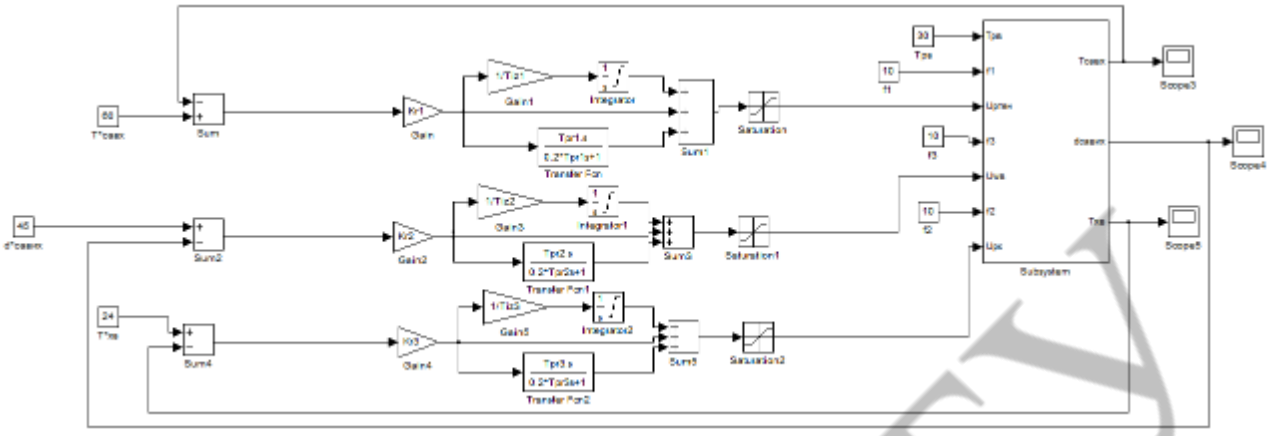


Fig. 22 – Block diagram of ACS modeling with PID controller for optimal parametric synthesis

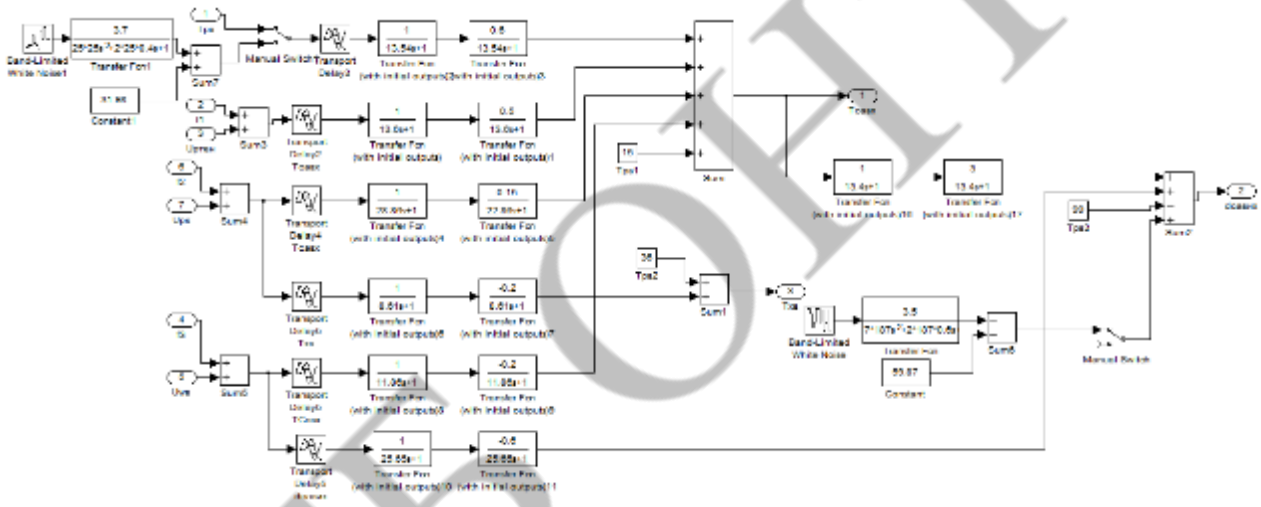
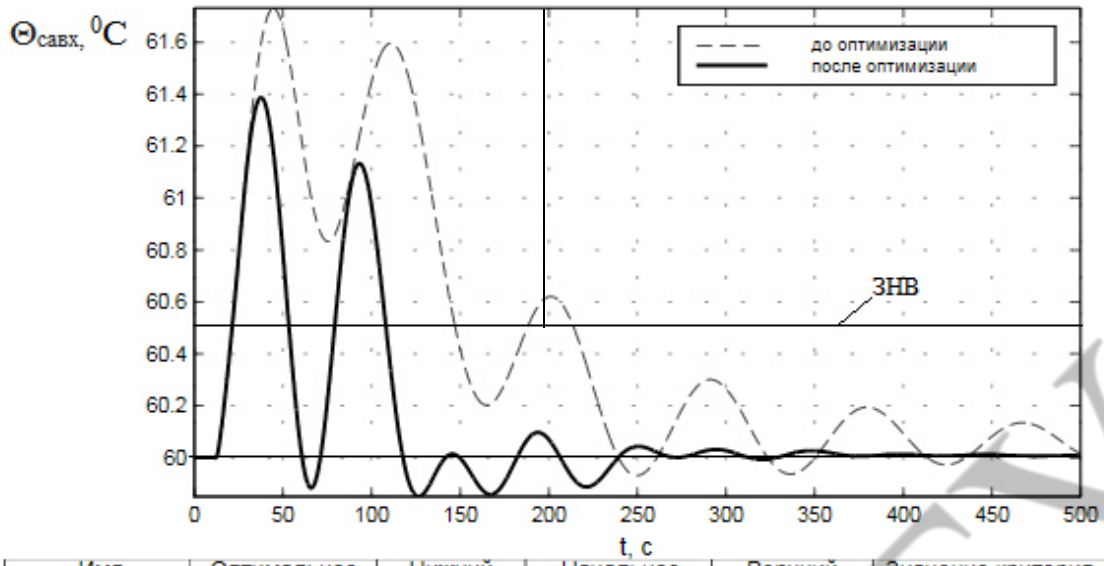
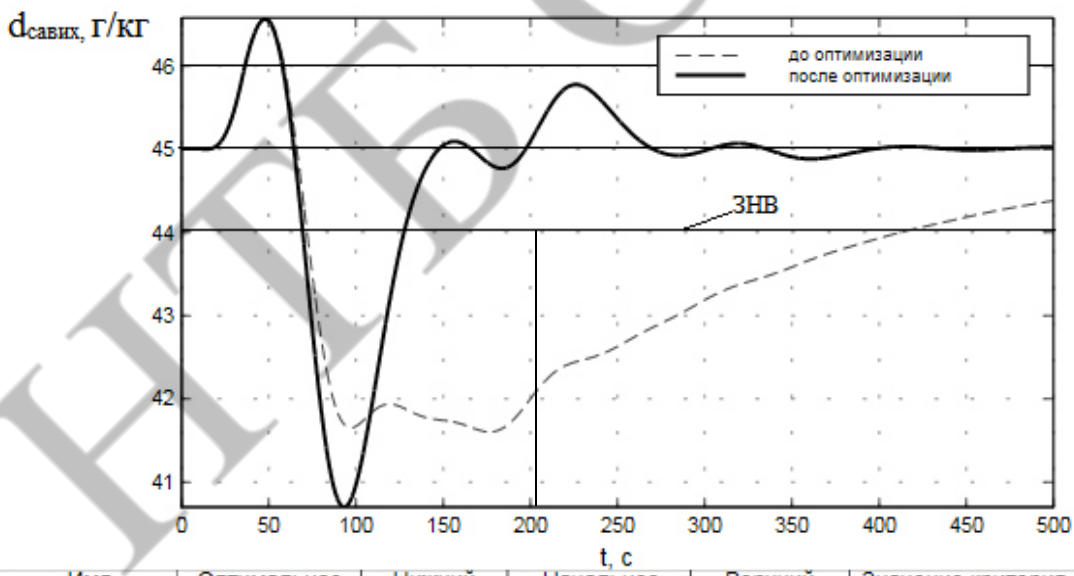


Fig. 23 – Block diagram of the modeling OK PID controller settings



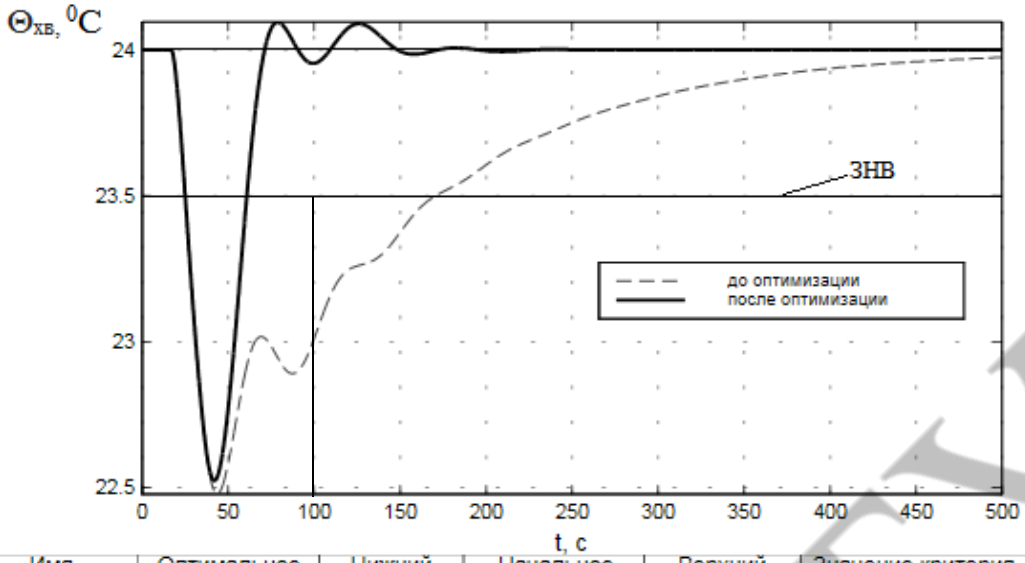
Имя переменной	Оптимальное значение	Нижний предел	Начальное приближение	Верхний предел	Значение критерия оптимальности: до - 43.2736; после - 16.1712 оптимизации.
Kr1	3.8986	1	1.86	100	
Tiz1	26.0378	1	41.8	100	
Tpr1	12.6204	1	14.63	100	Количество шагов процедуры оптимизации: максимальное - 1000; фактическое - 147

Fig. 24 – The results of optimizing the settings of the PID controller by channel «$U_{ртен}$ – $\Theta_{савх}$»



Имя переменной	Оптимальное значение	Нижний предел	Начальное приближение	Верхний предел	Значение критерия оптимальности: до - 180.1143; после - 53.4731 оптимизации.
Kr2	-2.9773	-10	-1.14	10	
Tiz2	34.5902	1	106.08	200	
Tpr2	15.9415	1	37.13	100	Количество шагов процедуры оптимизации: максимальное - 1000; фактическое - 306

Fig. 25 – The results of optimizing the settings of the PID controller by channel «$U_{ов}$ – $d_{савих}$»



Имя переменной	Оптимальное значение	Нижний предел	Начальное приближение	Верхний предел
Kr3	-4.62	-10	-2.44	10
Tiz3	18.8539	1	47.08	100
Tpr3	8.4817	1	16.48	100

Значение критерия оптимальности:
до - 63.3675
после - 15.8597
оптимизации.

Количество шагов процедуры оптимизации:
максимальное - 1000
фактическое - 153

Fig. 26 – The results of optimizing the settings of the PID controller by channel «$U_{рк} – Θ_{хв}$»

Research of ACS with PID-regulator on roughness will be carried out at variation of ± 20% of time of delays OK. The results of the rough analysis are shown in Fig. 27.

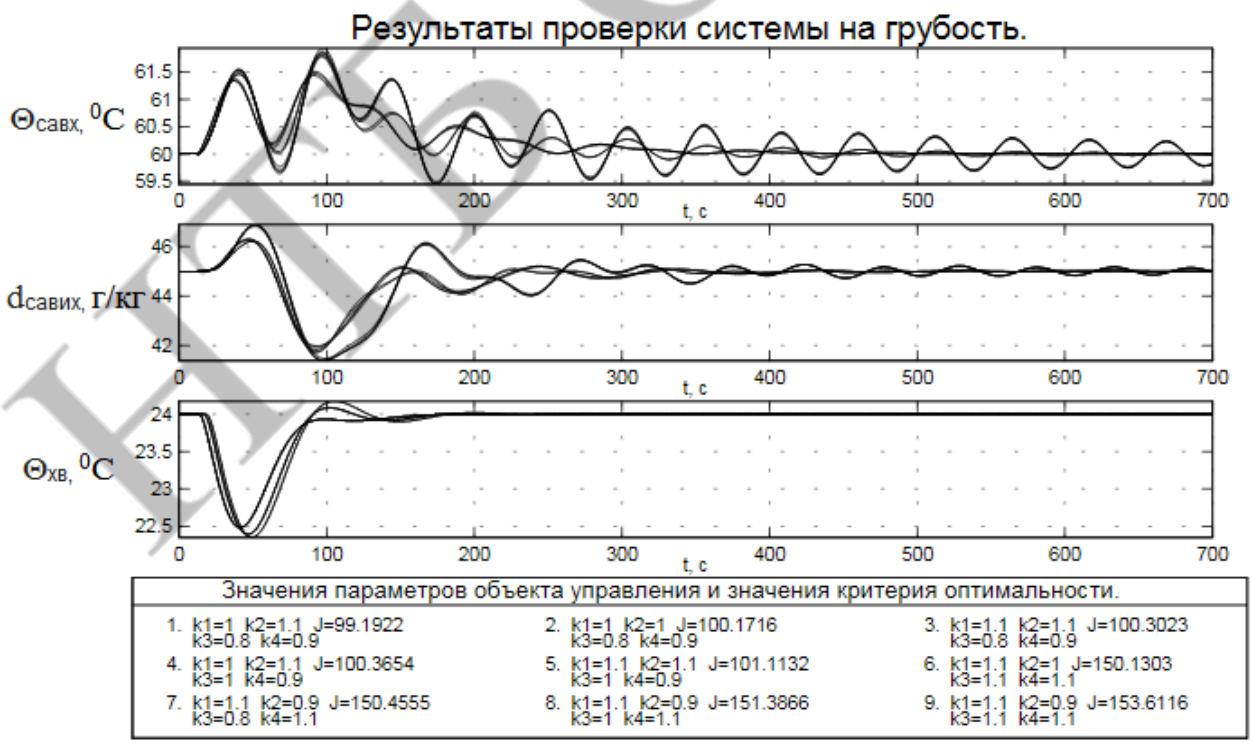


Fig. 27 – The results of the test ACS with PID-regulator for roughness

As can be seen from the results, the ACS with the PID controller is rough, because in conditions of variation of the parameters of the OK gives convergent transients.

3.6. Structural and parametric synthesis and analysis of ATS increased dynamic accuracy

The main way to increase the dynamic accuracy of the considered ACS is to build an ACS invariant to the action of controlled perturbation. Accordingly, the block diagram of the ACS will look like Fig. 28.

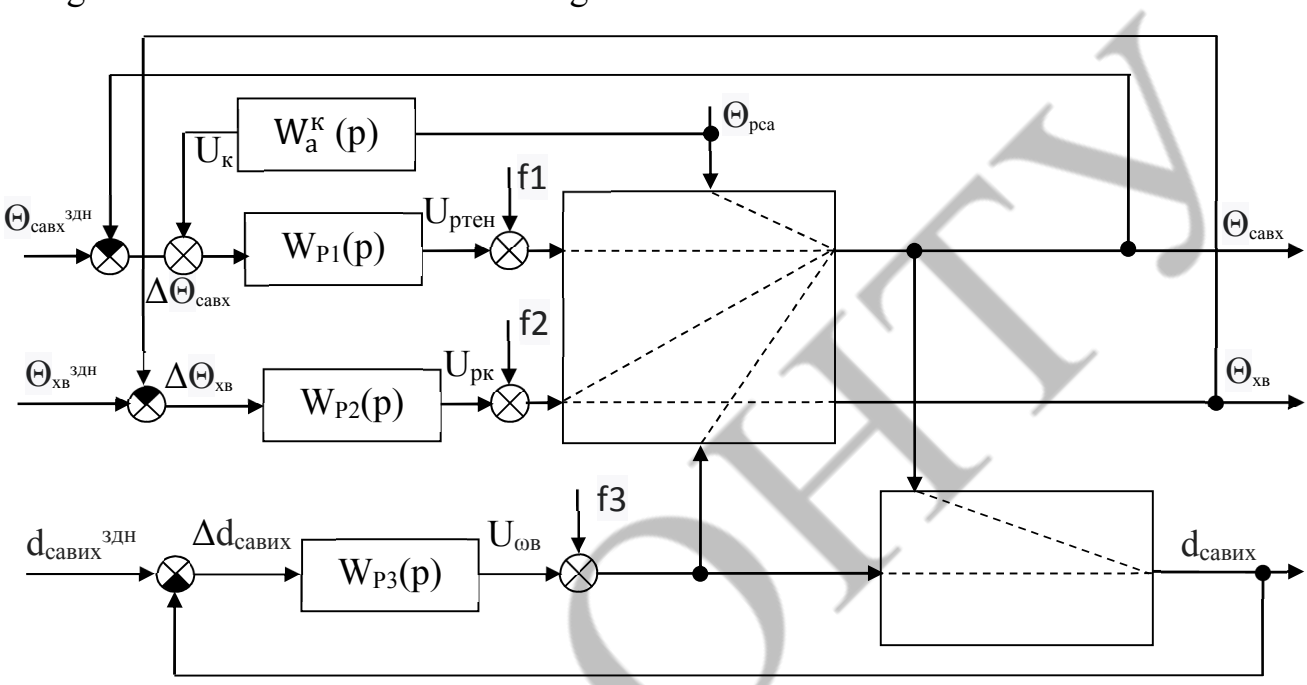


Fig. 28 – Block diagram of ACS of the increased dynamic accuracy
In the diagram $W_a^к(p)$ – transfer function corrective communication.

Before the simulation, a corrective link was calculated and simplified. The block diagram of modeling of ACS of the increased dynamic accuracy is resulted on Fig. 29, and the results - on Fig. 30.

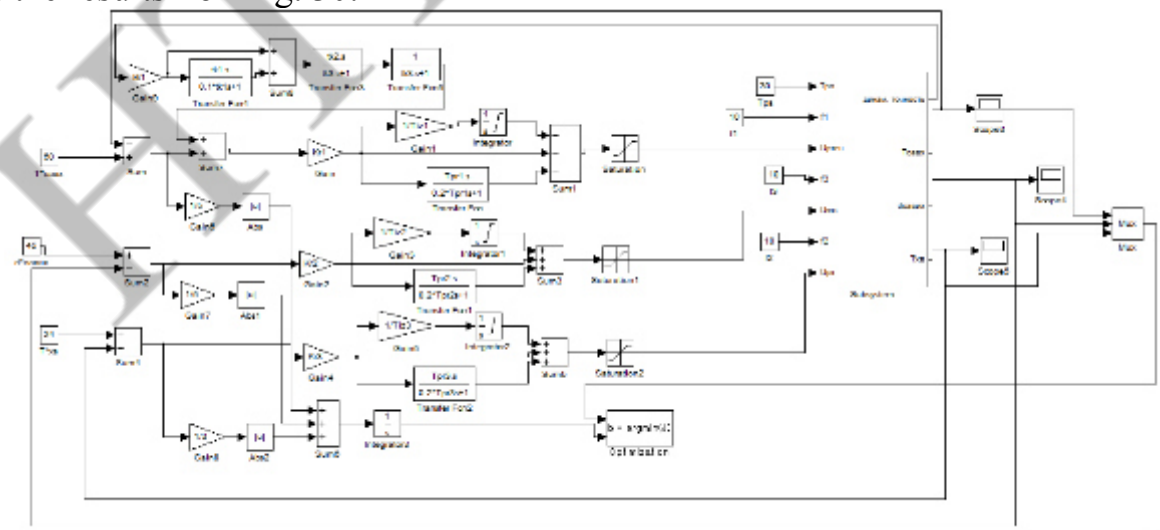
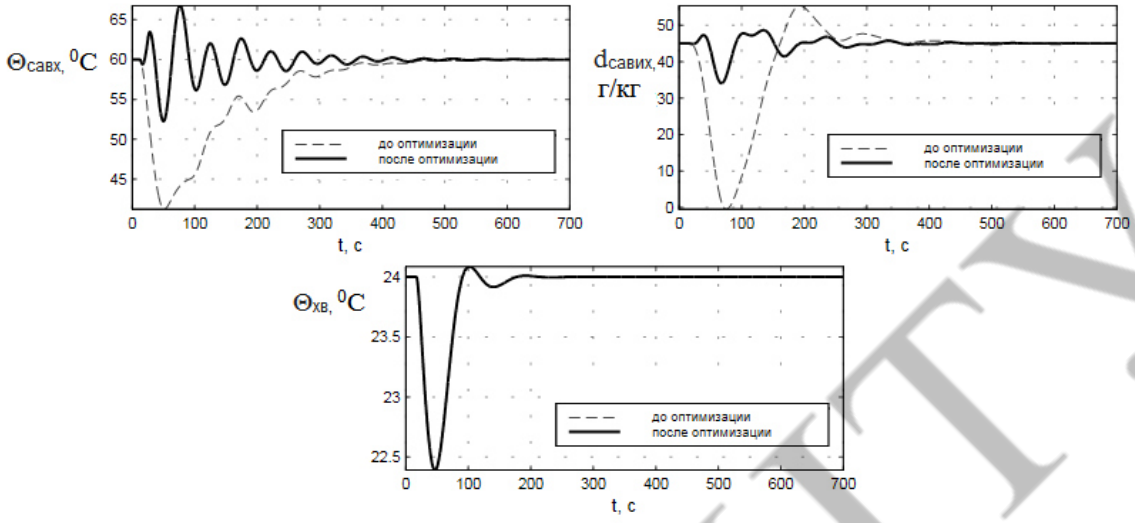


Fig. 29 – Block diagram of ACS modeling
increased dynamic accuracy

As in the case of ACS base structure, the study of ACS increased dynamic accuracy for roughness will be carried out with a variation of ± 20% of the delay time OK. The results of the analysis for roughness are shown in Fig. 31.

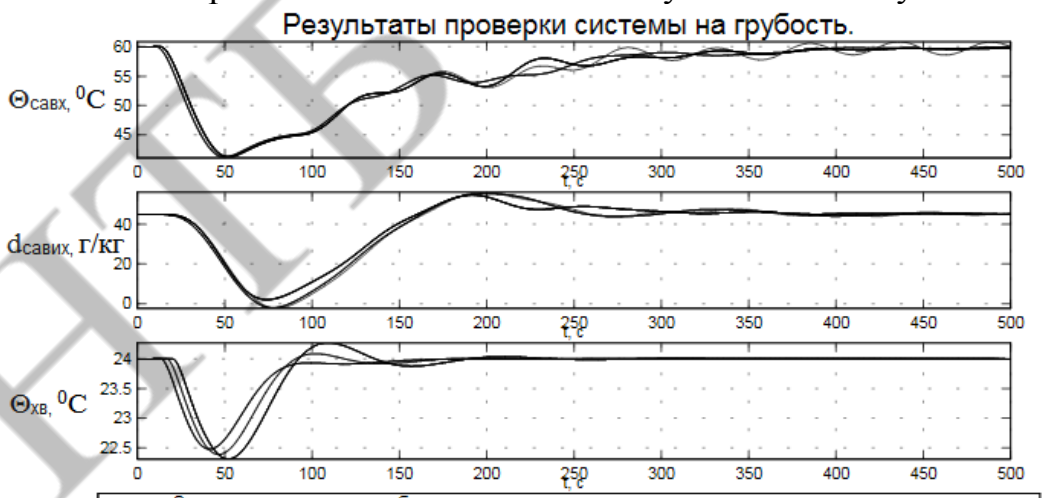
As can be seen from the results, the ACS of high dynamic accuracy is rough, because in the variation of the parameters of the OK gives convergent transients.



Имя переменной	Оптимальное значение	Нижний предел	Начальное приближение	Верхний предел
kk1	-2.3047	-20	-1.9	10
tk1	4.0658	-10	15.1	100
tk2	77.2096	1	83	100
tk3	2.2478	1	30.6	200

Значение критерия оптимальности:	
до -	1337.3361
после - оптимизации.	275.207
Количество шагов процедуры оптимизации:	
максимальное -	1000
фактическое -	106

Fig. 30 – The results of optimizing the parameters of the corrective link as a part of ACS of the increased dynamic accuracy



Значения параметров объекта управления и значения критерия оптимальности.

1. k1=1.1 k2=0.8 k3=1 k4=0.8 J=1284.6977	2. k1=1.1 k2=0.8 k3=0.8 k4=0.8 J=1284.8532	3. k1=1.1 k2=1 k3=1 k4=0.8 J=1285.6952
4. k1=1.1 k2=1 k3=0.8 k4=0.8 J=1285.7414	5. k1=1.1 k2=1.2 k3=0.8 k4=0.8 J=1287.1114	6. k1=0.9 k2=0.8 k3=1.2 k4=1.2 J=1396.6312
7. k1=1.1 k2=1.2 k3=1.2 k4=1.2 J=1397.2635	8. k1=0.9 k2=1 k3=1.2 k4=1.2 J=1398.0402	9. k1=0.9 k2=1.2 k3=1.2 k4=1.2 J=1399.9153

Fig. 31 – The results of the test for the severity of ACS increased dynamic accuracy

IV. RESULTS OF WORK

We will conduct a comparative analysis of transients in parametrically optimal systems by the value of the criterion of optimality and indicators for which the maximum allowable values. Comparison of ACS of basic structure and ACS of the increased dynamic accuracy is given in Fig. 32 and in table 5.

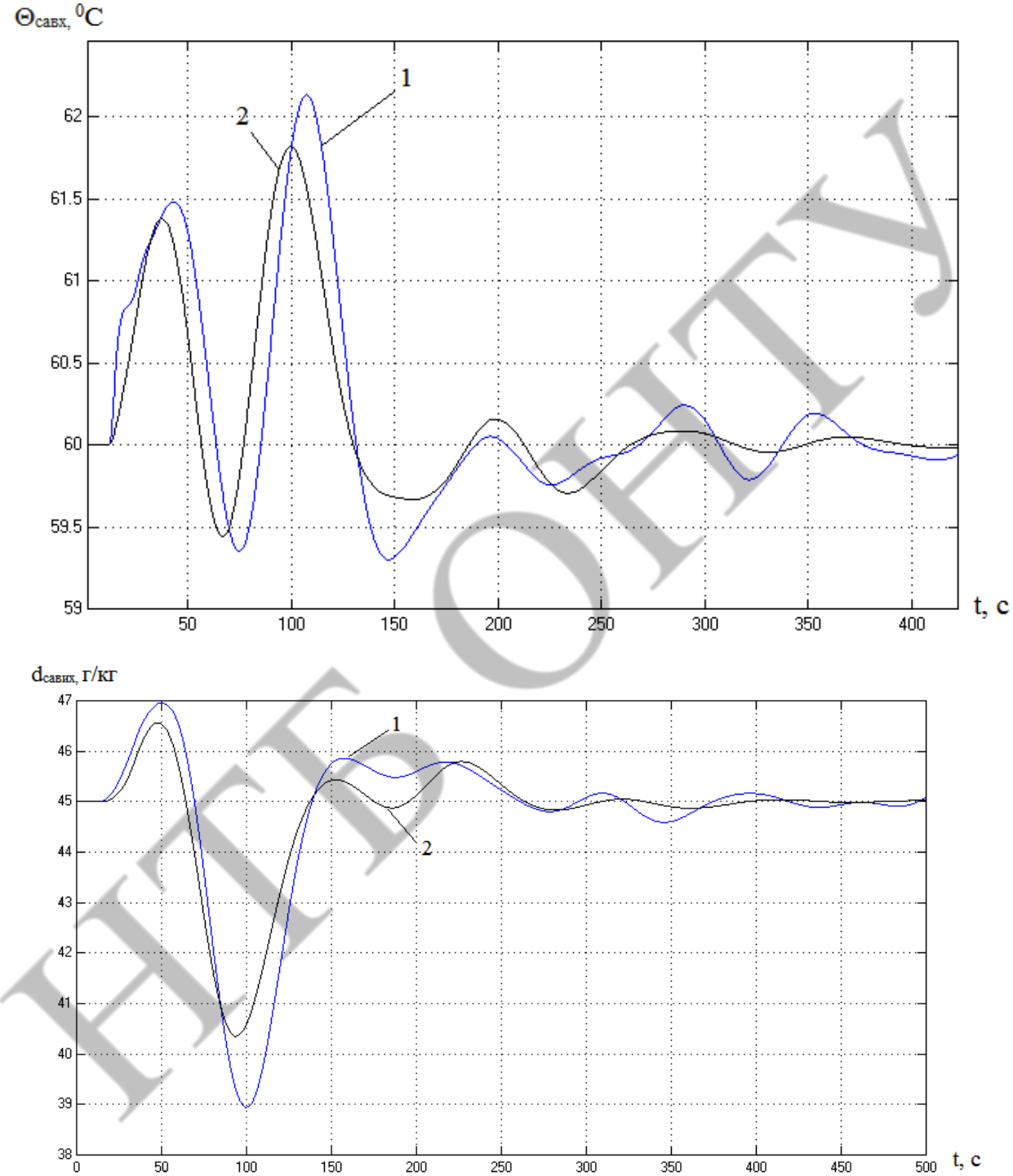


Fig. 32 – Results of comparison of ACS of basic structure (1) and ACS of the increased dynamic accuracy (2)

Table 5 - Comparison of ACS bass structure and ACS increased dynamite accurations

Option ACS	Direct quality indicators			Adjustment time, c			Criterion
	$\Delta\ \Theta_{савх}$ max	$\Delta\ d_{савих}$ max	$\Theta_{хв}$	«$U_{ртен}$ - $\Theta_{савх}$»	«$U_{\omega в}$ – $d_{савих}$»	«$U_{рк}$ – $\Theta_{хв}$»	
ПІД	2	2	1,5	150	150	80	147
ПДТ	1,6	1,3	1,3	100	90	60	51

As can be seen from the results of the comparison of transients, the ACS of increased dynamic accuracy in terms of quality is almost no different from the ACS of the basic structure, except for a slight reduction in the criterion of optimality. But the ACS of increased dynamic accuracy is coarser with a variation of ± 20% of the delay time OK, this can be seen by comparing the results of testing the ACS of the basic structure and ACS of increased dynamic accuracy for roughness (Fig. 27 and Fig. 31).

V. CONCLUSIONS

The scientific work was performed in order to study the possibilities of increasing the energy efficiency of the process of condensation drying of raw materials with energy recovery through the use of a heat pump by improving control algorithms.

The analysis and synthesis of ACS of the increased dynamic accuracy is executed. The synthesis of ACS was implemented and tested using the Simulink emulator Matlab medium.

Increasing the dynamic accuracy of the ACS with PID-regulator gave a significant improvement in the quality of transients and the system became rougher.

ACS invariant to controlled perturbation was chosen as the structure.

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RESEARCH APPLICATION OF THE SPAM FILTERING AND SPAMMER DETECTION ALGORITHMS ON SOCIAL MEDIA

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Abstract: *There are a bunch of different social networks and messengers today, which in times of pandemic corona-virus have take a really big part of our entire live, especially in our work activities. Besides that, the problem with the spam and spammers is the most relevant than ever, the count of spam in the work text stream is continuously increased.*

Under spam we understand the text content that is not necessary in the particular text stream, in case of spammer it is meant the person that is sending the spam messages in his or her own purposes.

The project was design to solve the scientific and applied problem of detecting spammers and identifying spam messages in the text context of any social network or messenger using various spam detection algorithms and spammer detection approaches. We have implemented 4 algorithms: an algorithm using naive Bayesian classifier, Support-vector machine, multilayer perceptron neural network and convolution neural network.

The project was developed in purpose of implementing a spam detection algorithm that is easy to integrate in a messenger (in our case we used Telegram as an example). Design algorithm recognizes spam based on the context of a particular text stream, deletes the spam message and blocks the spammer until one of the application managers unblock the spammer-user. Since the spam detection task is essentially the task of sorting messages into two classes, the usage of the design application is not limited to dealing with spam.

Keywords: *spam, social network, naive Bayesian classifier, Support-vector machine, multilayer perceptron neural network, convolution neural network, spammers detection.*

I. INTRODUCTION

Thanks to various anti-spam and spammer algorithms, the share of spam in global email traffic in 2020 was down by 6.14 p.p. when compared to the previous reporting period, averaging 50.37% [1] (Fig. 1.1).

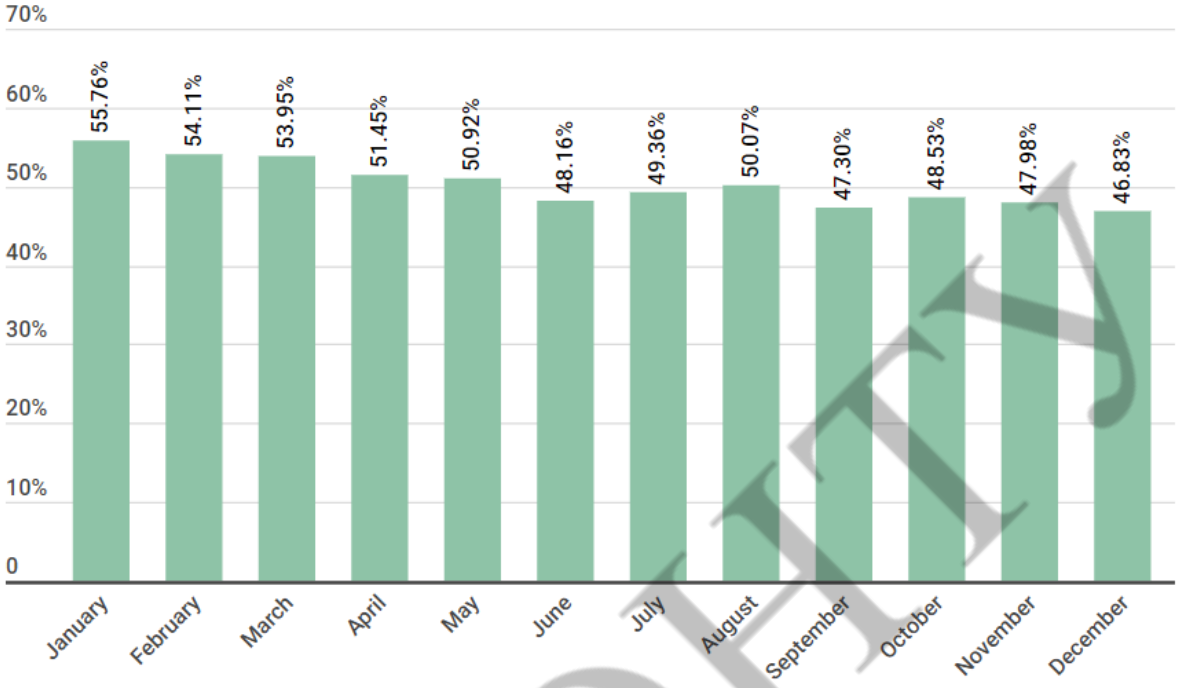

Fig 1.1. Percentage of spam in email traffic in 2020

Most probably only inboxes have built-in the anti-spam algorithms, the others chat rooms do not have such functionality. It can be the reason why the spam percentage in the mail-boxes and others message is mostly the same. For instance, the malicious link injected to the message and sent to the company employ can be a big danger for the whole company. Therefore, our today's world has an issue of monitoring the incoming text stream in social networks and messengers. Is also necessary to identify and ban spammers, this facilitates the work of algorithms and complicates the life of spammers, and the most important is that it reduce the share of the spam as we see from Fig. 1.1.

The ability to filter spam messages, identify and ban spammers in messengers and social networks can save a bunch of humanity time and prevent loss of information and money.

To solve the problem we used algorithms using a naive Bayesian classifier, support vector method, multilayer perceptron neural network and convolution neural network. We also developed a simple algorithm that identifies and blocks the user that was recognized as a spammer. An approach with integrated application of the investigated algorithms can begin to solve the problem of spam in social networks and messengers.

II. LITERATURE ANALYSIS

2.1. Characterization of spam. Ways to deal with spam

Let's start and firstly discuss what is the spam actually. Spam is a mass mailing of correspondence of an advertisement to people who have not expressed a desire to receive it [2].

Here is the different types of spam: advertisements; phishing; Nigerian emails; mass mailings of letters with religious content; mass mailings to put the mail system out of service (causing the system crush); mass mailings of letters containing computer viruses (for their initial spread); mass mailings on behalf of another person in order to cause a negative attitude towards that person;

The most popular spam spreading methods are the following [2, 3]: e-mail; usernet; messengers; substitution of Internet traffic; SMS messages; phone calls, etc.

The receiver of the spam usually has to pay the Internet provider for the time used to receive the spam, in the same time for sender of the spam messages it costs almost nothing. Th load traffic is also messed up because of the mass spread of spam, it also complicates the operation of information systems and resources. Due to mass mailings the user has to spend unnecessary time filtering the messages. To avoid this, we use anti-spam filters to save our time. But spam filters can also accidentally erase an important message by recognizing it as spam.

The surest way to deal with spam is to prevent spammers from getting your email address.

Auto-Spam Detection Software is called Anti-Spam Filters. They can be applied by end-users or on servers. This software has two main approaches [4]:

1) the content of the message is analyzed and based on the algorithm decides whether it is spam or not. If a message is classified as spam, it can be marked, moved to another folder, or even deleted. Such software can run both on the server and on the client computer. With this approach you don't see the spam filtered, but you continue to pay the full cost for receiving it, because the anti-spam software receives each spam message anyway (wasting your money) and only then decides whether to show it or not;

2) it classifies the sender as a spammer without looking at the text of the message. This software can only work on the server which directly receives the messages. With this approach it's possible to reduce the cost - money is only spent on communicating with spam mailers (i.e. refusing to accept the messages) and on contacting other servers for verification. The gain, however, is not as great as you might expect. If the recipient refuses to accept the message, the spammer program tries to bypass the protection and send it another way. Every such attempt has to be handled separately, which adds to the overhead on the server.

This project discusses a statistical Bayesian spam filtering method using a support vector method and a multilayer perceptron neural network.

2.2. Analysis of spam detection algorithms. Naive Bayesian classifier

A naive Bayesian classifier is a probabilistic classifier that uses Bayes theorem to determine the probability of an observation (sample element) belonging to one of

the classes under the assumption of (naive) independence of the variables [5]. Here are the examples of the method usage: recognizing spam, analyzing emotional coloring of texts, detecting racism in text voters, any information processing systems and the like.

Classification on new examples is performed with Bayes' rule by selecting the class that is most likely to have generated the example [6].

The naive Bayes classifier is the simplest of these models, in that it assumes that all attributes of the examples are independent of each other given the context of the class. This is the so-called "naive Bayes assumption" [7].

While this assumption is clearly false in most real-world tasks, naive Bayes often performs classification very well.

Mathematically Bayes' theorem is [8]:

$$P(A \mid B) = \frac{P(B \mid A)\, P(A)}{P(B)} \tag{2.1}$$

where A and B are events:

– P (A) and P (B) are the probabilities of A and B without relation to each other;

– P (A | B) is the probability of observing event A if B is true;

– P (B | A) is the probability of observing event B if A is true.

2.3. Analysis of spam recognition algorithms. Support-vector machine

A support vector machine (SVM) is a supervised machine learning algorithm that can be used for both classification and regression tasks. In SVM, we plot data points as points in an n-dimensional space (n being the number of features you have) with the value of each feature being the value of a particular coordinate. The classification into respective categories is done by finding the optimal hyperplane that differentiates the two classes in the best possible manner [9, 10].

Hyperplanes can be considered decision boundaries that classify data points into their respective classes in a multi-dimensional space. Data points falling on either side of the hyperplane can be attributed to different classes.

For a given set of training samples, each marked as appropriate to one or the other of two categories, the SVM training algorithm builds a model that assigns new samples to one or the other category, making it a probabilistic binary linear classifier. (Fig. 2.1).

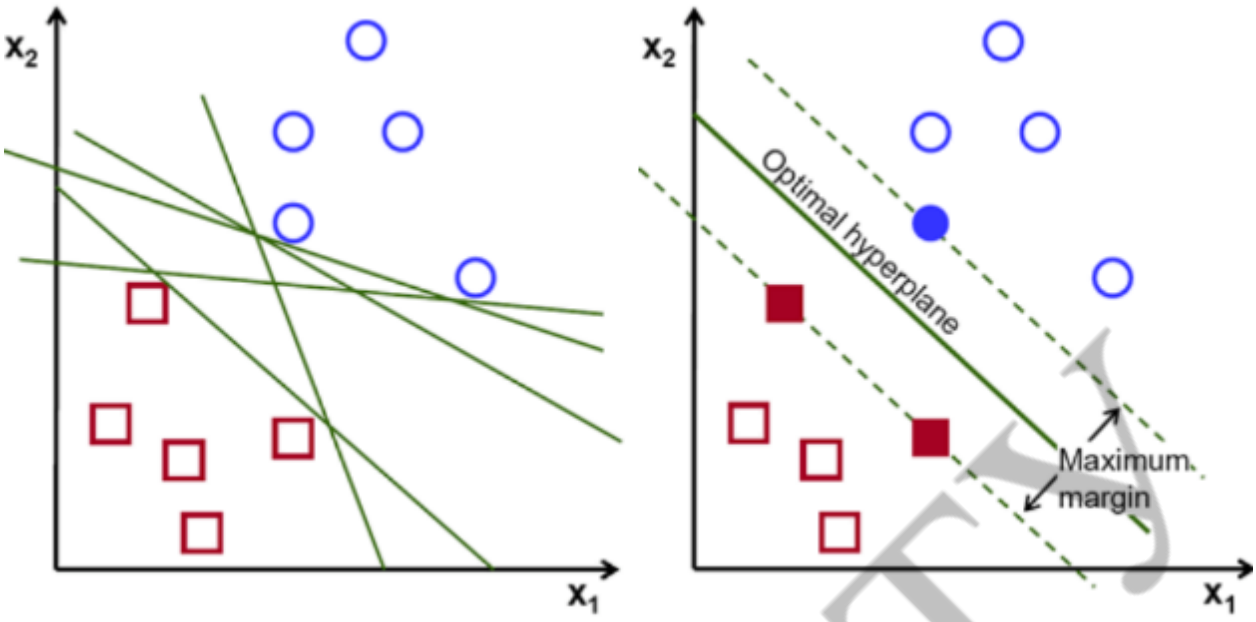

Fig. 2.1. SVM deals with linearly separate data

There are a bunch of cases when the data are not linearly separable. For this reason, it has been proposed to map the primary finite-dimensional space into a space with more dimensions, presumably making splitting easier in this space (Fig. 2.2).

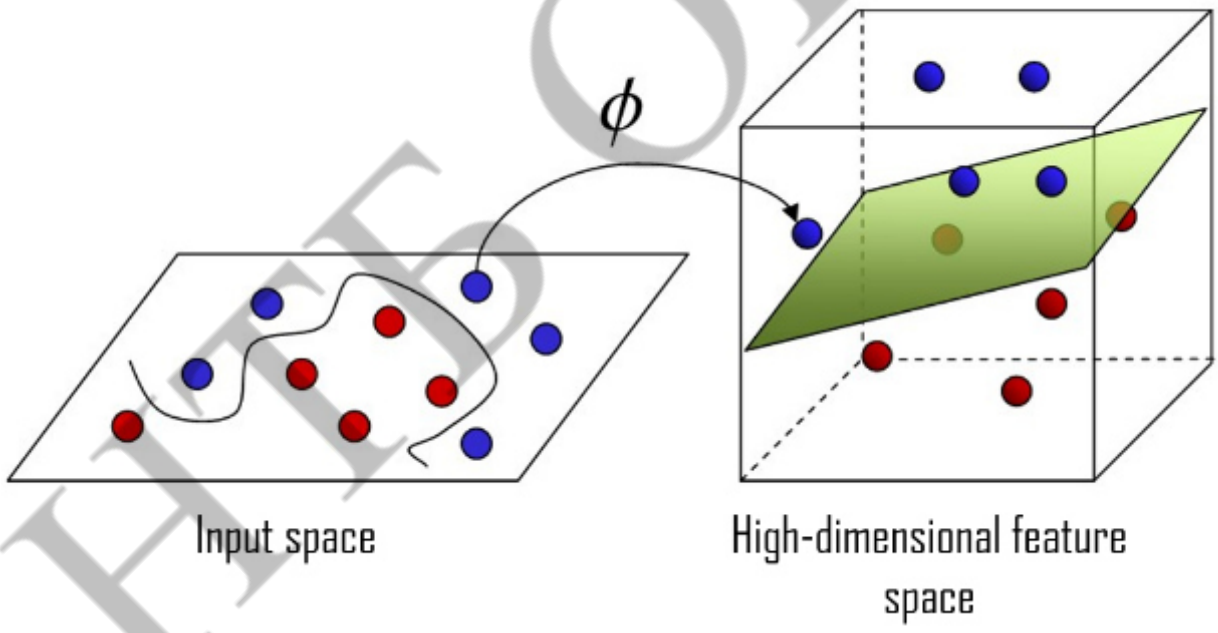

Fig. 2.2. Linearly inseparable data

2.4. Analysis of spam recognition algorithms. Perceptron

A Perceptron is an algorithm used for supervised learning of binary classifiers. Binary classifiers decide whether an input, usually represented by a series of vectors, belongs to a specific class. In short, a perceptron is a single-layer neural network. They consist of four main parts including input values, weights and bias, net sum, and an activation function [11, 12].

The process begins by taking all the input values and multiplying them by their weights. Then, all of these multiplied values are added together to create the weighted sum. The weighted sum is then applied to the activation function, producing the perceptron's output. The activation function plays the integral role of ensuring the output is mapped between required values such as (0,1) or (-1,1). It is important to note that the weight of an input is indicative of the strength of a node. Similarly, an input's bias value gives the ability to shift the activation function curve up or down [13].

Fig. 2.4 shows a model of the basic perceptron.

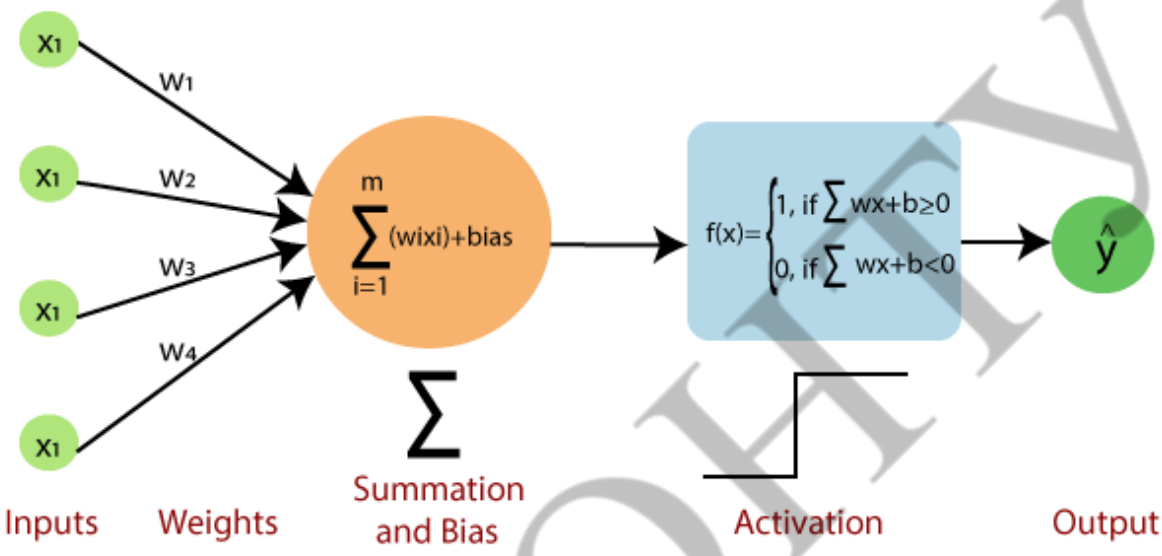

Fig. 2.4. Logic diagram of the basic perceptron

2.5. Analysis of spam recognition algorithms. CNN

Convolutional neural network, (CNN) – special architecture of artificial neural networks, proposed by Jan Lekun in 1988 [14] and aimed at effective pattern recognition, is part of Deep learning technologies. The structure of the network is unidirectional, without feedback, fundamentally multilayered.

CNN is designed to automatically and adaptively learn spatial hierarchies of features through backpropagation by using multiple building blocks, such as convolution layers, pooling layers, and fully connected layers [15].

The structure of the CNN we used is shown in Fig. 2.5.

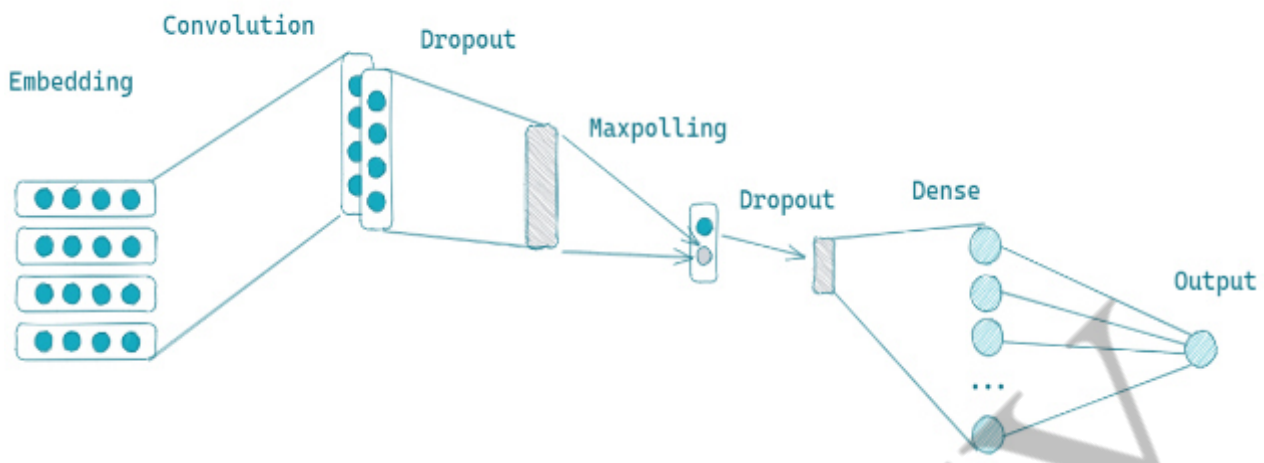

Fig. 2.5. The structure of the used CNN.

III. DETECTION AND BLOCKING OF SPAMMERS

3.1. Basic Spammer Detection Methods

Fake Content Based Spammer Detection [16]: “Gupta" performed an in-depth characterization of the components that are affected by the rapidly growing malicious content. It was observed that a large number of people with high social profiles were responsible for circulating fake news. To recognize the fake accounts, the authors selected the accounts that were built immediately after the Boston blast and were later banned by Twitter due to violation of terms and conditions. About 7.9 million distinctive tweets were collected by 3.7 million distinctive users. This dataset is known as the largest dataset of the Boston blast. The authors performed the fake content categorization through temporal analysis.

The aspects that were taken into account during spammer detection:

1) the average number of the verified accounts (spam / non-spam);

2) the number of followers of the account;

3) the fake content propagation metrics, such as: global engagement, topic engagement, likability and credibility.

Fake User Identification [16]: A categorization method is proposed by Erşahin to detect spam accounts on Twitter. The dataset used in the study was collected manually. The classification is performed by analyzing user-name, profile and background image, number of friends and followers, content of tweets, description of account, and number of tweets. The dataset comprised 501 fake and 499 real accounts, where 16 features from the information that were obtained from the Twitter APIs were identified. Two experiments were performed for classifying fake accounts. The first experiment uses the Naïve Bayes learning algorithm on the Twitter dataset including all aspects without discretization, whereas the second experiment uses the Naïve Bayes learning algorithm on the Twitter dataset after the discretization.

Detecting Spam In Trending Topic [16]. It is a method which is classified on the basis of two new aspects. The first one is the recognition of spam tweets without any

prior information about the users and the second one is the exploration of language for spam detection on Twitter trending topic at that time.

IV. OBJECT, SUBJECT AND METHODS OF RESEARCH

The aim of the work is to study the possibility of using different algorithms in the development of software for filtering spam in the textual content of social network messengers, quickly reacting to the spam message and identifying spammers.

The aim is to do the following tasks:

a) the analysis of the special possibilities of the recognition of spam messages;

b) the analysis of the existing methods of spam recognition;

c) the realization of the methods of combating spam based on the naive Bayesian Classifier, the method of reference vectors and multilayers perceptron neural network;

d) the analysis of the used algorithms;

e) the analysis of the basic existing spam detection algorithms;

f) the implementation of the spammer detection.

The object of the research is the process of identifying spam in the text context of SOCIAL networks messengers.

Subject of study – the process of filtering spam messengers in social networks using the base of methods for recognizing spam and spammer identifying and banning.

Research methods: classification theories, probabilistic classifiers, the theory of neural quantities, statistical methods of analysis of linguistic methods, spammer detection.

Scientific novelty – improved methods for the recognition of spam in the messenger using text messages of a particular text stream, identifying spammers and reacting to messages from spammers.

V. RESULTS

As a training dataset was chosen the dataset of spam messages from the kaggle SMS Spam Collection Dataset, but the dataset of messages from a particular company can also be used to train the algorithm [17]. To implement the spam filtering algorithms, we used the Python 3.6 programming language, the PyCharm. programming environment and the Keras, NumPy, Sklearn and Pandas libraries, MySQL DB for storing spammers and all users of the text stream [18, 19].

The simulation was performed on a LifeBook E744 notebook with 8Gb RAM, an Intel Core i7 CPU (up to 3.2 GHz) and an Intel HD Graphics 4600 video processor.

The spam message analyzing process is shown in Figure 5.1.

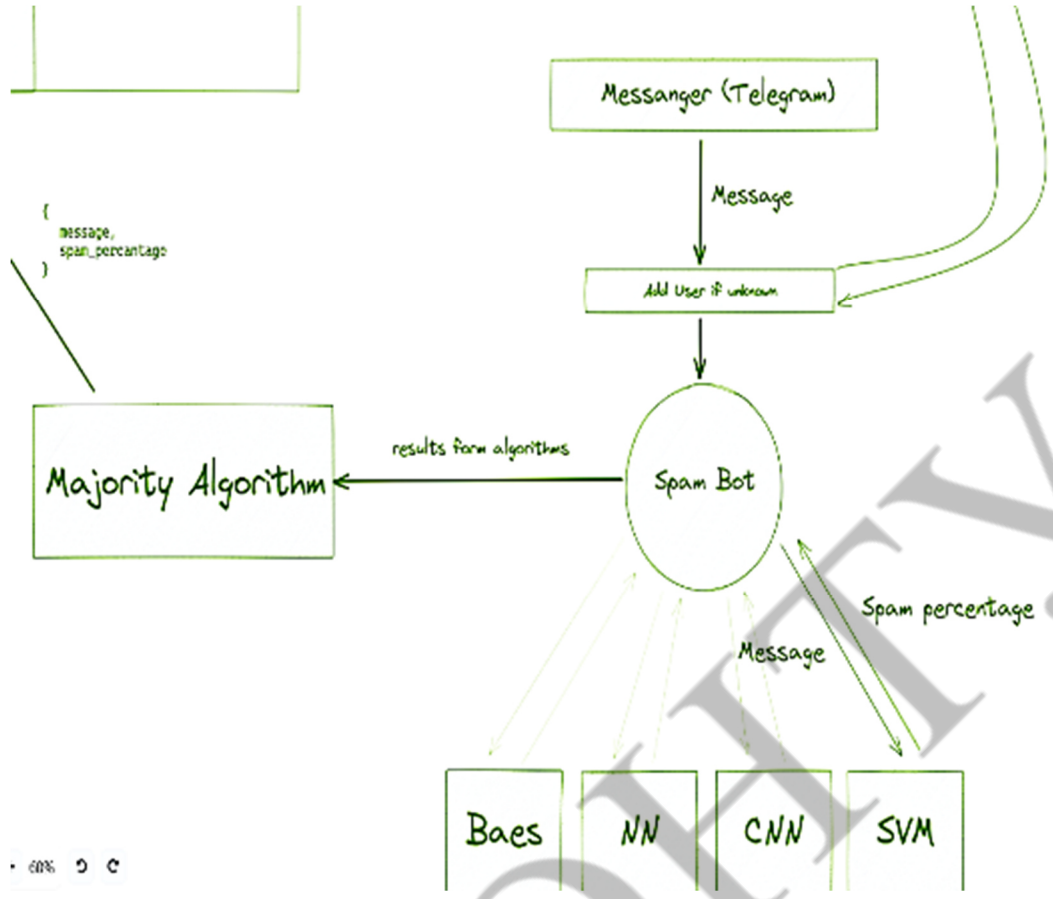

Fig. 5.1. The spam message analyzing process

We used 4 most popular spam recognition algorithms: Naïve Baes Classifier, Perceptron, Convolution Neural Network and Support Vector Machine.

We get the message from the user (in our case, form Telegram user) then if the user is unknown in our system, we add him to our database (DB) with all of the users of the application, after that we analyze the message using all of the existing algorithms, passing the results from all algorithms to the Majority algorithm we calculate the spam percentage of the message [20].

Then the result of the Majority Algorithm is passed to the Spam Analyzer, which decides if the user that sent the message is spammer or not based on the provided spam percentage of the message and two last predictions. So to identify the user as a spammer we analyze his 3 last messages and if the average spam percentage is bigger than specified edge, we recognize the user as a spammer and put his id to the DB with spammers.

The proposed complex majority algorithm shown in Figure 5.2 uses as inputs for the majority scheme the solutions of the Bayesian spam filtering method, Perceptron, Support vector method and Convolutional neural network algorithms. To match the outputs of the algorithmic blocks (0… 1) with the inputs of the majority scheme (0, 1), their binarization with a threshold of 0.95 is performed.

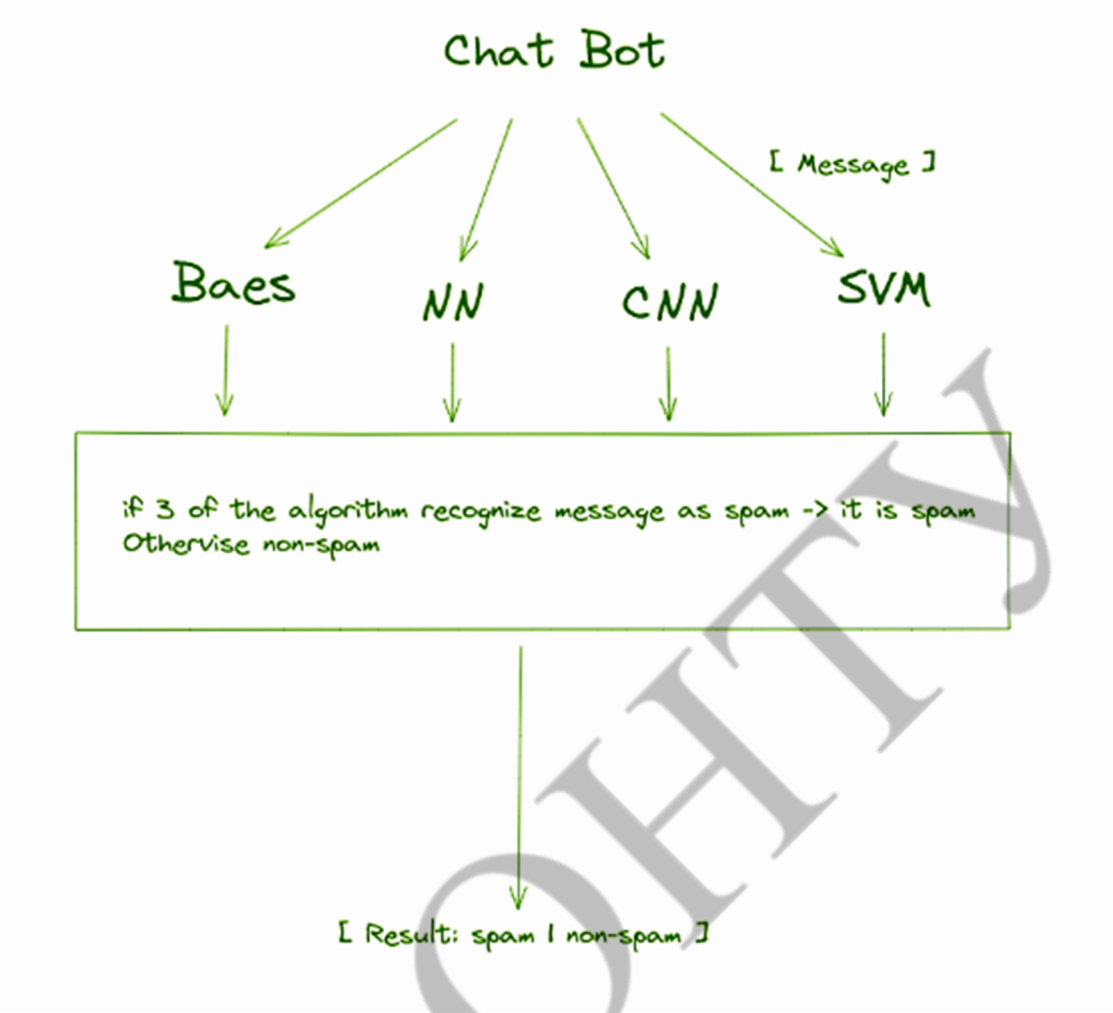

Fig. 5.2. The majority algorithm process

The results of the complex algorithm of antispam bot in the form of an estimate of the probabilistic of correct spam recognition for the test samples are shown in Figure 5.3.

```
mistake: 0.0317
acc: 99.9683
```

Fig. 5.3. The results of recognition of the complex algorithm of antispam bot

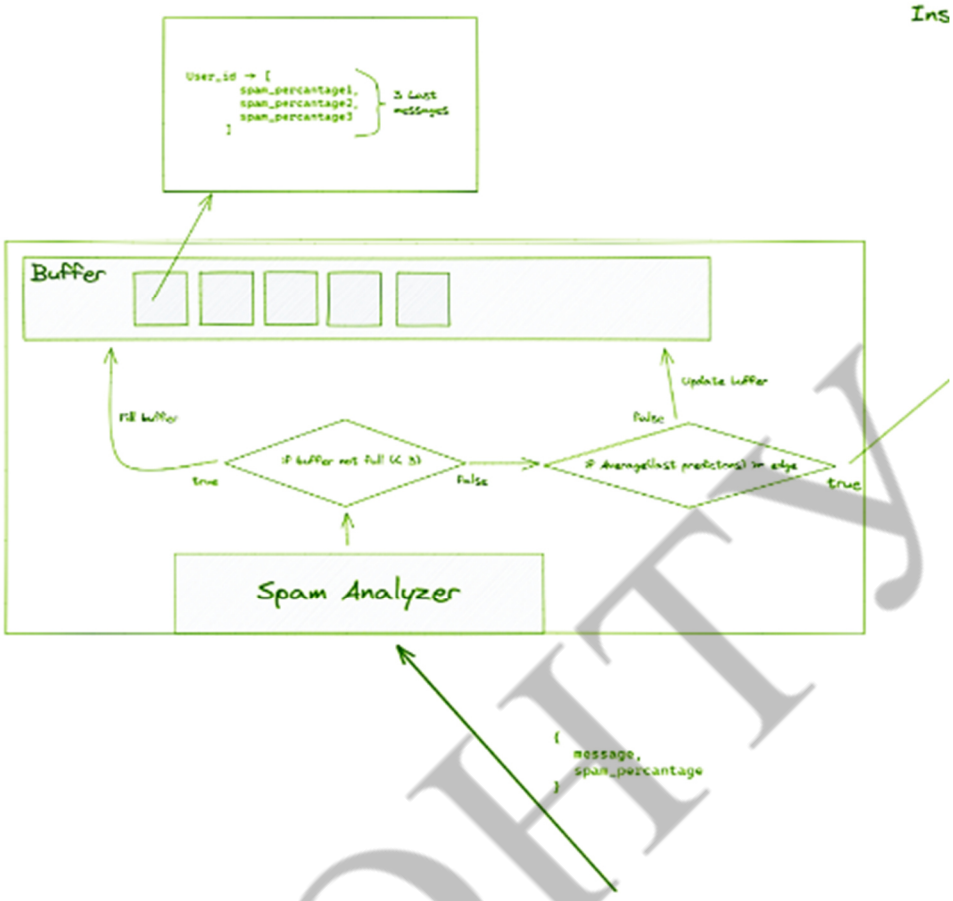

Fig. 5.4. The implementation of the spam analyzing, spammer analyzing.

If a user is in the spammers DB his messages are being deleted without even analyzing them. The user receives the message that he was blocked. Only the manager of the application is able to remove users from the spammers.

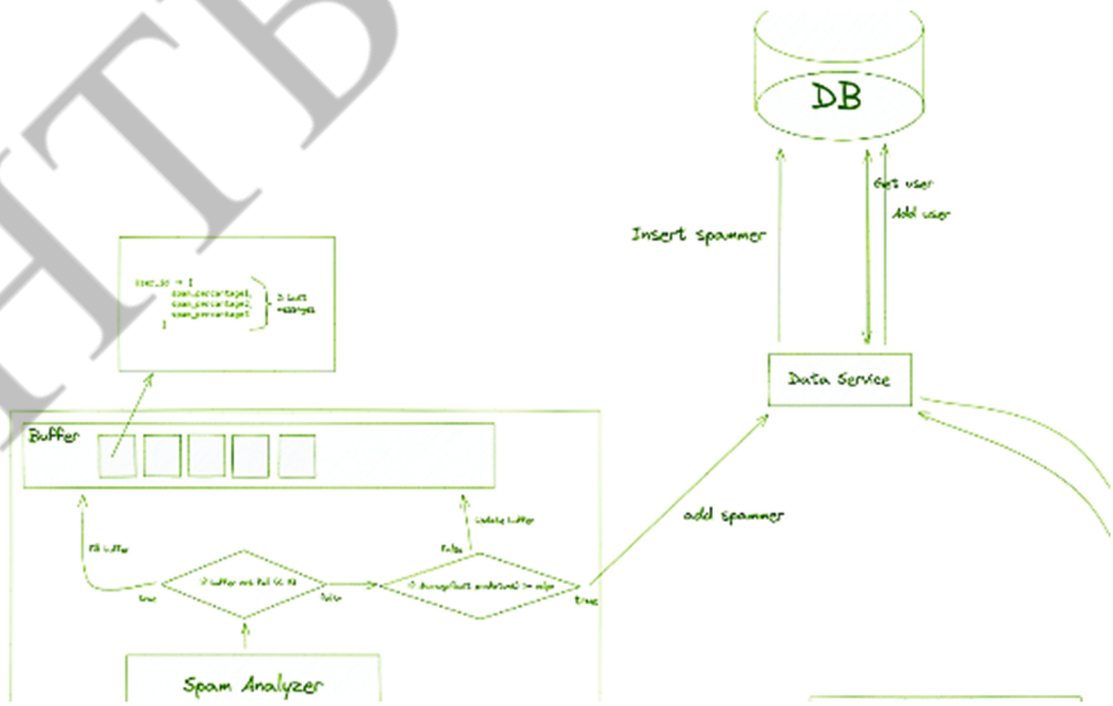

Fig. 5.5. The process of putting spammers to the DB. The communication of the spam analyzer and the DB.

The general scheme of execution of the developed software application is given in Fig 5.6 [21, 22].

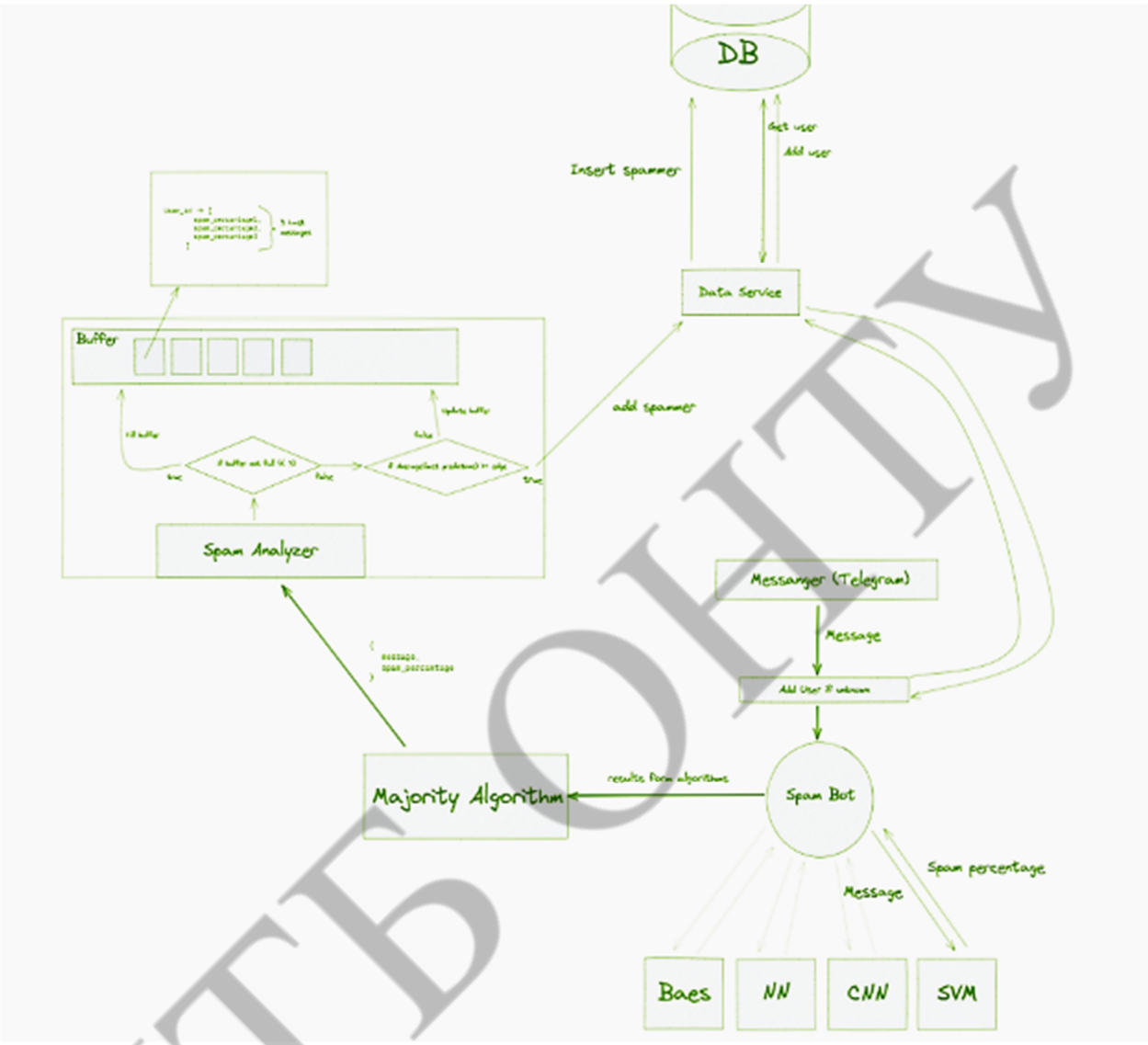

Fig. 5.6. The general scheme of execution of the developed software application

Algorithm of analyzing spam messages contains the following steps:

1) the user enters into the software application the initial text that should be analyzed;

2) software application parses the initial text into array of words, then each word is converted to the infinitive, then the resulting set of words is vectorized and transmitted to the input to the all of the used algorithms;

3) the algorithms analyze the received data and returns the result as the probability of belonging the received data to the class (each algorithm has two classes: spam and non-spam);

4) the received data passed through the Majority Algorithm to calculate the spam percentage;

5) the app decides if the user should be marked as spammer based on the last 3 spam prediction of his messages;

6) if the user was identified as a spammer he is blocked.

VI. TESTING AND COMPARISON

Also, in addition to the usual accuracy metric for evaluating selected algorithms, we used F1 score.

Accuracy is a ratio between the correctly classified samples to the total number of samples. Nowadays it is the most used metric of classification performance.

$$accuracy = \frac{TP + TN}{TP + FN + TN + FP} \quad (1)$$

where TP – (True Positive) correctly classified positive sample;

FN – (False Negative) the sample is positive but it is classified as negative;

TN – (True Negative) the sample is negative and it is classified as negative;

FP – (False Positive) the sample is negative but it is classified as positive.

	Predicted Positives	Predicted Negatives
Positives	True Positives	False Negatives
Negatives	False Positives	True Negatives

Fig. 6.1. The explanation of accuracy evaluation

The results of the tests using accuracy metric are shown at Table 6.1.

Table 6.1. The results of the testing algorithms on training and test samples

Algorithm	Training sample	Test sample
Bayes	0.988	0.982
SVM	0.998	0.989
NN	0.997	0.979
CNN	0.990	0.985
Majority	1.000	0.999

VII. CONCLUSIONS

As part of this research, the scientific and applied problem of determining spam in the textual context of social networking messengers was solved by the example of Kaggle SMS Spam Collection Dataset using chatbots in the popular messenger Telegram. Besides that, the basic spam detection algorithms were analyzed and the one was implemented in the application.

1. Considered the relevance of spam detection and possible problems due to spam intervention.

2. Consider the basic methods of spam recognition, namely naive Bayesian classifier, the method of support vectors, multilayer perceptron neural network and convolution neural network.

3. Consider the basic methods of spammer detection.

4. It was developed a program to filter spam and spammers detection in the messenger Telegram, that uses 4 implemented algorithms for spam recognition and proposed complex majority algorithm. All of the text traffic is also checked for the spammers.

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SYNTHESIS OF THE CONTROL SYSTEM WITH NEUROCONTROLLER

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Abstract. *The synthesis of the control system with a neurocontroller is considered in this article. The neurocontroller was developed based on the characteristics of a typical regulator using the MATLAB/Simulink software environment. A comparative analysis of the quality of regulation of various control systems, such as a control system with a typical PID controller, a control system with a fuzzy controller and a neurocontroller, is presented. The results of modeling various control systems under conditions of deterministic and random disturbances are considered.*

Keywords: *Neuroregulator, Fuzzy controller, Control system, Neural network, Neurocontrol, PID controller.*

I. INTRODUCTION

Potential applications of artificial neural networks are those where human intelligence is inefficient and traditional calculations are time consuming or physically inadequate. The relevance of the use of neural networks increases many times when there is a need to solve poorly formalized problems. The main areas of application of neural networks: automation of the classification process, automation of forecasting, automation of the recognition process, automation of the decision-making process; management, encoding and decoding of information; approximation of dependencies, etc.

Pieces of neural networks at the same time are widely known in the various subject areas themselves. One of the most important directions in the selection of piecewise neural networks is neurocontrol in systems of automatic circulation of different types. Neurofeedback is the first step in intellectual healing, when the quality of the instrument for unraveling the task of healing is blocked by piecewise neural networks.

The artificial neural network as a neuroregulator performs nonlinear conversion of the input signal and the formation of the control effect. The controller can have a large number of optimized parameters (coefficients of interneuronal connections), which makes it possible to optimize it for almost any object with a nonlinear static characteristic. In this paper, a neural network is a mathematical model with optimized parameters that will perform the functions of a previously developed fuzzy logic controller.

II. LITERATURE ANALYSIS

The development of neural network of control algorithms is due to modern progress in information technology. Neurocontrol is a special case of intelligent control that uses artificial neural networks to solve problems of controlling dynamic objects [1–3]. Neural networks have a number of unique properties that make them a powerful

tool for creating control systems: the ability to learn from examples and generalize data, the ability to adapt to changes in the properties of the control object and the environment, suitability for the synthesis of linear controllers.

Known examples of practical applications of neural networks for solving problems of controlling the initial[4, 5], robot body, engine speed [6], hybrid car engine], electric furnace, turbogenerator [7], welding, pneumatic cylinder.

To implement control system, based on ANN, the production of neurochips and neurocontrollers (NC) is currently growing.

The noted positive features of neurocontrollers make it possible to take into account a significant factor in increasing fuzzy control in neurocontrol.

This approach is quite effective for controlling non-linear objects.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The neurocontroller in our case is an artificial neural network characterized by nonlinear characteristics. Due to this, the use of a neurocontroller based on the neural network will achieve higher results in management. A neural network is a sequence of neurons (neuroelements) connected by synapses. The structure of the neural network came into the world of programming directly from biology. The most common structure - multilayer, used as controllers of neural network control algorithms

The mathematical model used as a neuroelement in the neural network control algorithm is similar to the known most common models, which are similar to the formal McCulloch-Pitts neuron model. In this model (Figure 1), the signals received at the inputs of the neuroelement are multiplied by their weight. The signal of the first input x_1 is multiplied by the corresponding weight w_1. As a result, we obtain x_1w_1. And so to the nth entrance. As a result on the last input we receive x_nw_n. Then all multiplications are transferred to the adder. Based on his name, you can understand what he is doing. It simply summarizes all the input signals multiplied by the corresponding weights:

$$x_1w_1 + x_2w_2 + \cdots + x_nw_n = \sum_{i=1}^{n} x_iw_i$$

Just to give a balanced amount to the exit is quite meaningless. The neuroelement must somehow process it and generate an adequate output signal. It is for these purposes and use the activation function. It converts the weighted sum into a number, which is the output of the neuron.

Due to the fact that the fuzzy regulator determines the increase in control action, both positive and negative values, the synthesis of neurocontrollers must choose the activation functions of neurons that take values from -1 to 1. In our case, we will use the hyperbolic tangential function (tansig). This function allows you to get the output values of various characters (for example, from -1 to 1), which may be necessary in the control system. Graphical representation of the function is shown in Figure 2.

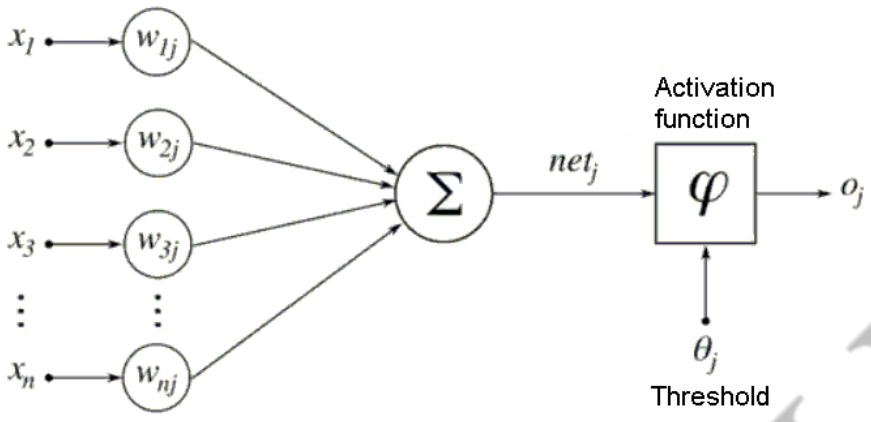


Fig. 1. Block diagram of the model of the neuroelement of the neural regulator

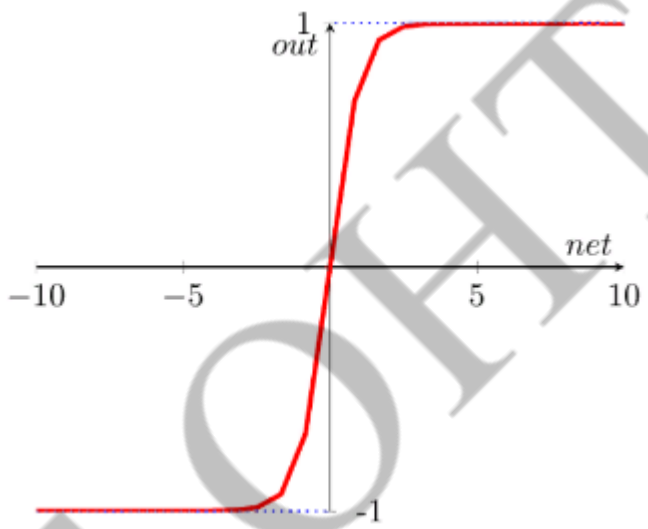


Fig. 2. Graphical representation of the activation functions of an artificial neuron, which is detected in the neuroregulator

Analytically, the function is written as follows:

$f(net)=\frac{2}{1+\exp(-\alpha \cdot net)}-1$, where net is the input argument.

It is known that a single-layer neural network has limited capabilities. Multilayer four-layer is already redundant to solve various problems. In this case, the neurocontroller will be represented by a neural network with two layers, as shown in Figure 3. Figure 3 also shows the errors of each neuron for backpropagation correction. If such a structure is insufficient, it is necessary to increase the number of neurons in the input layer of the network and increase the number of layers to three.

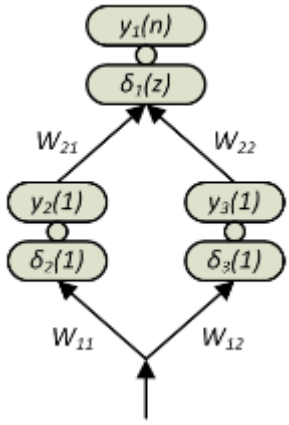


Fig. 3. Block diagram of the neuroregulator of the integral or proportional component

The MATLAB software environment was used to determine the weights between neural connections by the inverse propagation method, which allows to create a given neural network based on input and output signal values. Thus, to train the neural network, it is necessary to specify the input and output values of the signals of the neurocontroller, and more precisely, the values of control errors and the increase in control influence.

The artificial neural network, which acts as a regulator, is synthesized on the basis of the characteristics of a fuzzy logic controller. These characteristics are presented in tabular form in the form of input and output values of the fuzzy controller (table 1). The data presented in Table 1 are based on a fuzzy controller model.

Table 1. Input and output values of the controller signals

№	ΔT	u	Δu
1	1,5	13,48	0,05056
2	1,2	10,79	0,04045
3	0,9	8,09	0,03034
4	0,6	5,393	0,02022
5	0,3	2,697	0,01011
6	0	0	0
7	-0,3	-2,697	-0,01011
8	-0,6	-5,393	-0,02022
9	-0,9	-8,09	-0,03034
10	-1,2	-10,79	-0,04045
11	-1,5	-13,48	-0,05056

Next, create an M-file in the Mathlab environment and in this file prescribe commands to create and train our neurocontroller. Input and output values of neurocontrollers were obtained on the basis of the characteristics of the fuzzy logic controller, obtained on the basis of simulation schemes presented in Figure 4.

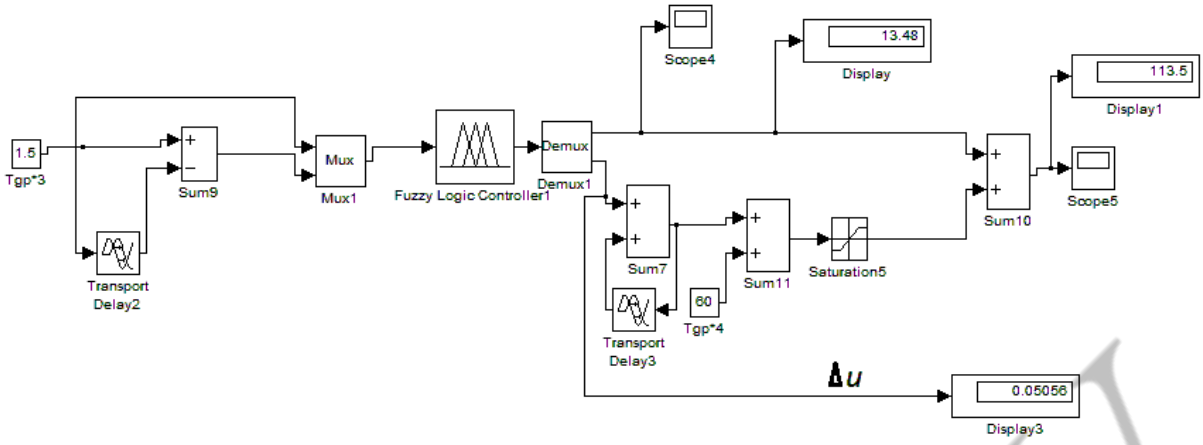


Fig. 4. Scheme of data acquisition for neural network training

The executable code was written in the M-file, which is presented in Figures 5 and 6 according to the proportional and integral component of the controller. The presented executable code can also be written in the command line Mathlab - command window, resulting in the generation of the corresponding neural network.

```
» p=[-1.5 -1.2 -0.9 -0.6 -0.3 0 0.3 0.6 0.9 1.2 1.5];
» t=[-0.1348 -0.1079 -0.0809 -0.05393 -0.02697 0 0.02697 0.05393 0.0809 0.1079 0.1348];
» net=newff([-1.5 1.5], [2 1], {'tansig' 'tansig'});
» net.trainParam.epochs=100;
» net=train(net, p, t);
TRAINLM, Epoch 0/100, MSE 0.826665/0, Gradient 2.59336/1e-010
TRAINLM, Epoch 25/100, MSE 1.04072e-008/0, Gradient 3.72063e-005/1e-010
TRAINLM, Epoch 50/100, MSE 4.87942e-009/0, Gradient 7.66684e-006/1e-010
TRAINLM, Epoch 75/100, MSE 3.47343e-009/0, Gradient 3.73493e-006/1e-010
TRAINLM, Epoch 100/100, MSE 2.79983e-009/0, Gradient 2.30556e-006/1e-010
TRAINLM, Maximum epoch reached, performance goal was not met.

» a=sim(net,p)

a =

  Columns 1 through 7

   -0.1347   -0.1079   -0.0810   -0.0540   -0.0269    0.0001    0.0270

  Columns 8 through 11

    0.0539    0.0809    0.1078    0.1349

» gensim(net)
```

Fig. 5. Executive code for generating a neural network that reproduces the proportional component of the neurocontroller

In this executable code, p is the input value of the neural network (control error), t is the corresponding value of the output of the neural network. On the third bar we set the range, the number of layers of the neural network and the activation function. We also set the number of training steps, neural network training and generation command.

```
» p=[-1.5 -1.2 -0.9 -0.6 -0.3 0 0.3 0.6 0.9 1.2 1.5];
» t=[-0.05056 -0.04045 -0.03034 -0.02022 -0.01011 0 0.01011 0.02022 0.03034 0.04045 0.05056];
» net=newff([-1.5 1.5], [2 1], {'tansig' 'tansig'});
» net.trainParam.epochs=100;
» net=train(net, p, t);
TRAINLM, Epoch 0/100, MSE 0.179928/0, Gradient 2.20533/1e-010
TRAINLM, Epoch 25/100, MSE 1.38645e-008/0, Gradient 3.01186e-005/1e-010
TRAINLM, Epoch 50/100, MSE 5.85436e-009/0, Gradient 6.30847e-006/1e-010
TRAINLM, Epoch 75/100, MSE 1.35436e-009/0, Gradient 5.01382e-005/1e-010
TRAINLM, Epoch 100/100, MSE 4.43248e-010/0, Gradient 7.63926e-006/1e-010
TRAINLM, Maximum epoch reached, performance goal was not met.

» a=sim(net,p)

a =

  Columns 1 through 7

   -0.0506   -0.0404   -0.0303   -0.0202   -0.0101    0.0000    0.0101

  Columns 8 through 11

    0.0202    0.0303    0.0404    0.0506

» gensim(net)
```

Fig. 6. Execution code for generating a neural network that reproduces the integral component of the neurocontroller

The accuracy characteristics of the training are shown in Figure 7, from which it can be seen that somewhere in step 70 of the training, the weight adjustment between neural connections was completed.

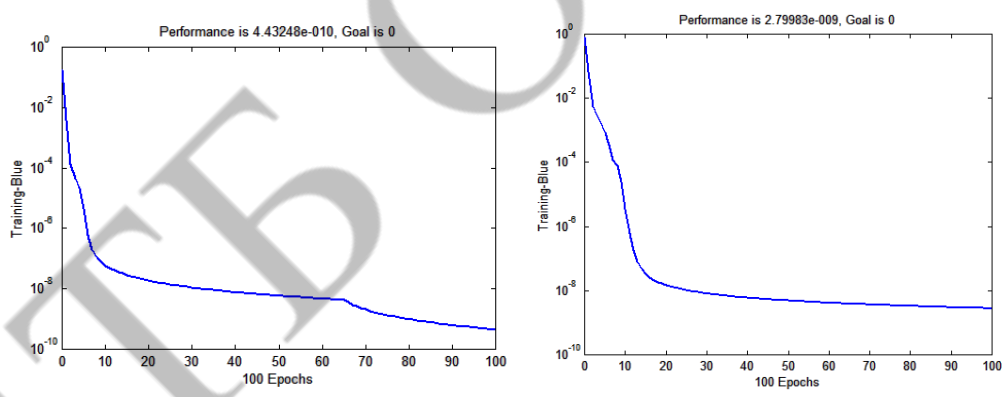


Fig. 7. Characteristics of the accuracy of learning the proportional (right) and integral (left) component of the neurocontroller

The generated neural networks were defined in the simulation scheme instead of a fuzzy controller, as shown in Figure 8. In this method with a neuro-synthesized model of the SAR-regulator environment MATLAB \ Simulink, the block diagram is shown in Figure 8.

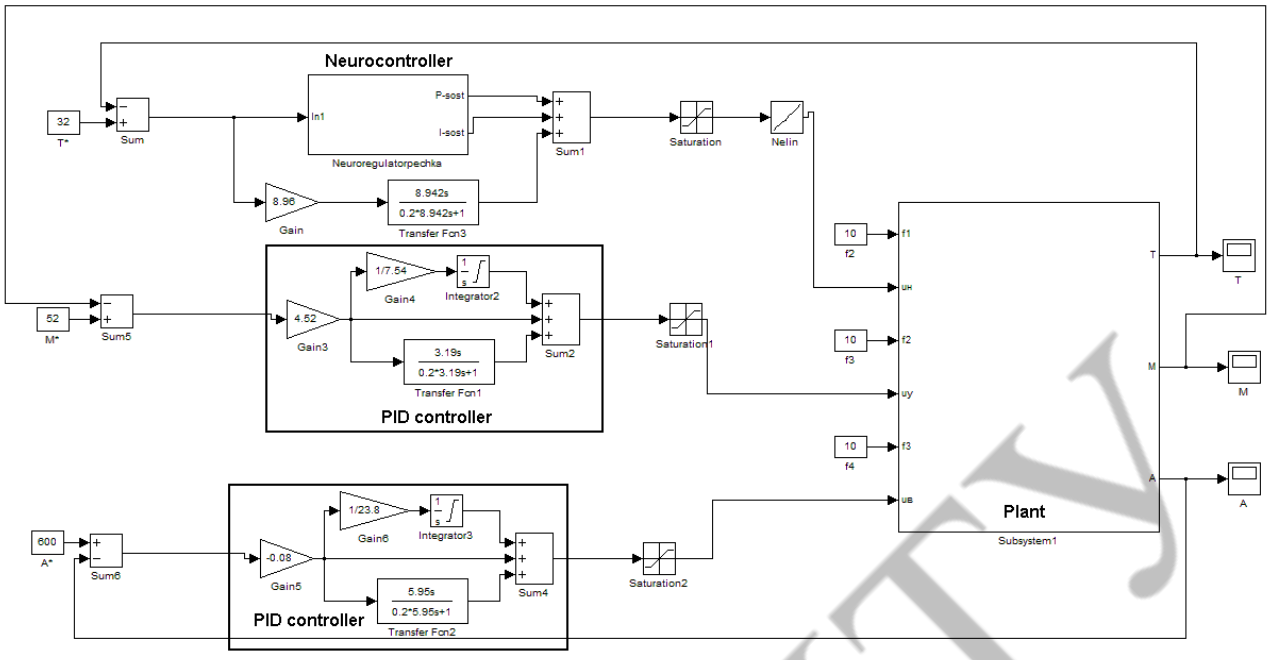


Fig. 8. Block diagram of the ACS model with neurocontroller, which is represented by MATLAB \ Simulink.

Based on these parameters of the formed neural network, the scheme of the neurocontroller in the environment MATLAB \ Simulink was determined. The scheme of the neurocontroller, which is presented in Figure 9, is an expanded scheme, which is presented in the previous figure 8.

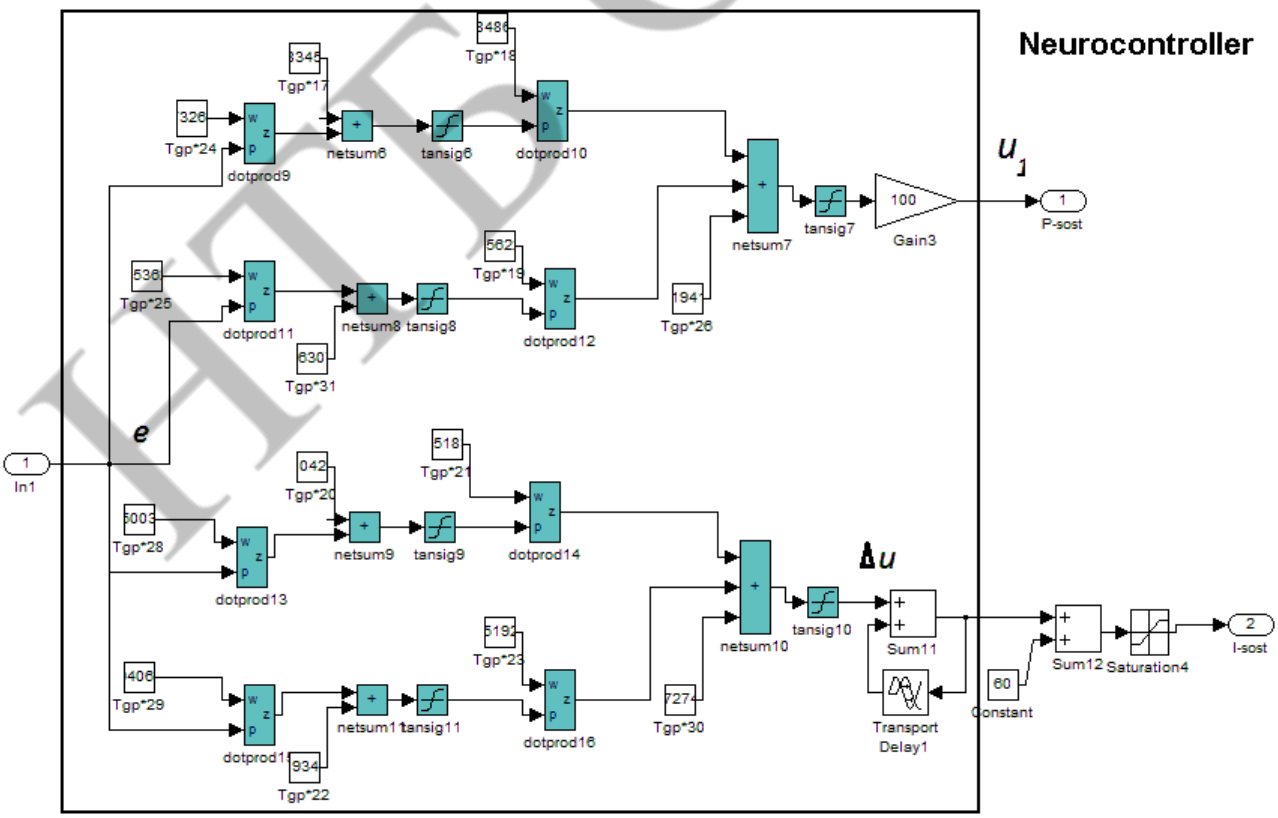


Fig. 9. Scheme of neuralcontroller modeling

IV. RESULTS

. As a result of modeling SAR with a neurocontroller, graphs of transients were obtained in the same conditions as in the modeling of SAR with a fuzzy regulator and a traditional PID regulator. These graphs are presented in Figures 10. From the graphs of transients, it is possible to see that the quality of regulation of SAR with a neurocontroller works at night no worse than automatic control system with a fuzzy regulator and PID-regulator. But with the help of optimization it was possible to achieve the best possible figure.

As can be seen from Fig. 9. A regulator synthesized on the basis of artificial neural networks has 8 interneuron connections, as well as 6 offsets. It was found by trial and error that it is optimal to optimize only 4 weights in the input layer, as changing the values of other coefficients causes errors in statistics in the system.

It can be concluded that based on the quality of regulation of different automatic control system, you need a neurocontroller of optimization in the same conditions as the previous traditional PID-controller to determine the final conclusion on the feasibility of using different automatic control system.

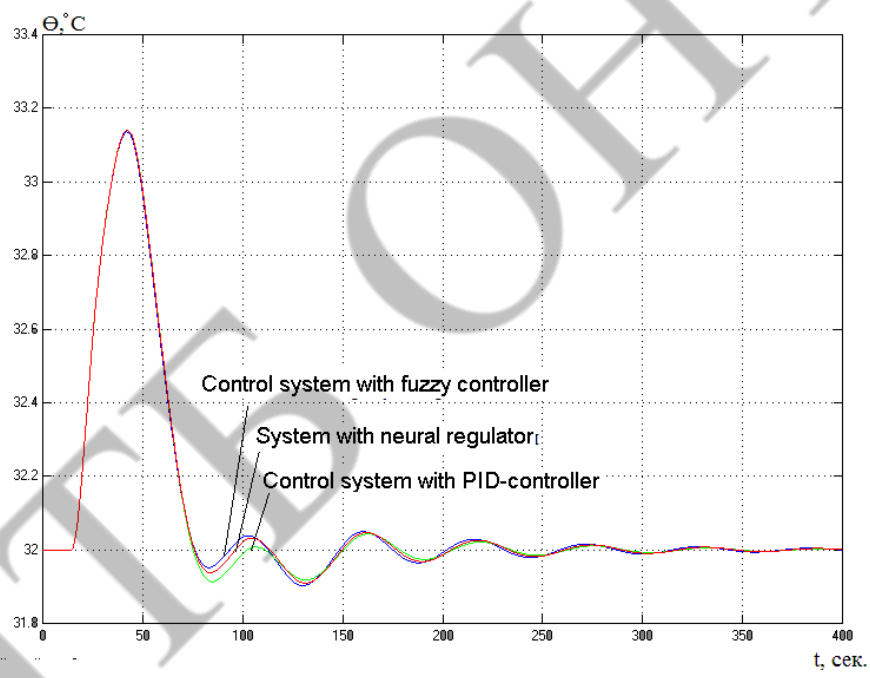


Fig. 10. Graphs of transients on the control channel «Uн – θ», obtained in the simulation of different automatic control system

To improve the quality control, parametric optimization of automatic control system with a neural controller was performed. Four tuning parameters of neurocontrollers were optimized - the weights of the neural combined first-input layer of the artificial neural network. Optimization of the neural regulator was performed under the same conditions as when optimizing the automatic control system with a traditional PID-controller. Thus, the integrated indicator of the quality of functioning in the optimization was chosen in the same way as in the optimization of SAR with a traditional PID controller. In the MATLAB \ Simulink 5.2 software environment, a

automatic control system model with a neurocontroller and a parametric optimizer was identified, the block diagram of which is shown in Figure 11.

As a result of parametric optimization, graphs of transients before and after optimization were obtained, as well as optimal determined weights of interneuron connections of the first layer of the neural network. The graphs of the corresponding transients and the values of the weights are presented in accordance with the results optimization window presented in Figure 12. Figure 12 shows the optimal result obtained in 8 previous processes, optimized by a certain integrated criterion of the quality of the system.

After optimization it is possible to check up system on roughness From results of the analysis of system of check of system on quality (fig. 13) it is possible to see that the system is rough, and means, working.

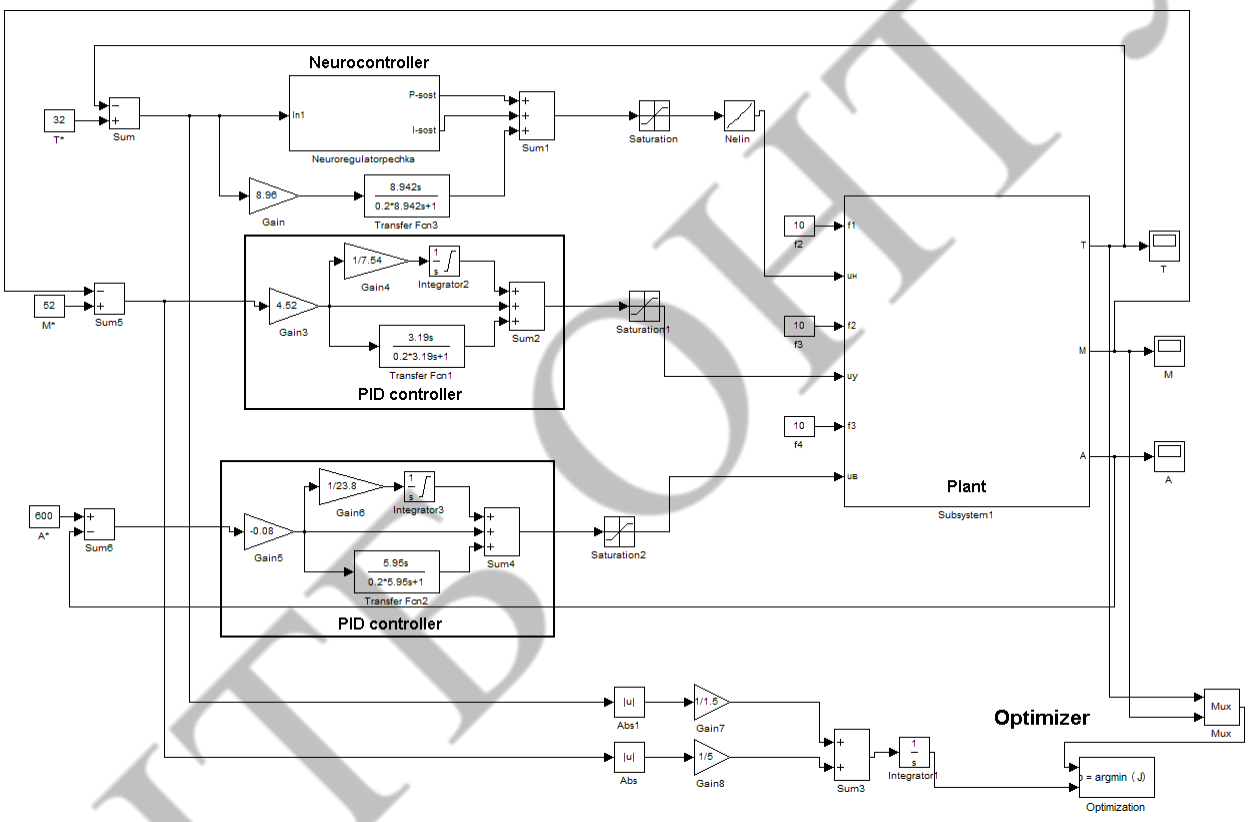
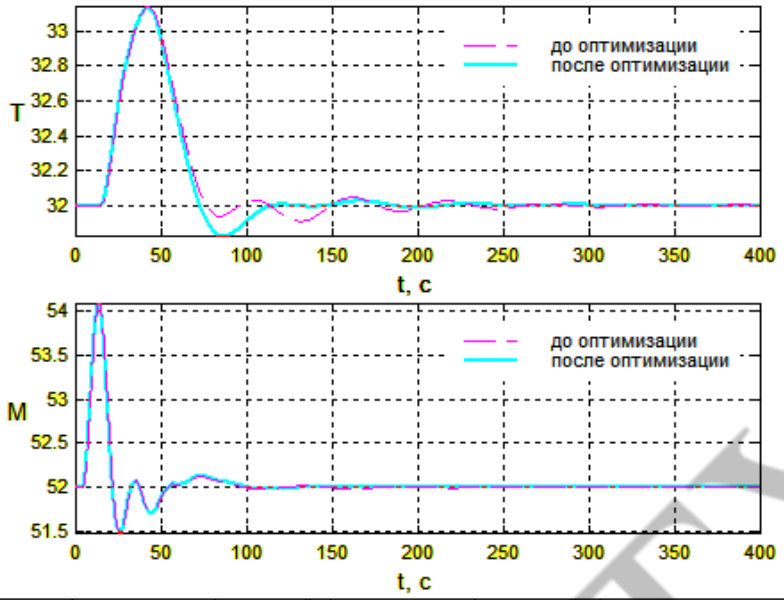
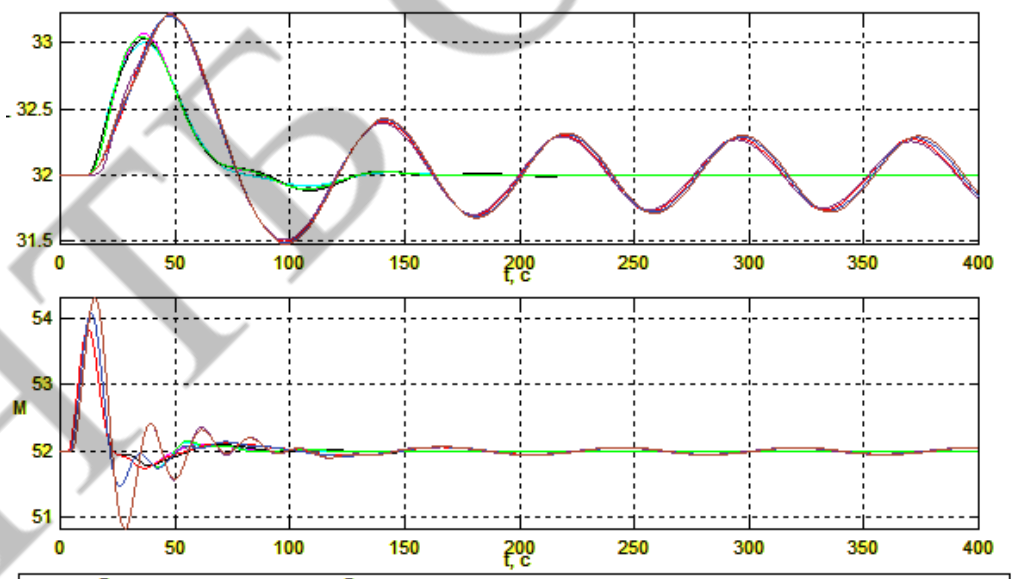


Fig. 11. Block diagram of the automatic control system model with neural controller and parametric optimizer, implemented using MATLAB \ Simulink to determine the optimal parameters of the control system for nonlinear conditions of static characteristics of the control channel «Uн – θ»



Имя переменной	Оптимальное значение	Нижний предел	Начальное приближение	Верхний предел	Значение критерия оптимальности:
k1	0.17251	-10	0.2106	10	до - 35.6433
k2	-0.17272	-10	-0.1629	10	после - 34.4203
k3	-0.28291	-10	-0.0576	10	оптимизации.
k4	-0.27016	-10	0.0776	10	Количество шагов процедуры оптимизации:
					максимальное - 1000
					фактическое - 156

Fig. 12. Window of results of optimization of parameters of the controller represented by an artificial neural network



Значения параметров объекта управления и значения критерия оптимальности.

1. k5=0.8 k6=0.8 J=29.2372 k7=0.8 k8=0.8
2. k5=0.8 k6=0.8 J=29.8928 k7=1 k8=0.8
3. k5=0.8 k6=0.8 J=29.9162 k7=0.8 k8=1
4. k5=0.8 k6=1 J=29.9288 k7=0.8 k8=0.8
5. k5=0.8 k6=0.8 J=30.5654 k7=1 k8=1
6. k5=1.2 k6=0.8 J=80.3907 k7=0.8 k8=0.8
7. k5=1.2 k6=0.8 J=82.0699 k7=1 k8=1.2
8. k5=1.2 k6=0.8 J=82.7932 k7=0.8 k8=1
9. k5=1.2 k6=0.8 J=86.7004 k7=0.8 k8=1.2

Fig. 13. Window of results of check of automatic control system with a neurocontroller on roughness

At the final stage of automatic control system development, a comparative analysis of the functioning of different automatic control system on the quality of regulation was performed. As a result of modeling different automatic control system, graphs of transients under deterministic and random perturbing effects were obtained.

Thus, Figure 14 presents graphs of transients under deterministic perturbation.

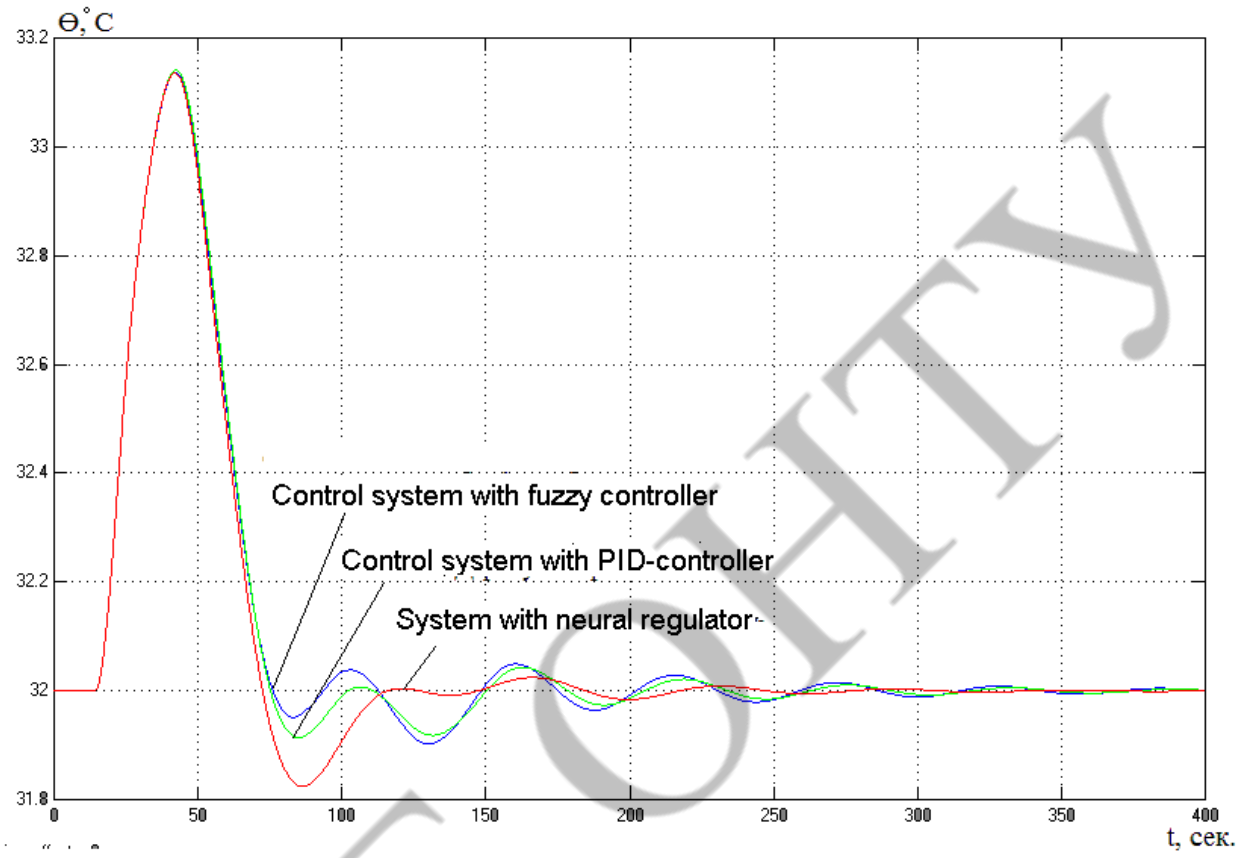
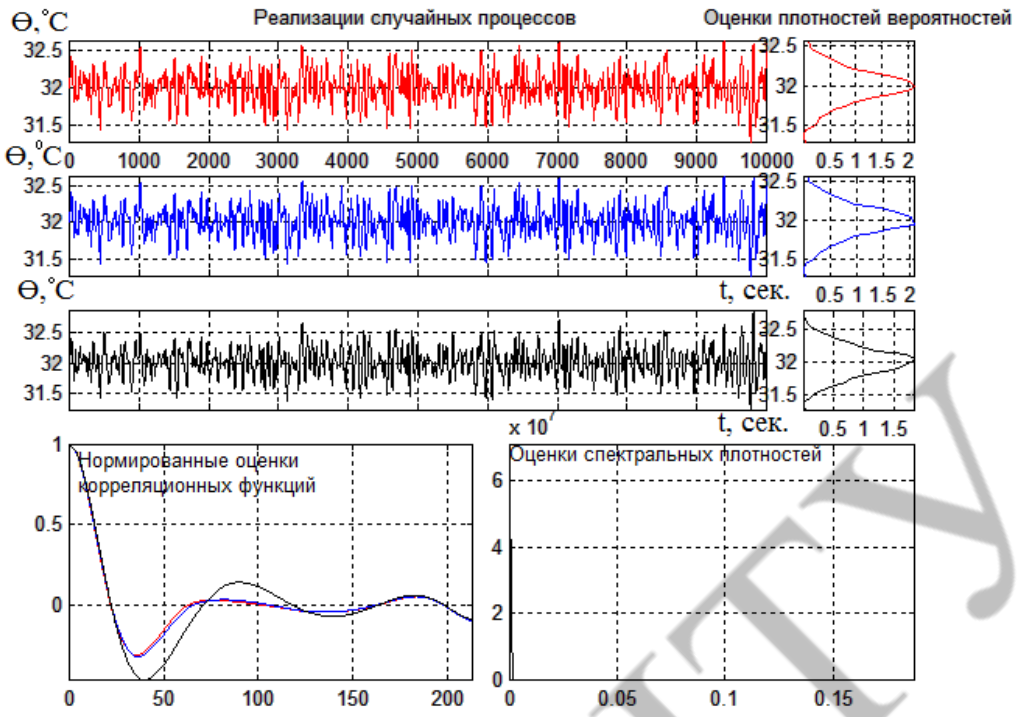


Fig. 14. Graphs of transients under deterministic deterministic influence, according to the control channel «Uн – θ», obtained in the simulation of different automatic control system

Also on the basis of the analyzer of probabilistic characteristics which was built in the MATLAB \ Simulink environment, quality of regulation of various automatic control system at casual disturbing influences was defined. This level compares the standard squares of the deviations of the values of the error of regulation of different automatic control systems under random influences. The results presented in Figure 15, in the image of the analysis of the results window, which shows the standard deviations and mathematical expectations of the value of the control error in different automatic control system.



Числовые оценки по всему интервалу моделирования:	Номер процесса		
	1	2	3
Оценка среднего значения (математического ожидания)	32.0	32.0	32.0
Оценка среднеквадратического отклонения	0.21	0.21	0.23
Оценка среднеквадратического периода / частоты	66.9 / 0.094	69.2 / 0.091	71.2 / 0.088

Fig. 15. Window of the results of the analysis of the analyzer of probabilistic characteristics

From the figures above it can be seen that the automatic control system with a neural controller works almost equally with the automatic control system with a PID controller and with a fuzzy controller.

V. CONCLUSIONS

In the process of work, a model of automatic control system with a fuzzy regulator was developed. The fuzzy controller is developed in the corresponding MATLAB \ Simulink environment editor. The functions of belonging to fuzzy sets were determined, the base of rules of functioning of the regulator in tabular form and in the window of the corresponding editor was formed, the algorithm of fuzzy output - Sugeno 0-order was defined. Mamdani's algorithm was also considered.

It was found that the quality of regulation of such automatic control system operates almost identically to the automatic control system with a traditional PID controller for a control object with a nonlinear static characteristic on the control channel «Uн – θ».

For further implementation of parametric optimization of automatic control system, according to the characteristics of the fuzzy regulator, a certain artificial neural network was trained, which can act as a neurocontroller. The training of the artificial network was also performed using the MATLAB \ Simulink environment. An automatic control system model with a regulator representing an artificial neural network was developed. Parametric optimization of automatic control system with

neurocontroller was performed under the same conditions as automatic control system with traditional PID-controller.

As a result of modeling different automatic control systems, it was found that the quality of regulation of automatic control system with neurocontroller works worse than automatic control system, for integrated quality indicators according to other 1212, automatic control system with fuzzy regulator - 1080, and 1087 for automatic control system with traditional PID-controller. The standard deviation of the regulated changes from the set value, random perturbations, is almost the same for different automatic control system: with traditional PID-controller - 0.21, with fuzzy controller - 0.21, with neurocontroller - 0.23.

Thus, based on the synthesis and analysis of different automatic control system, it can be concluded that the neurocontroller is of fundamental suitability for practical use on the basis of an industrial controller for control objects with nonlinear characteristics for control channels.

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4. POWER ENGINEERING AND ENERGY EFFICIENCY

INFLUENCE OF HEATING AND VENTILATION MODES ON THE ENERGY CONSUMPTION OF UNIVERSITY EDUCATIONAL BUILDINGS UNDER QUARANTINE CONDITIONS IN UKRAINE

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Abstract. *In the work, a dynamic energy model of the building was created on the example of the educational building № 17 Igor Sikorsky Kyiv Polytechnic Institute. Simulation dynamic modeling of the energy consumption of the educational building for heating needs was carried out for normal operating conditions and quarantine conditions (only a certain part of the premises is operated where the standard temperature value is maintained during the stay of people) when implementing the three proposed modes of operation of the heating and ventilation system. Based on the results of the study, recommendations were formulated for the introduction of energy-saving heating modes in the normal and quarantine regimes. The features of the energy consumption of the building during quarantine restrictions, subject to the partial use of the building, are analyzed, the main disadvantages of such a regime are identified.*

Keywords: *quarantine, educational institutions, average radiation temperature, energy consumption, energy saving, air exchange*

I. INTRODUCTION

Since the end of 2019, humanity has faced an unprecedented phenomenon for the modern world - the global pandemic COVID-19, which has dramatically changed the lives of each of us. First of all, the changes for people concerned the usual modes of work for them - most organizations introduced remote modes of work for their employees, or - semi-remote, when employees partially visited their jobs. The same changes have taken place in the field of education. Educational institutions, particularly in Ukraine, have switched to remote or mixed mode. At the same time, the issue of expediency in maintaining the normative operational characteristics of educational buildings for their entire heating volume with partial use has become especially relevant. Therefore, simulation dynamic modeling of the consumption of heat energy by the building of the educational building for the heating season for various modes of operation of the heating and ventilation system during the quarantine period with partial use of the building is the most convenient tool in order to obtain a set of energy characteristics that will help draw conclusions about the feasibility of implementation. a specific mode of operation of the heating and ventilation system and choose the most energy-saving mode, as well as analyze the features of heat energy consumption during quarantine. Carrying out a number of simulations allows us to estimate the amount of heat transfer between the premises for different modes of their operation and to justify the location of the premises that will be used during the period of quarantine restrictions.

II. LITERATURE ANALYSIS

Energy saving and increasing the level of energy efficiency are priority areas of political activity in Ukraine (as well as in the world as a whole), since they are mandatory conditions for the European integration of the national energy system. Buildings deserve special attention in the field of energy saving, because they account for more than a third of the world's energy consumption [1]. At the same time, when evaluating and developing an energy saving action plan, it is necessary to take into account a number of parameters that characterize the building, and, first of all, these are its operational and behavioral factors that determine the set of conditions under which the building is operated (work schedule, indoor air temperature, quantity and the period of stay of people, the mode of operation of lighting, equipment, etc.). Educational institutions are interesting from the point of view of operation, since during normal operation they are characterized by a large number of people staying during working hours [2, 3], which in turn largely affects the integral characteristics of heat gains into the premises and energy consumption depending on the level of awareness potential consumers (whether the light is turned off, the faucet is closed towards the end, windows are opened / closed, etc.) [4, 5]. However, the COVID-19 pandemic has had a significant impact on the energy demand of public institutions, in particular higher education institutions. Since the beginning of 2020, the virus began to spread rapidly around the world. In March 2020, the World Health Organization declared the COVID-19 outbreak a global pandemic. At the same time, it was indicated that social distancing, sufficient ventilation of enclosed spaces and personal hygiene are the main measures that can prevent the spread of COVID-19 [6].

Therefore, to avoid crowds, most countries have introduced partial or complete closure of educational institutions, commercial and industrial companies [7]. This has led to radical changes in energy consumption [8]. In Ukraine, in the field of education, some institutions continued their work in a blended learning mode, while some completely switched to remote mode (depending on the epidemiological situation in the district where the institution is located) to prevent the spread of coronavirus disease (at the same time, if necessary, some educators visited their workplaces). In such conditions, to avoid excessive use of energy and ensure the normal functioning of buildings, a very important issue arises - to have schedules for the rational use of energy for heating needs, considering the operation of the premises

Therefore, it is obvious that it is relevant to conduct an in-depth analysis of the introduction of intermittent and energy-saving modes of operation of the heating system for isolated rooms of a building of educational institutions for quarantine conditions in order to regulate energy consumption in accordance with the Law of Ukraine "On the Energy Efficiency of Buildings" [9], as well as an analysis of the influence of modes ventilation of premises on their energy consumption.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of the study is the educational building №17 of NTUU “I. Sikorsky KPI" The subject of the study is the consumption of heat energy by the building for the heating season under various modes of operation of the heating and ventilation system under quarantine and normal conditions. Research task:

1. Create a dynamic model of the building on the example of the educational building №17 Igor Sikorsky Kyiv Polytechnic Institute Igor Sikorsky in the DesignBuilder program, considering the internal zoning of premises.

2. Simulate the energy consumption of the building for normal operation under three proposed scenarios: №1 – at a constant temperature and steady air exchange (t = const, n = const); №2 – with intermittent heating mode (lowering the temperature during non-working hours and weekends) and steady air exchange (t = var, n = const); №3 - with intermittent heating and intermittent air exchange (t = var, n = var).

3. Conduct a simulation of the energy consumption of the building under quarantine, considering the schedules for using the premises and the permissible levels of temperature drop in them when implementing the three proposed scenarios (№1, №2, №3 - similarly).

4. Analysis of the results of modeling and assessments of the possible level of energy consumption of the building during the period of quarantine restrictions.

To create a building model in the DesignBuilder software environment, the educational building №17 of the Igor Sikorsky Kyiv Polytechnic Institute was used. It was built in 1969. The building is located in Kiev. Geometrically, the building is a regular extended rectangular shape. The main part of the facades is oriented to the north and south sides of the world. The building has 5 floors, as well as a heated basement and an unheated technical floor.

The heating volume of the building is 42371,34 m^3, the area is 12184,75 m^2. All windows of the building were replaced with metal-plastic single-chamber double-glazed windows with air-filled chambers, with the exception of the technical floor, where glass blocks are installed. At the same time, the share of the area of translucent structures is 36,73%, 12,02%, 35,44% and 12,02% in the northern, eastern, southern and western orientations, respectively. The bearing layer of the outer walls of the building is made of expanded clay concrete. For external walls U-Factor with Film – 1,021 $W/m^2 \cdot K$. Covering of the building – flat roof, rolled: U-Factor with Film – 0,803 $W/m^2 \cdot K$; one part of the coverage is the coverage of the 5th floor, another part is the coverage of the technical floor. Foundation – concrete blocks (floor U-Factor with Film – 0,748 $W/m^2 \cdot K$. Glass U-Factor for windows – 2,382 $W/m^2 \cdot K$. The building is supplied with heat through the networks of a centralized heating system, the model of which allows the introduction of intermittent heating modes. In addition, it is provided that the heating devices installed in the premises are M140 cast-iron radiators with thermostatic heads, which allow adjustment by building zones.

The ventilation system is natural - it is provided at the level of 0,7 ac / h by opening the windows; another 0,3 ac/h is provided by the infiltration component (due to the looseness of the enclosing structures). Thus, the total air exchange is 1 ac/h, which corresponds to the standard for educational buildings. The number of people in the building during normal operation is 2763. The hourly climate data used for the simulation is an IWEC hourly file for a typical year for Kiev conditions [14]. The 3D model of the building of educational building №17, created in the DesignBuilder software environment, is shown in Fig.1 [15-17].

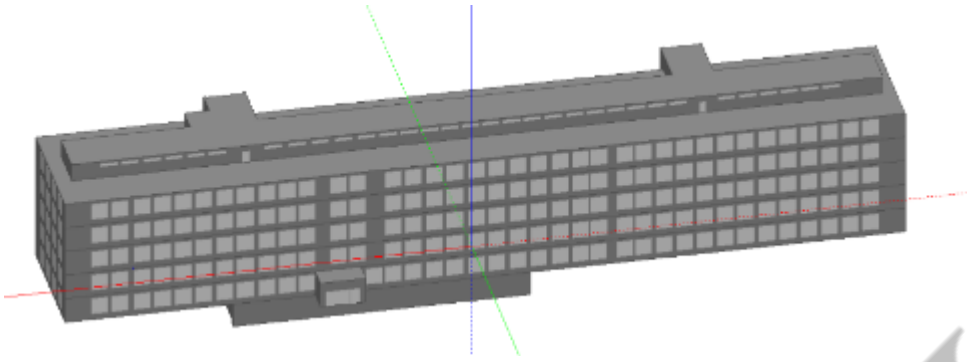
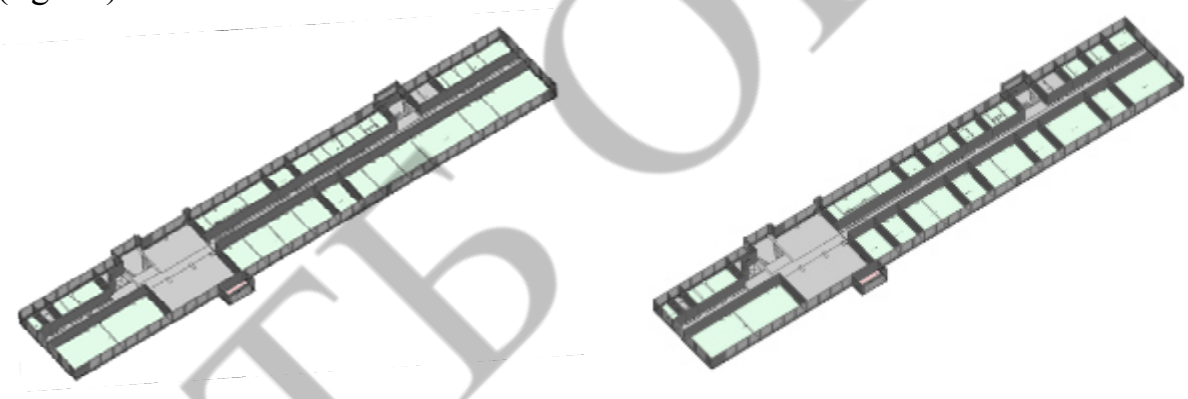


Fig. 1. 3D-model of educational buildings №17 NTUU "Igor Sikorsky KPI" [15-17]

For the normal mode of operation of the building, the premises of the same functional purpose were combined into thermal zones (auditoriums, corridors, toilets, basement, attic, vestibules). In normal operation, heat and mass flows between classrooms are quite active, and the parameters (temperature, air exchange, number of people per unit area) are the same, so to separate each audience in a separate area is not advisable (fig.2a). For the quarantine regime, as the difference between heat and mass flows, as well as the parameters set between the zones is significant, additional thermal zones were identified that geometrically coincide with the classroom boundaries and set the necessary parameters for each zone according to the scenario that is simulated (fig. 2b).



a b

Fig. 2. Zoning, 1st floor:
a – normal mode, b – quarantine mode

The calculation of the basic level of energy consumption was carried out in accordance with the comfort parameters according to the standards [9 – 13] and typical climatic conditions for Kiev [14]. For the normal mode of operation of the building and premises used during quarantine, scenario №1 provides for maintaining the temperature and air exchange at stable values throughout the entire time; when implementing scenario №2 – lowering the temperature during non-working hours and weekends to 17°C; under scenario №3 - temperature decrease during non-working hours and weekends to 17°C and a decrease in the standard air exchange during non-working hours and weekends to the level of 0,3 ac/h (during non-working hours, the windows are not open and only the infiltration component remains). Detailed parameters of the proposed modes are given in table 1.

Table 1. Parameters of the proposed modes

Scenario	Normal mode of operation	Quarantine mode	
		Used premises (separate auditoriums on the 1st and 2nd floors, as well as toilets on the 1st and 2nd floors)	**All other unused premises**
№1 ***t = const*** ***n = const***	t = 20°C [24/7] n = 1 ac/h [24/7]		t = 14°C 24/7 n = 0,3 ac/h 24/7 (*only infiltration*)
№2 ***t = var*** ***n = const***	$t_{heating}$ = 20°C [from 7:00 until 18:00] $t_{heating\ set\ back}$=17°C [from 18:00 until 07:00 + Weekends]		
№3 ***t = var*** ***n = var***	$t_{heating}$ = 20°C [from 7:00 until 18:00] $t_{heating\ set\ back}$=17°C [from 18:00 until 07:00 + Weekends] n = 1 ac/h [from 7:00 until 18:00] n = 0,3 ac/h [from 18:00 until 07:00 + Weekends] (*only infiltration*)		

IV. RESULTS

Consumption of heat energy, according to the results obtained in the simulation are given in table 2. The first number in the designation shows the mode of operation: 1X - normal mode, 2X - quarantine; the second number corresponds to the scenario number (for example, X3 is scenario №3). Similar designations will be maintained here and below.

Table 2. Heat consumption by created models (part 1)

1	**Scenario**	**11**	**21**	**Δ%**
2	Heating area of the building, m^2	12184,75		**-**
3	Area of premises used during quarantine, m^2	12184,75	992,12	**-91,86**
4	The need for heating, used premises, kWh/season	-	219482,97	**-**
5	Energy consumption for the heating season, kWh/season	1596335,75	617532,91	**-61,32**
6	Specific energy consumption, kWh/m^2		50,68	**-61,32**
7	Specific energy consumption of used premises, kWh/m^2	131,01	221,23	**68,86**
8	Specific energy consumption of the used representative premises, north orientation kWh/m^2	131,907	241,700	**83,23**
9	Specific energy consumption of the used representative premises, south orientation kWh/m^2	115,116	215,134	**86,88**

Table 2 (part 2)

1	**12**	**22**	**Δ%**	**13**	**23**	**Δ%**
2	12184,75	12184,75	**-**	12184,75	12184,75	**-**
3	12184,75	992,12	**-91,86**	12184,75	992,12	**-91,86**
4	-	169745,73	**-**	-	120678,27	**-**
5	1363925,06	592825,96	**-56,54**	829736,11	546852,79	**-34,09**
6		48,65	**-56,54**		44,88	**-34,09**
7	111,94	171,09	**52,85**	68,10	121,64	**78,62**
8	110,793	185,150	**67,11**	66,878	134,261	**100,76**
9	94,375	161,989	**71,64**	53,039	112,237	**111,61**

Graphically, the results are shown in fig 3.

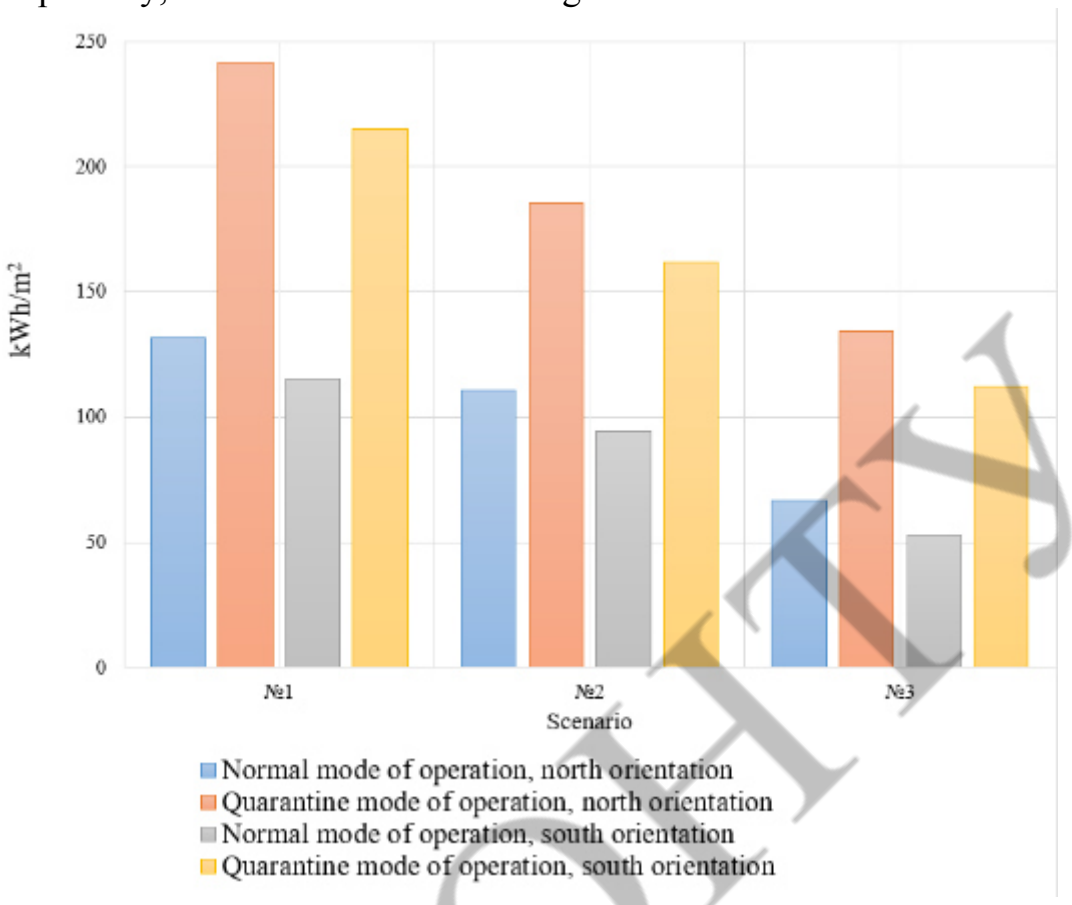
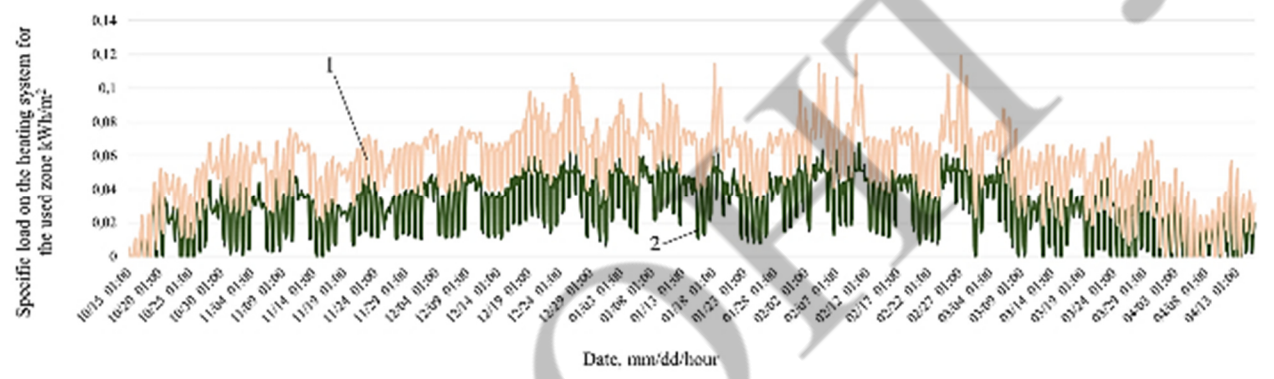


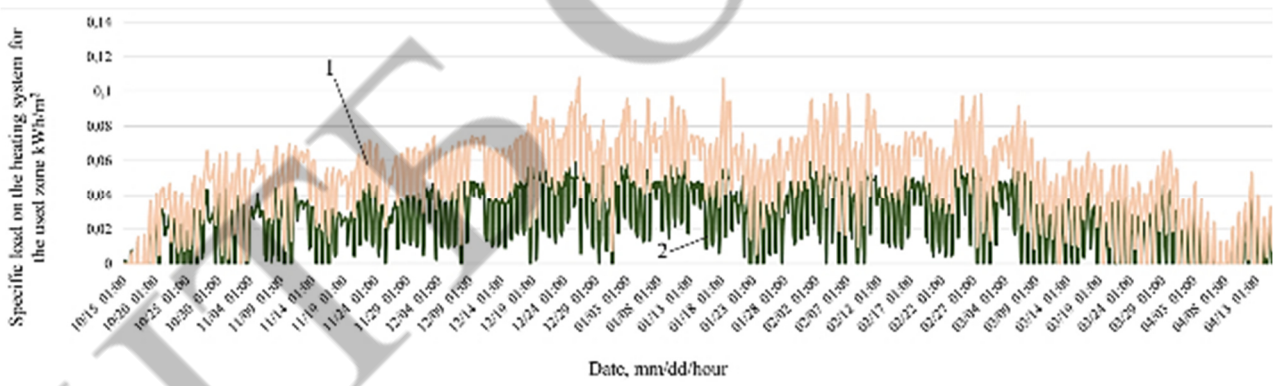
Fig. 3. Specific consumption of heat energy of the research premises during the heating season

Thus, according to the results of scenario №1 we have: partial use of the building during quarantine allows to reduce the consumption of heat energy during the heating season by 61,32%. At the same time, the specific consumption to the total heating area is reduced by the equivalent value. However, if we compare the specific consumption of heat energy in heated rooms to the appropriate level, this value increases by 68,86% compared to the usual mode. If we consider a single room, which is zonally separated in both models for analysis, its specific consumption increased by 83,23% and 86,88% for the northern and southern orientation compared to the usual regime, respectively. Similar observations can be made for scenarios №2 and №3. If we compare the scenario №1 and №2, we see that the use of intermittent heating mode reduces energy consumption both in normal operation (by 14,55%) and in quarantine (by 4%, due to the flow to adjacent premises savings are reduced). The reduction in heat energy consumption during quarantine is not so significant, as only a small part of the premises are operated and, accordingly, will have a decrease in temperature during non-working hours. Scenario №3 is the most energy efficient, as evidenced by the results obtained. Energy savings compared to scenario №2 for the normal regime is 39,17% and for the quarantine – 7,75%. Thus, the total energy savings between scenarios №1 and №3 for normal/steady state are 48,02% and for quarantine – 11,45%.

However, as noted, the specific energy consumption per unit of heating area (up to the appropriate temperature level) has increased. Figure 4 shows the graphical hourly specific consumption of heat energy for the heating of a separate room, which is operated for quarantine and normal conditions. To compare the consumption of heat energy at different orientations, the azimuth of the building model was rotated in the program by 180 ° and one room was considered for two cases. The room under consideration has an area of 37,43 m^2 and two windows (5,4 m^2), the glazing factor is 0,524. The increase in specific consumption indicates that in rooms where the proper temperature is maintained during working hours, the heat flow through the inner walls intensifies to neighboring rooms, where the level of heating is reduced. The southern orientation is characterized by more frequent shutdowns / reductions in the load on the heating system compared to the northern orientation, which is due to the intensity of solar revenues.



a



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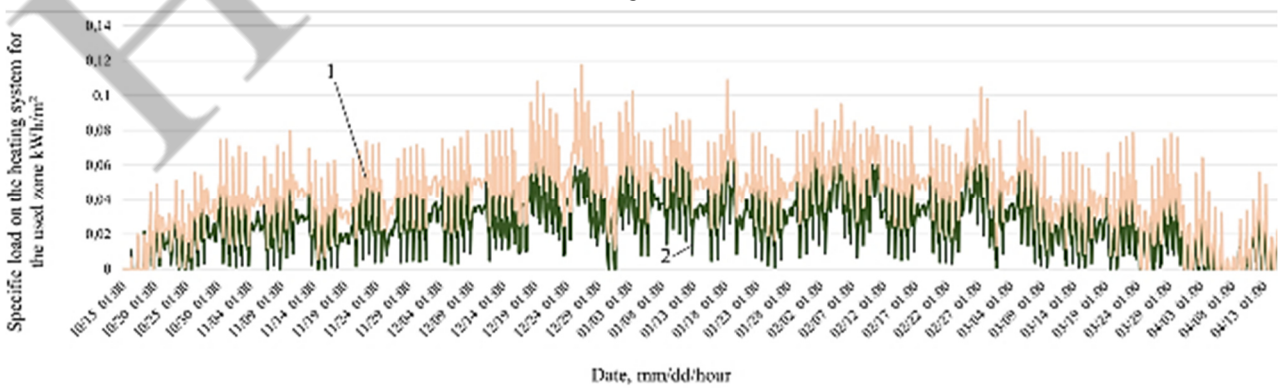

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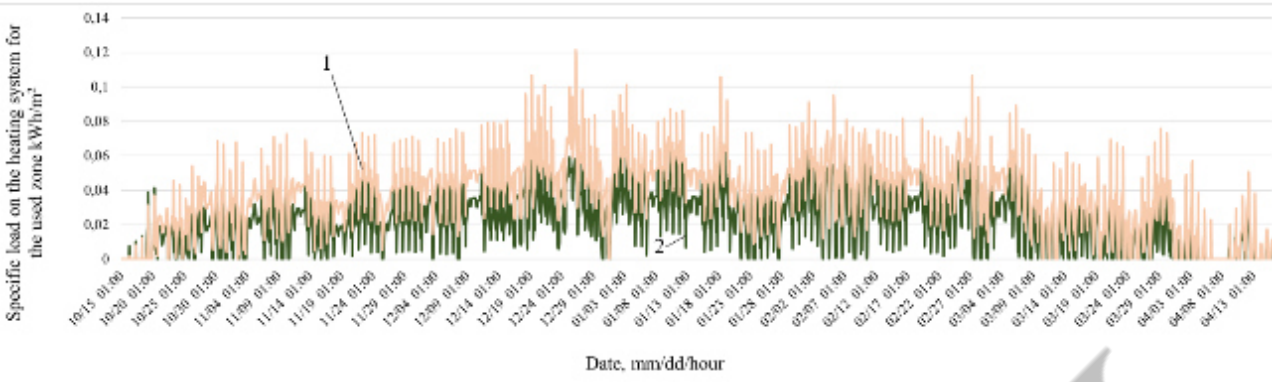

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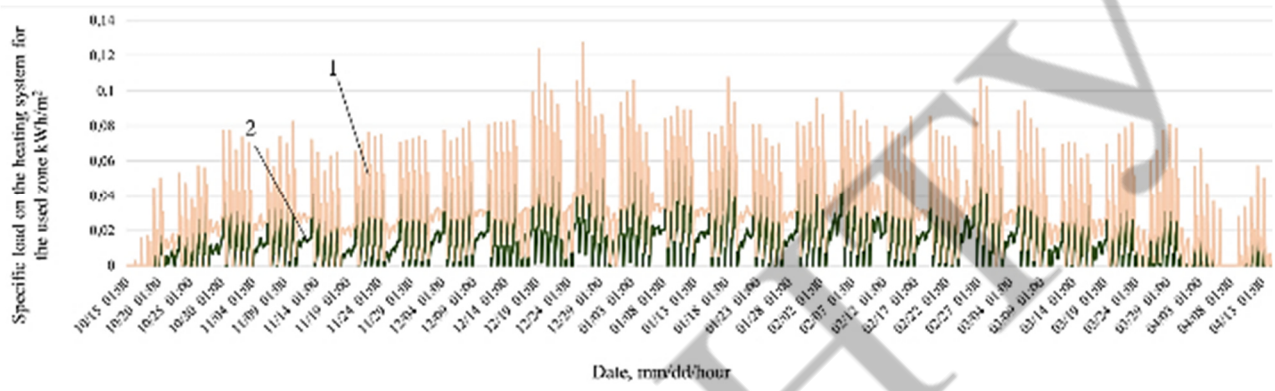

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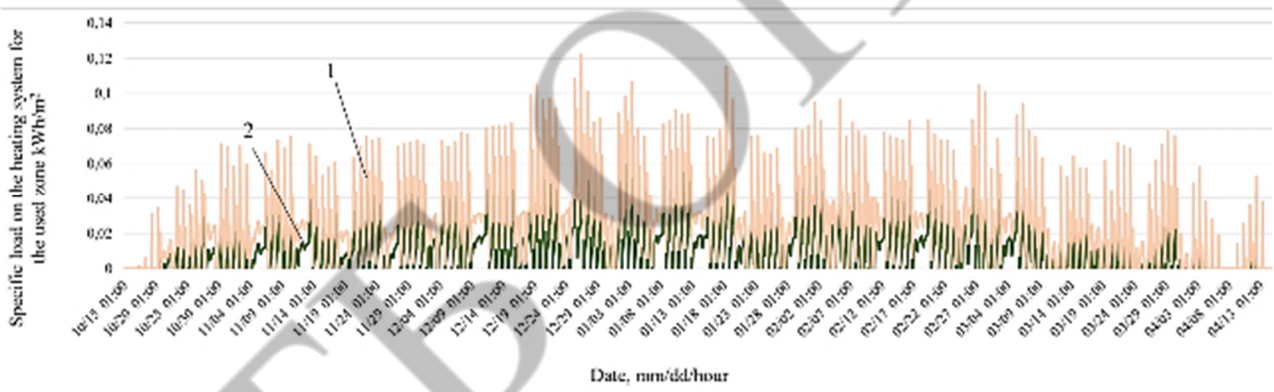


f

a – 1_N, b – 1_S, c – 2_N, d – 2_S, e – 3_N, f – 3_S

Fig. 4. Hourly heat consumption by a representative premises:
1_X – scenario №1; 2_X – scenario №2; 3_X – scenario №3;
X_N – north; X_S – south
1 – quarantine mode, 2 – normal mode

Figure 5 shows the hourly load on the heating system of the building as a whole for normal operating conditions and quarantine restrictions. It follows from Fig.4 and 5 that when the proposed operating modes are implemented under quarantine restrictions, the load on the heating system is generally reduced, and scenario №3 is the most energy efficient for both operating modes.

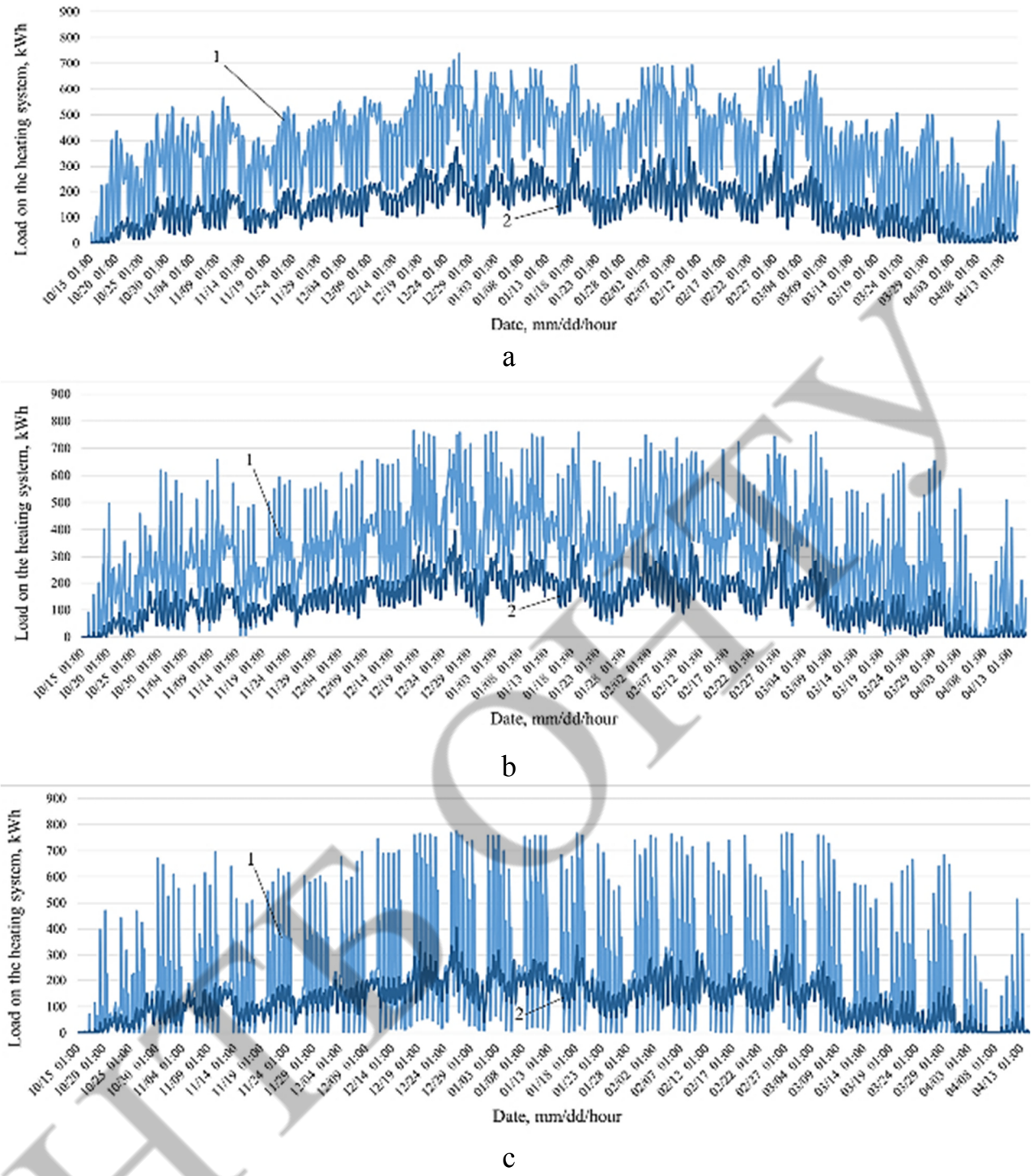
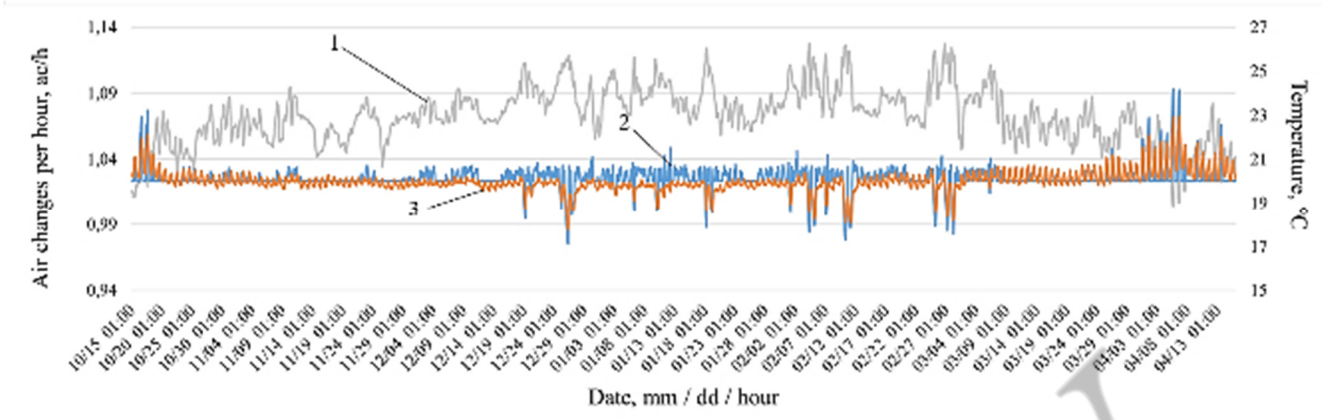
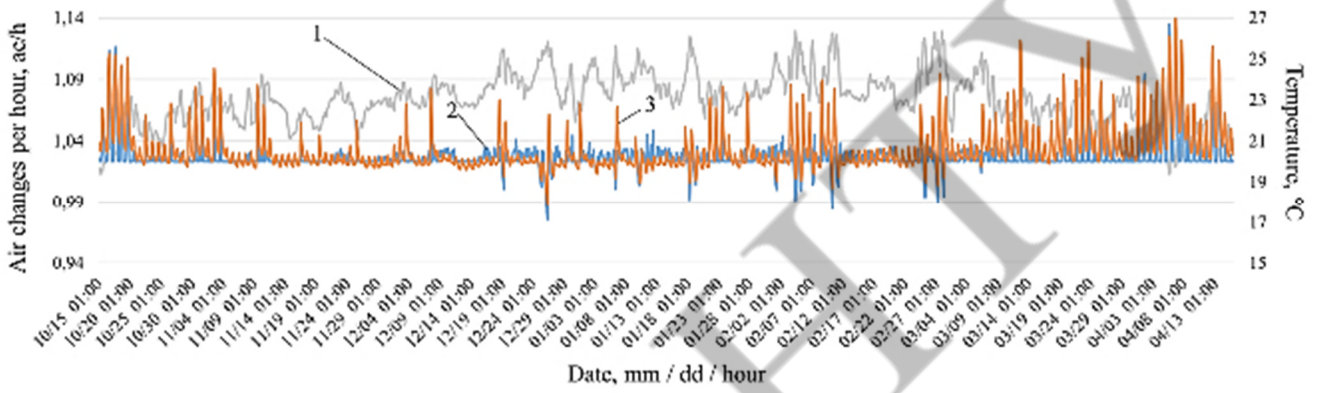


Fig. 5. Hourly heat consumption by the building:
a – scenario №1, b – scenario №2, c – scenario №3
1 – normal mode, 2 – quarantine mode

Figure 6 shows hourly graphs of air temperature changes in the considered representative rooms of Monday and Friday orientations, average radiation temperature and air exchange in them for normal operation and quarantine. In fig. 7 shows the hourly change in outdoor temperature and the level of solar heat gains that the room receives through window structures, per unit of heated area of this room



a



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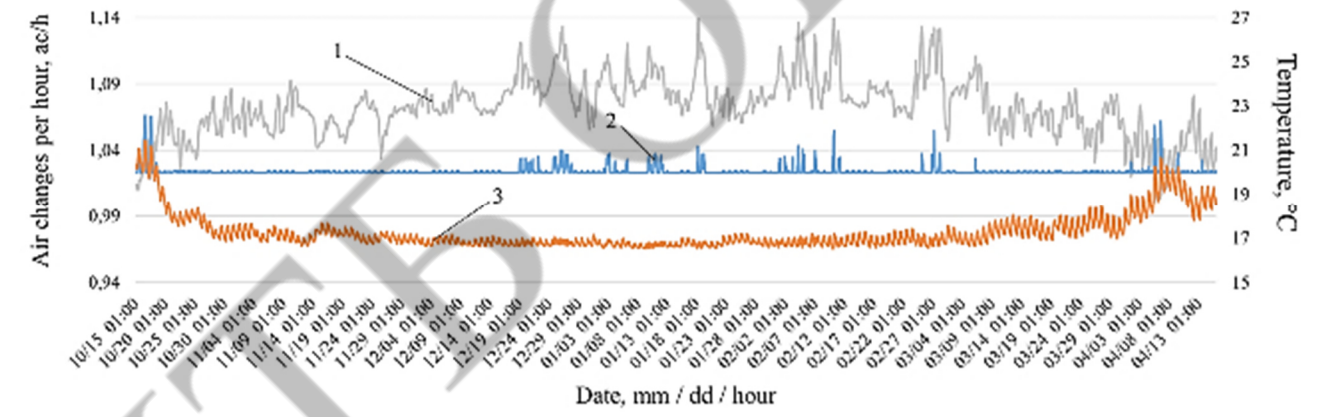

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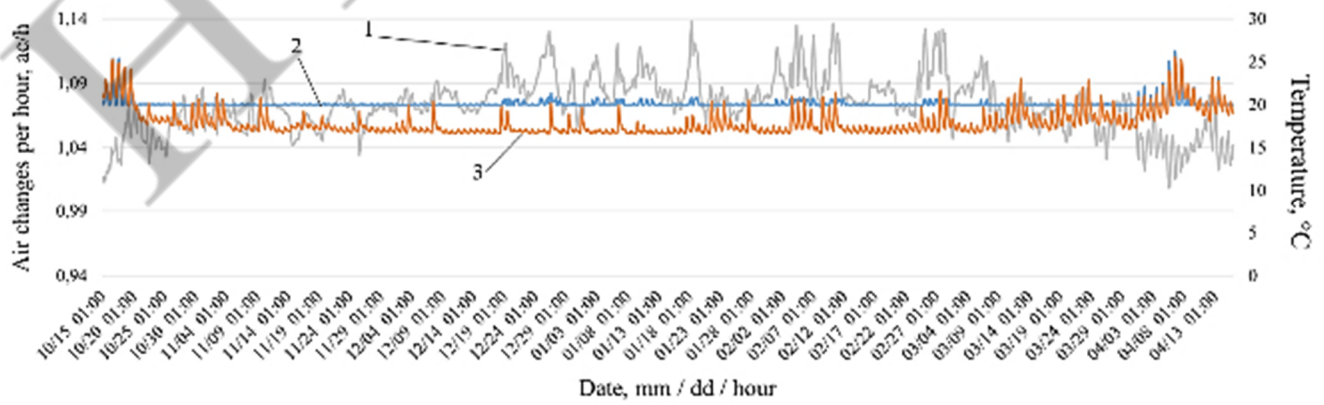

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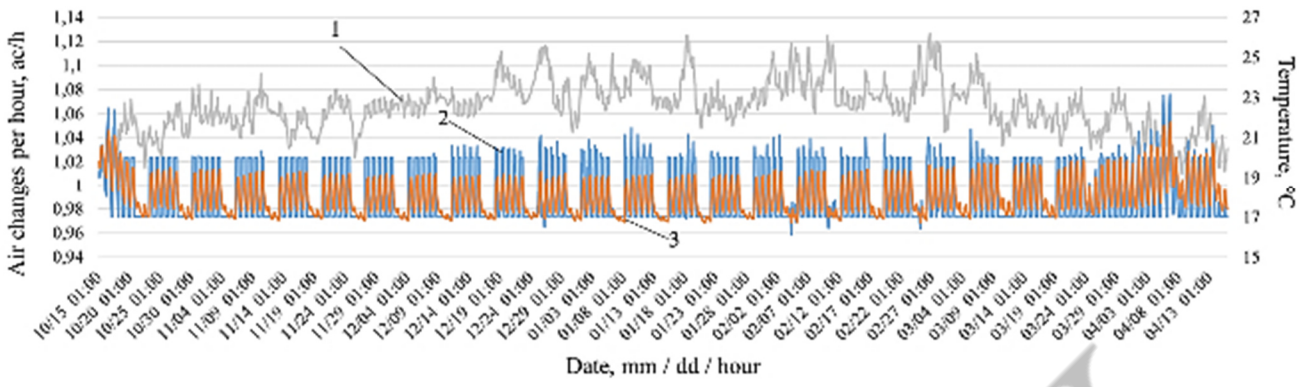

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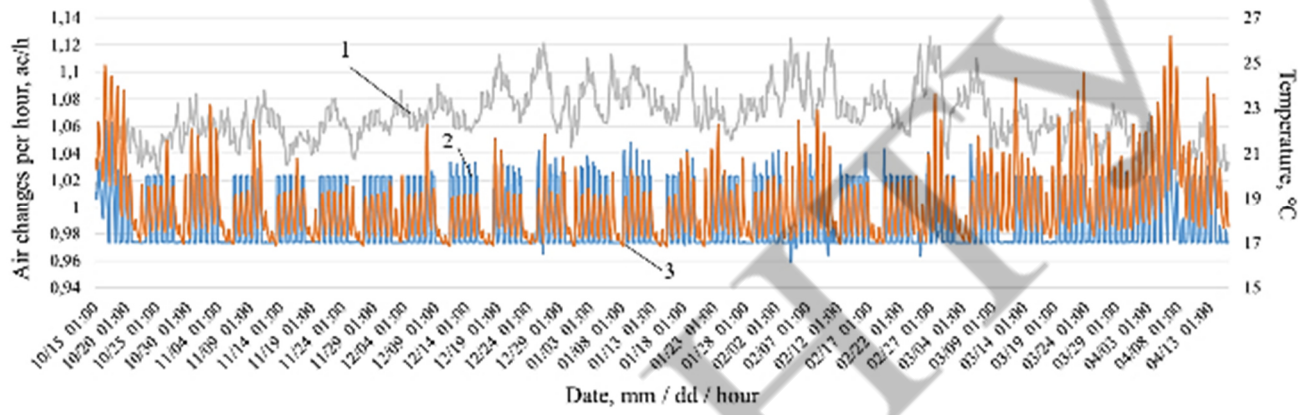

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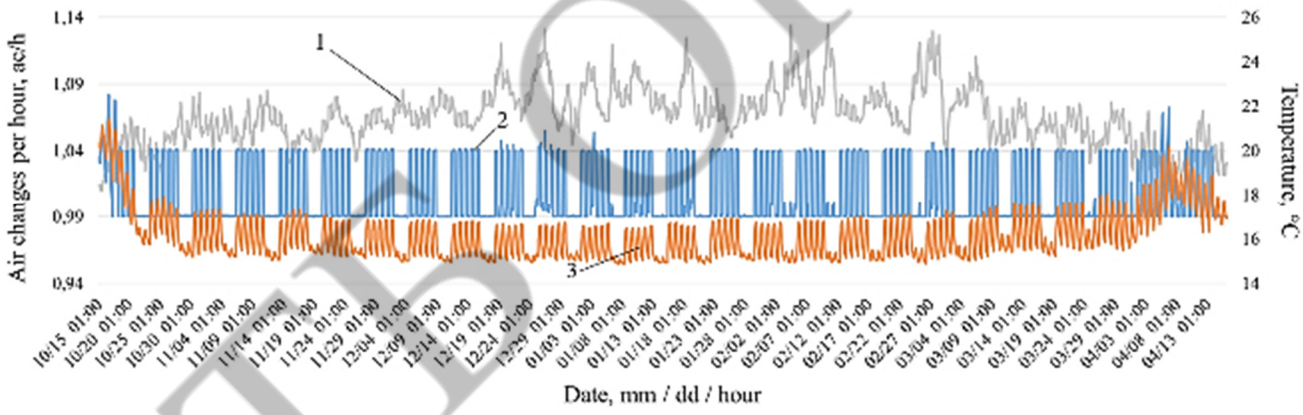

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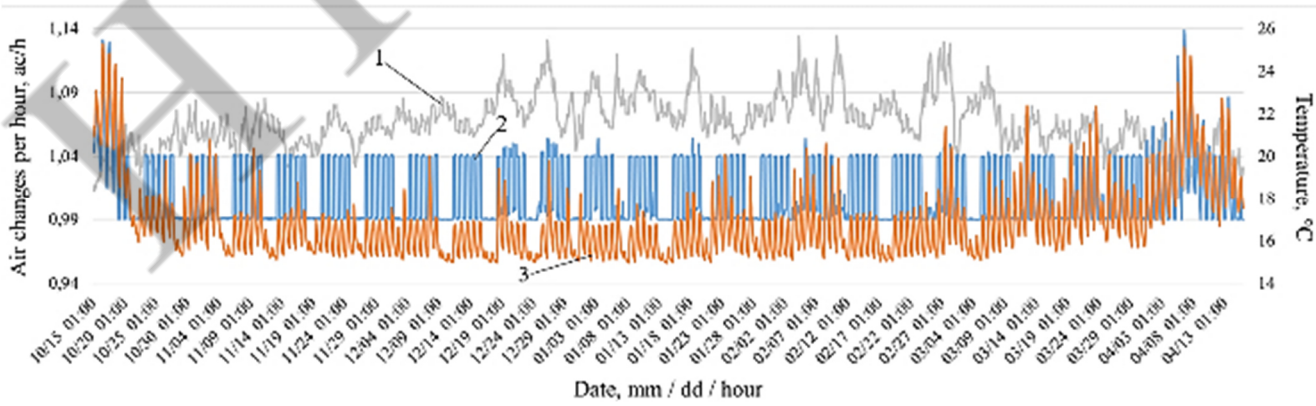

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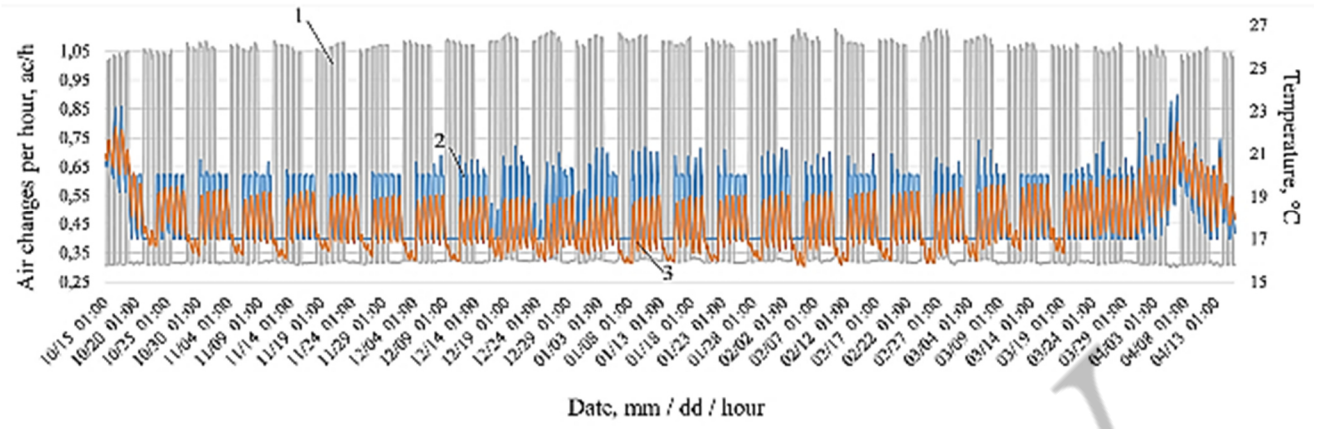

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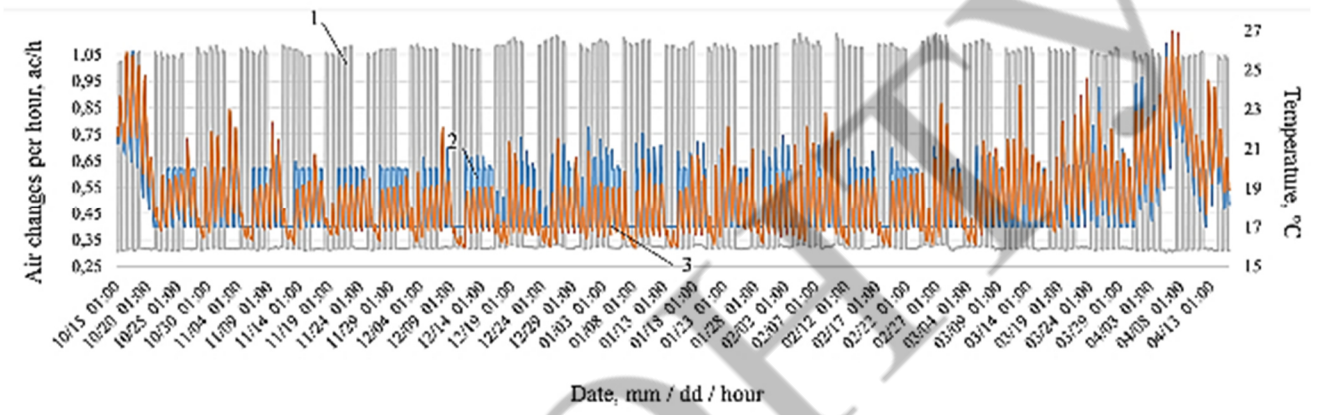

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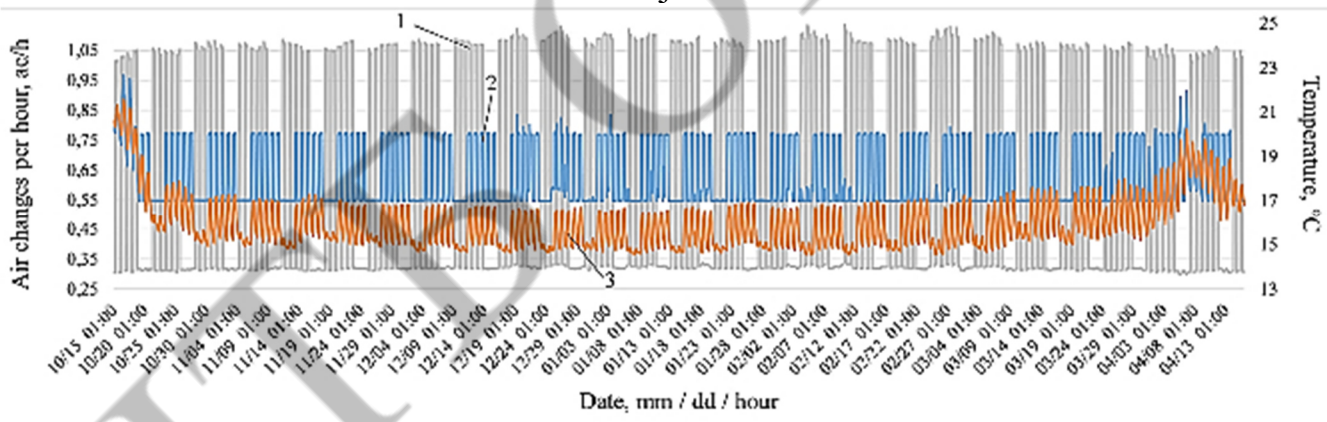

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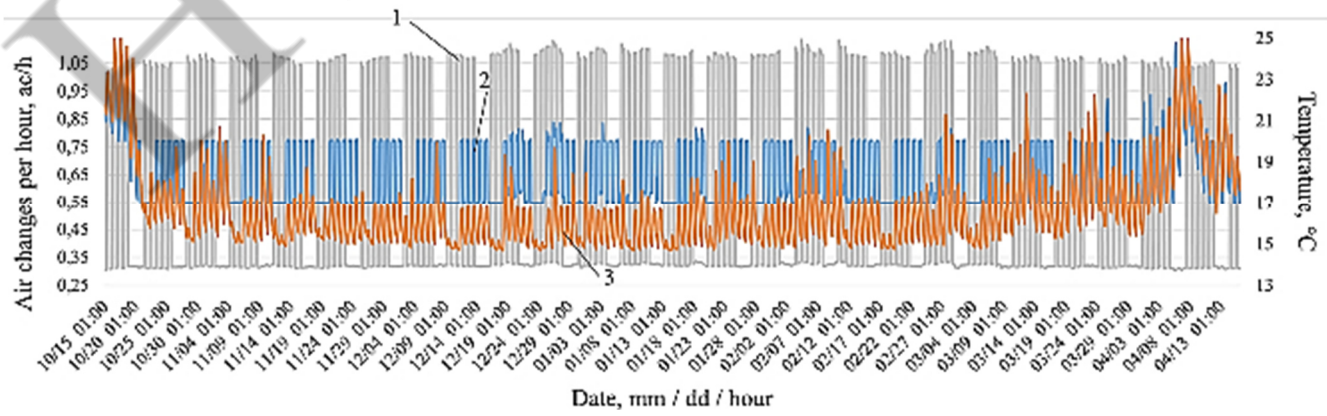

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a – 11_N, b – 11_S, c – 21_N, d – 21_S, e – 12_N, f – 12_S, g – 22_N, h – 22_S, i – 13_N, j – 13_S, k – 23_N, l – 23_S

Fig. 6. Chang in air temperature, average radiation temperature, air exchange level during the heating period for a representative premises:
1X – normal mode, 2X – quarantine mode, X1 – scenario №1, X2– scenario №2, X3– scenario №3, XX_N – north, XX_S – south, 1 – air exchange; 2 – deviation of indoor air temperature, 3 – deviation of the average radiation temperature,

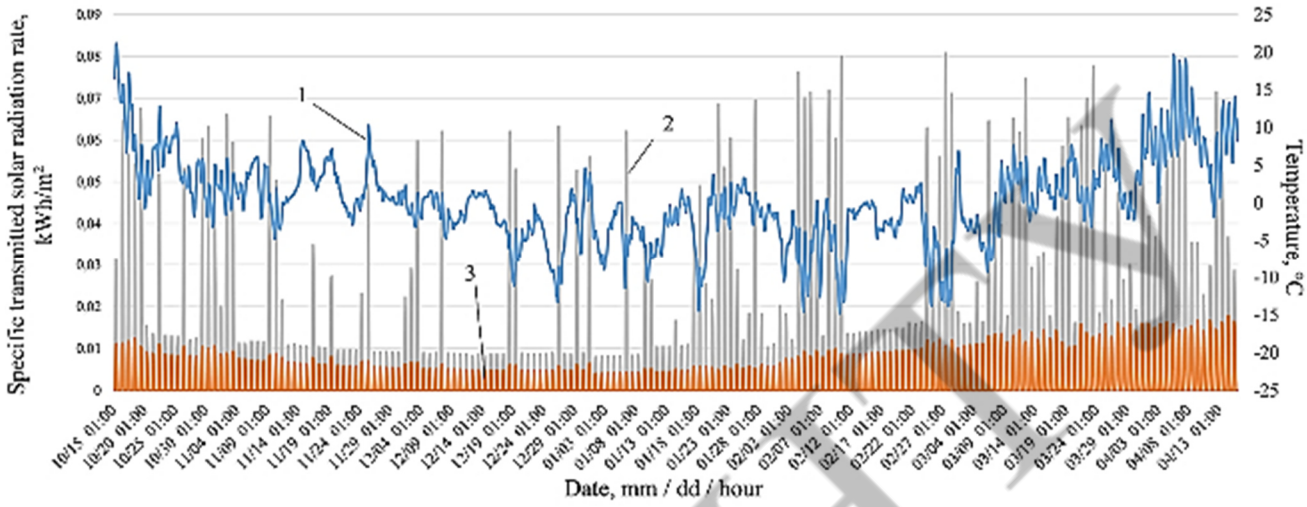

Fig. 7. Hourly values of outdoor temperature and solar radiation rate per heated area according to the IWEC weather file [14]:
1 – outside air temperature, 2 – solar radiation rate on the south side,
3 – solar radiation rate on the north side

Consider the average difference between the room temperature and the average radiation temperature for the calculation period (table 3).

Table 3. Indoor air temperature and average radiation temperature for the obtained models

11_S		**11_N**		**21_S**		**21_N**	
t_{air_in}	t_{mean_rad}	t_{air_in}	t_{mean_rad}	t_{air_in}	t_{mean_rad}	t_{air_in}	t_{mean_rad}
20,11	20,02	20,25	20,60	20,06	17,28	20,15	17,94
Δ = 0,09		Δ = -0,35		Δ = 2,78		Δ = 2,21	
12_S		**12_N**		**22_S**		**22_N**	
t_{air_in}	t_{mean_rad}	t_{air_in}	t_{mean_rad}	t_{air_in}	t_{mean_rad}	t_{air_in}	t_{mean_rad}
18,09	18,07	18,26	18,67	18,08	16,17	18,22	16,88
Δ = 0,02		Δ = -0,41		Δ = 1,91		Δ = 1,34	
13_S		**13_N**		**23_S**		**23_N**	
t_{air_in}	t_{mean_rad}	t_{air_in}	t_{mean_rad}	t_{air_in}	t_{mean_rad}	t_{air_in}	t_{mean_rad}
18,30	17,86	18,64	18,61	18,13	16,02	18,34	16,76
Δ = 0,45		Δ = 0,03		Δ = 2,10		Δ = 1,59	

Visual representation of the results is shown in fig.8, 9.

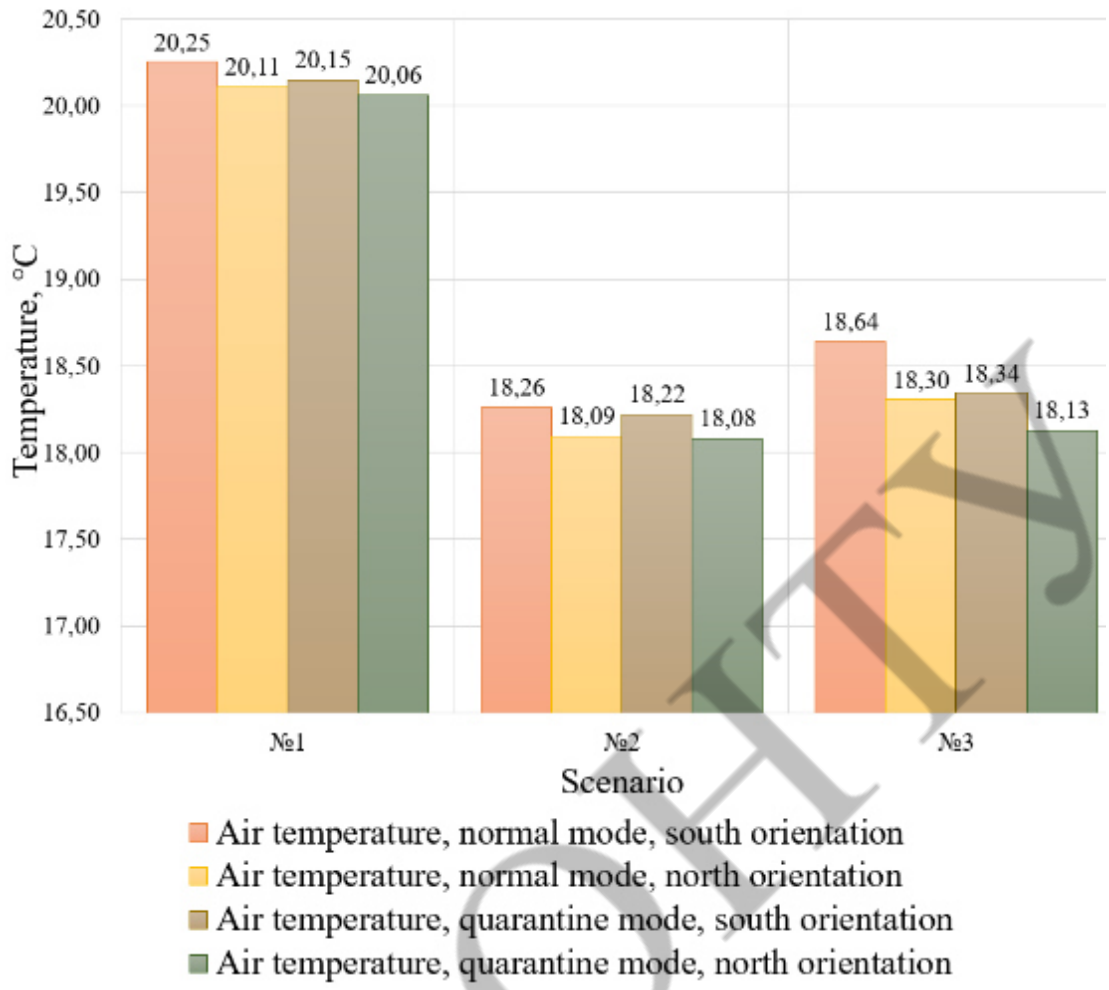

Fig. 8. The average temperature in the room during the heating season

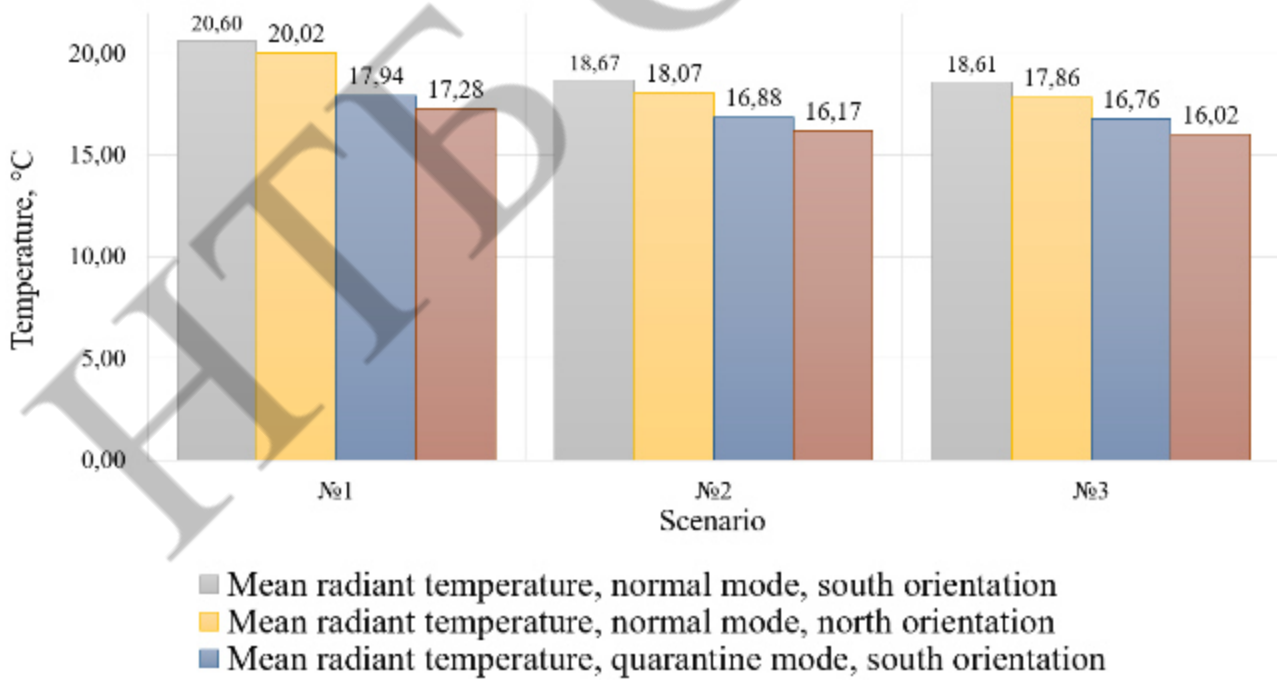

Fig. 9. The average value of the average radiation temperature for the heating season

From the given graphs and diagrams, it follows that the parameters of comfort in the premises used under quarantine restrictions are deteriorating (the average

radiation temperature decreases). This phenomenon is due to the fact that these rooms are in contact with cold areas, where a constant temperature is maintained at all times (t_{air_in} = 14°C). Internal heat flows lead to a transferring heat to cold zones and decrease in the average radiation temperature (t_{mean_rad}). For scenario №1, the lowest average radiation temperature is typical for the northern orientation room used in quarantine. The highest – for the southern orientation in normal operation (in this case, the average radiation temperature even exceeds the air temperature by 0,35°C). A characteristic feature of south-facing rooms, in addition to the general increase in average radiation temperature, is the increase in the amplitude of fluctuations in both average radiation temperature and indoor air temperature during the day and night, due to additional heat from the sun on the south side. Similar analogies are observed for scenarios №2 and №3. Scenario №2 is characterized by a decrease in the average value of the average radiation temperature and air temperature during the heating season. At the same time the difference between the room temperature and the average radiation is reduced too. Scenario №3 compared to №2 is characterized by an increase in indoor air temperature, as the air exchange in the premises during non-working hours decreases. However, this slightly reduces the average radiation temperature. As a result, in the implementation of scenario №3, the moisture in the air condenses to a greater extent than in №2 and diffuses into the enclosing structures, removing heat from them and as a result reducing the average radiation temperature. However, the reduction is very small compared to the savings of heat energy in scenario №3, so it is most appropriate to use for both modes of operation scenario №3.

V. CONCLUSIONS

1. According to the results of modeling of the three proposed modes of operation of the heating system and natural ventilation, it is established that the most energy-saving mode corresponds to scenario №3. The total energy savings between scenarios №1 and №3 for the normal mode is 48,02% for quarantine – 11,45%.

2. It is established that in case of partial use of the building during quarantine in the presence of zone regulation the total energy consumption of the building decreases by 61,32%, 56,54%, 34,09% in the implementation of scenarios №1, №2 and №3 respectively.

3. The specific consumption of heat energy per unit of heating area to the appropriate level during the partial use of the building in quarantine increases compared to the normal mode of operation by 68,86%, 52,85% and 78,62% for the scenario №1, №2 and №3 respectively. In this case, if we consider a separate research room with north and south orientation, the difference in specific consumption in the southern orientation will be greater (+86,88%) compared to the northern orientation (+83,23%), due to uneven heat from the sun.

4. The introduction of intermittent heating allows to reduce energy consumption in normal mode of operation by 14,55%, in quarantine – by 4% (internal heat flows lead to heat transfer to cold areas and reduced energy savings). The introduction of intermittent ventilation allows to increase energy savings by 39,17% for normal operation and 7,75% for quarantine. Thus, the total energy savings from the

introduction of intermittent heating and ventilation for the normal mode is 48,02% and for quarantine – 11,45%.

5. The increase in the specific consumption of heat energy by the premises used in quarantine is due to their proximity to cold zones, which also leads to a decrease in the average radiation temperature, and hence the comfort parameters, especially for premises with a northern orientation, as evidenced by the obtained hourly data on temperature changes air in the premises, the average radiation temperature and their average values for the heating season. Therefore, when choosing separate working areas during quarantine, preference should be given to south-facing rooms.

6. As a conclusion from the analysis of various parameters, we have: the most energy-saving mode is scenario №3. The disadvantage of this mode is a decrease in the intensity of mass transfer processes as a result of a decrease in the level of air exchange. This leads to moisture retention on the enclosing structures, which leads to a decrease in the average radiation temperature compared to scenario №2. However, this decrease is very small and imperceptible for the human body. Therefore, this mode can be recommended for implementation in quarantine mode and normal mode.

To ensure compliance with comfort under quarantine restrictions during partial operation of the premises, it is appropriate to study the effect on energy consumption of increasing the air temperature in the operated premises to a level that will correspond to the PMV comfort parameter in the range of -0.5…0.5.

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ENERGY EFFICIENT CIRCUIT SOLUTIONS FOR LOW-TEMPERATURE REFRIGERATION MACHINES BASED ON ENVIRONMENTALLY FRIENDLY REFRIGERANTS

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Abstract. *Modern refrigeration equipment and technology has two trends: energy efficiency and strict environmental requirements for substances used as refrigerants. Energy efficiency requires the use of refrigeration cycles that have minimal irreversible energy losses and are as close as possible to the Carnot cycle. This is especially true for low-temperature refrigeration machines, where to implement the cycle it is necessary to overcome a significant pressure drop. In the field of low-temperature refrigeration technology, energy-efficient solutions based on two- and multi-stage, as well as cascade refrigeration machines are used. A comparison of their effectiveness in terms of COP is presented in this paper.*

The environmental aspect of the problem today is solved through the use of natural and some artificial refrigerants, and is assessed primarily by LCCP, GWP and ODP. The paper considers refrigeration cycles based on R717, as well as its combinations with R23, R290, R744 and R32, used in the lower stage. For comparison, the result of the COP calculation using the base ozone-depleting refrigerant for the lower stage, which is R13, is presented.

The paper also analyzes the influence of the choice of the intermediate temperature of the phase transition in the evaporator-condenser on the energy efficiency of the cycle for the ratio of refrigerants of the upper and lower stages, which has the highest energy efficiency.

The practical significance of the work is to provide guidelines for further experimental studies of energy efficient solutions of low-temperature refrigeration machines.

Keywords: *thermal calculation, refrigeration machine, COP, cascade cycle.*

I. INTRODUCTION

Artificial cold has become one of the main indicators of the level of technical and cultural development of any country. The current stage of development of the refrigeration industry is characterized by the widest use of cold in all sectors of the economy. In fact, there are no industries where the cold is not used. [1] Many technological processes require the use of low temperatures (not higher than –40 °C), which can be created and maintained by low-temperature refrigeration machines. At the same time, they must have high energy efficiency, which is not achieved by using conventional single-stage steam compression refrigeration machines (SCRM). Therefore, it is necessary to apply other circuit solutions, among which are multistage and cascade refrigeration machines. It is necessary to address the issue of choice as the scheme itself.

However, since the Vienna Convention for the Conservation of the Ozone Layer in 1985, the Montreal Protocol on Substances that Deplete the Earth's Ozone Layer

(1987), and including subsequent agreements in London, Copenhagen, Vienna and Montreal, a large Earth's stratosphere ozone conservation program, aimed primarily at creating refrigerants, alternatives to ozone-hazardous, new types of refrigeration equipment, polymers, aerosols, fire extinguishers, etc.

Therefore, in addition to energy efficiency, modern refrigeration machines are also subject to strict environmental safety requirements, which are assessed by indicators such as ODP and GWP. Currently, the use of natural refrigerants (ammonia, carbon dioxide) and refrigerants that do not contain chlorine atoms in their molecule is promising. Hydrocarbons, components of natural gas, have become especially popular nowadays. These are propane, butane, pentane and their isomers. Research work is devoted to these topical issues.

II. LITERATURE ANALYSIS

2.1. Circuit solutions for low-temperature refrigerators and evaluation of their efficiency

Obtaining low temperatures (below –25 °C) requires the use of special refrigeration machines based on two- and multi-stage, as well as cascade cycles. This is due to a significant reduction in the feed rate of the compressor and a significant increase in its size, rising temperature of the refrigerant and oil, which can cause the formation of a deposit on the inner surface of the compressor cylinder, as well as spontaneous combustion, self-decomposition of oil. Possible modes of operation when the refrigerant compression can get wet steam and hydraulic shock, to prevent this create significant overheating of the refrigerant on suction into the compressor, which leads to additional irreversible energy loss during its supply at low temperatures. Another negative circumstance of the low-temperature cycle using a single-stage refrigeration machine or circuit solutions with parallel throttling is to obtain a relatively high degree of dryness of steam after throttling to boiling pressure, which further requires more mass consumption of refrigerant in the first and subsequent stages. All these factors negatively affect the energy efficiency of the cycle, which is estimated by the coefficient of thermal transformation COP.

Energy-efficient circuit solutions must include full use of two- and multi-stage refrigeration circuits with full interstage refrigerant cooling, which is realized in intermediate vessels, maximum use of ambient cold, minimal overheating of the refrigerant on suction in the first stage of the compressor, creation of the maximum supercooling of the refrigerant after the condenser, use of serial throttling, etc. Most of these requirements are met by a two-stage refrigeration cycle with complete intermediate cooling and sequential throttling. However, the implementation of such a circuit solution is complicated by the problem of separating the oil from the intermediate vessel, which gets there after the first stage compressor and through the throttle valve to the evaporator, significantly reducing the refrigeration capacity of the refrigerator. The solution to this problem was the use of automatic control and management devices or other less energy efficient but more reliable circuit solution using parallel throttle and coil in the intermediate vessel, shown in Fig. 1 and 2.

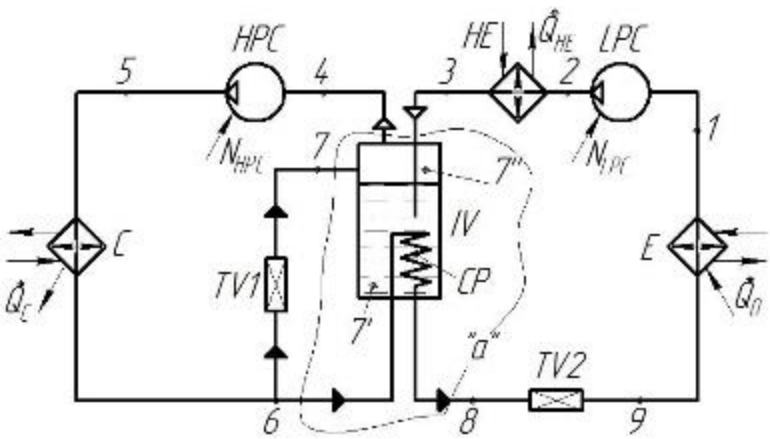
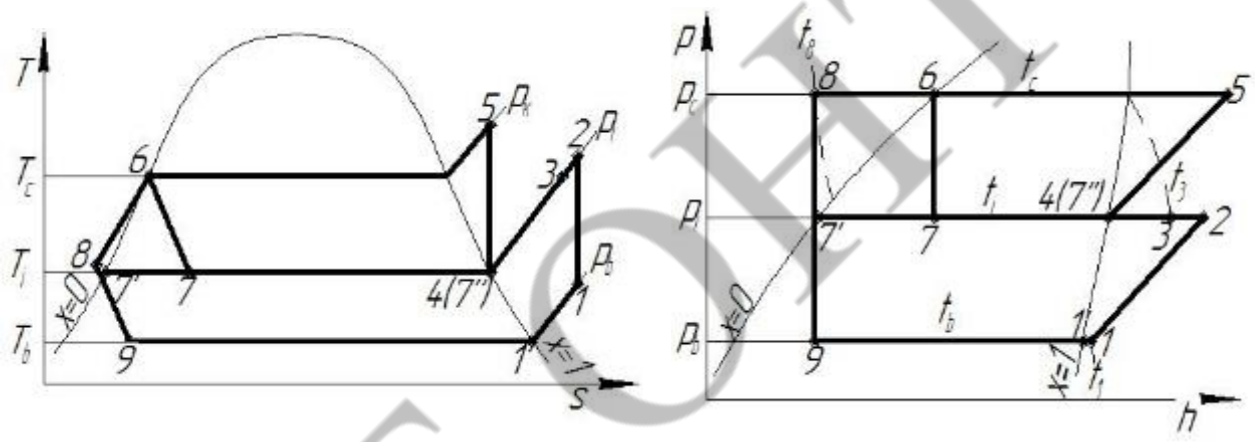


Fig. 1. Schematic diagram of a two-stage SCRM with a coil intermediate vessel: *LPC* – low pressure compressor (first stage); *HPC* – high pressure compressor (second stage); *HE* – heat exchanger; *IV* – intermediate vessel; *C* – condenser; *TV1, TV2* – throttle valves; *E* – evaporator; *CP* – coil pipe



a) *b)*

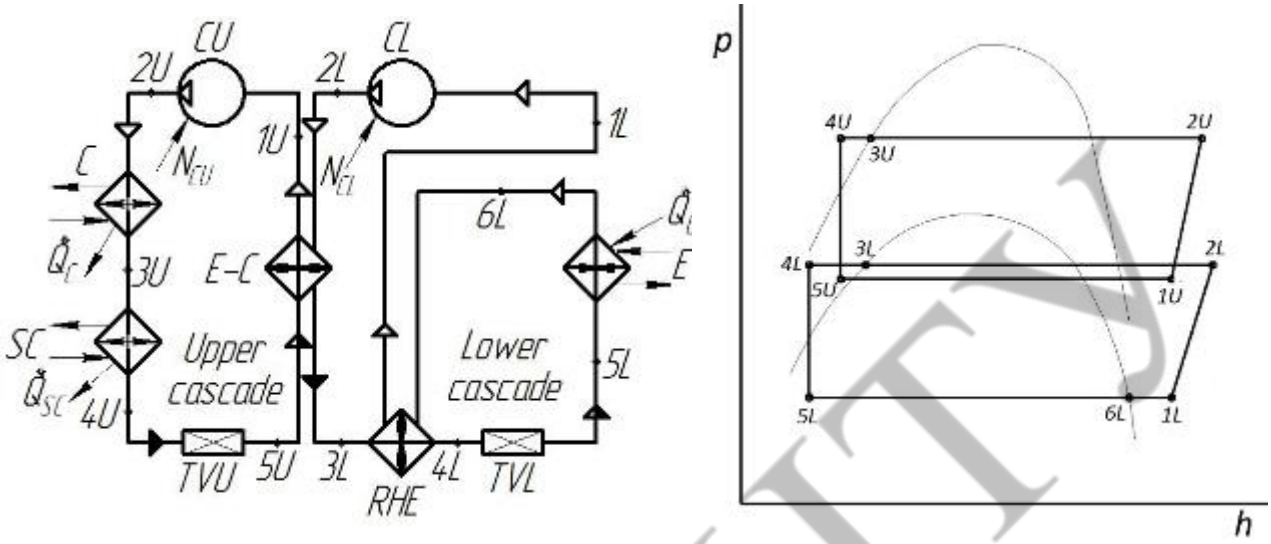
Fig. 2. Theoretical cycle of a two-stage SCRM with a coil intermediate vessel in *T–s* and *p–h* diagrams: p_b, T_b (t_b) – boiling pressure and temperature; p_c, T_c (t_c) – condensing pressure and temperature; p_i, T_i (t_i) – pressure and temperature in the intermediate vessel

Studies show that such a refrigeration machine has one of the best energy efficiency compared to other two-stage schemes and when ammonia is used as a refrigerant. This is ensured by the implementation of complete intermediate cooling of the refrigerant on the suction in the second stage of the compressor, as well as more complete supercooling of condensate in the intermediate vessel in combination with parallel throttling.

Another way to increase the energy efficiency of the low-temperature refrigeration cycle is the use of cascade circuits. The most widespread schemes consisting of two cascades: upper and lower. In fact, the cascade cycle combines two single-stage steam compression refrigeration machines. The lower and upper cascades interact through a special heat exchanger called an evaporator-condenser.

In the case of the use of CFCs in one of the cascades, a circuit solution with a regenerative heat exchanger is used, and in the case of the use of ammonia, a circuit with a subcooler is used.

Theoretical cycle of a cascade SCRM in *p–h* diagram of submissions on Fig. 3.



a) *b)*

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When calculating the cycle of the lower cascade, we assume that it is formed by a more energy-efficient scheme SCRM with RHE. When calculating the cycle of the upper cascade, we assume that it is formed by the cycle SCRM with subcooler, because the refrigerant in it is ammonia (R717).

When using a cascade cycle, two problems arise, which are investigated in this work, namely: the choice of refrigerant for the lower and upper cascade, as well as the choice of intermediate phase transition temperature in the condenser-evaporator.

Comparison of energy efficiency of cycles was performed by calculating the coefficient of thermal transformation COP. This value was determined by the following dependences, expressed in terms of specific values:

– two-stage steam-compression refrigeration machine with a coil intermediate vessel

$$COP = \frac{\dot{Q}_0}{N_{LPC}+N_{HPC}}, \quad (1)$$

$$COP = \frac{q_0}{l_{LPC}+\frac{\dot{m}_{HPC}}{\dot{m}_{LPC}}\cdot l_{HPC}}, \quad (2)$$

$$COP = \frac{q_0}{l_{LPC}+\frac{h_3-h_8}{h_4-h_6}\cdot l_{HPC}}, \quad (2a)$$

where $\dot{Q}_0$ – refrigeration capacity of the cycle, W;

N_{HPC} – high pressure compressor power, W;

N_{LPC} – low pressure compressor power, W;

$q_0 = h_1 - h_9$ – specific mass refrigeration capacity, kJ/kg;

$l_{LPC} = h_2 - h_1$ – specific mass work of the low pressure compressor, kJ/kg;

$l_{HPC} = h_5 - h_4$ – specific mass work of the high pressure compressor, kJ/kg;

$\dot{m}_{HPC}$ – mass consumption of refrigerant in the high pressure compressor, kJ/kg;

$\dot{m}_{LPC}$ – mass consumption of refrigerant in the low pressure compressor, kJ/kg.

– cascade refrigeration machine

$$COP = \frac{\dot{Q}_0}{N_{CL} + N_{CU}}, \tag{3}$$

$$COP = \frac{q_{0L}}{l_{CL} + \frac{q_{cL}}{q_{0U}} \cdot l_{CU}}, \tag{4}$$

where N_{CL} – lower cascade compressor power, W;

N_{CU} – upper cascade compressor power, W;

$l_{CU} = h_{2U} - h_{1U}$ – specific mass work of the upper cascade compressor, kJ/kg;

$l_{CL} = h_{2L} - h_{1L}$ – specific mass work of the lower cascade compressor, kJ/kg;

$q_{0U} = h_{1U} - h_{5U}$ – specific mass refrigeration capacity of the upper cascade, kJ/kg;

$q_{0L} = h_{6L} - h_{5L}$ – specific mass refrigeration capacity of the lower cascade, kJ/kg;

$q_{cL} = h_{2L} - h_{3L}$ – specific mass heat load of the lower cascade condenser, kJ/kg. [2]

2.2. Refrigerators and their properties

In addition to energy efficiency, modern refrigeration machines are also subject to strict environmental safety requirements, which are assessed by indicators such as LCCP, ODP and GWP. Currently, the use of natural refrigerants (ammonia, carbon dioxide) and refrigerants that do not contain chlorine atoms in their molecule is promising. Hydrocarbons, components of natural gas, have become especially popular nowadays. These are propane, butane, pentane and their isomers. Research work is devoted to these topical issues.

In the work the refrigerants have basic indicators, including ecological, which are given in Tab. 1.

Tab. 1. Characteristics of refrigerants considered in [2–4]

№	Symbol	Chemical formula	Critical parameters		Normal boiling point t_N, °C	ODP	GWP	LCCP	Combustibility	Toxicity
			pressure p_{cr}, МПа	temperature t_{cr}, °C						
1	R717	NH_3	11,333	132.2	–33.3	0	0	0,25	+	+
2	R13	$CClF_3$	3,879	28.8	–81.5	1,0	14400	130	–	+
3	R23	CHF_3	4,832	26.1	–82.0	0,0004	14310	270	–	–
4	R290	C_3H_8	4,251	96.7	–42.1	0	20	0,041	+	–
5	R744	CO_2	7,377	31.0	–78.4	0	1	120	–	–
6	R32	CH_2F_2	5,782	78.1	–51.6	0	670	4,9	+	+

T

. Among those listed in Tab. 1 refrigerants special attention is paid to natural refrigerants, namely: ammonia (R717), propane R290) and carbon dioxide (R744) as the most environmentally friendly.

Given the fact that the work involves the study of energy efficiency of an industrial design of a refrigeration machine, ie one with an average refrigeration capacity (at least 15 kW), as well as taking into account good environmental performance, based on refrigerant R717. In addition to environmental friendliness, ammonia has a number of advantages:

– low cost, which provides relatively low capital costs for the purchase and maintenance of refrigeration;

– high intensity of heat transfer in the devices, which provides a relatively small size;

– high density, which ensures the use of smaller diameters of pipelines;

– high specific heat of condensation (evaporation), which allows to ensure the lowest consumption of refrigerant in the cycle;

– low threshold of odor evaporation, which allows you to detect even the smallest leaks of refrigerant, even without the use of special equipment (current detectors).

The disadvantages of using ammonia as a refrigerant include its toxicity and flammability. However, with the observance of safety and labor protection measures, as well as the automation of the refrigeration machine, their harmful effects can be significantly reduced or even eliminated.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The aim of the research is to analyze the existing circuit solutions of low-temperature refrigeration machines and the impact of the properties of refrigerants on the environmental safety and energy efficiency of the refrigeration cycle.

To achieve this *goal*, the following tasks are formulated and solved:

– analysis of existing circuit solutions of low-temperature refrigeration machines;

– analysis of the impact of refrigerant properties on environmental safety and energy efficiency of the refrigeration cycle;

– development of recommendations for the calculation of the cascade

refrigeration cycle.

The objects of research are circuit solutions of cycles of low-temperature refrigeration machines and properties of refrigerants used in such cycles.

The subject of research is the energy efficiency of low-temperature refrigeration machine and the impact on it of the schematic diagram and thermodynamic and environmental properties of the refrigerant.

In solving the tasks such *methods* were used as: analysis of scientific and technical information, mathematical modeling using specialized software products (Refprop, Coolpack).

IV. RESULTS

4.1. Initial parameters and assumptions

Investigate the influence of the circuit solution of low-temperature SCRM of medium refrigeration capacity and the choice of refrigerant on the energy efficiency of the cycle (coefficient of thermal transformation COP).

For all cases ask:

– boiling point $t_b = -45\ °C$;

– condensation temperature (upper circuit for cascade refrigeration machines) $t_c = 45\ °C$;

– theoretical cycle (relative internal efficiency of the compressor $\eta_{oi} = 1$; there are no pressure losses in the devices;

– heat loss to the environment from appliances and other elements of the refrigeration machine are absent).

For cascade refrigeration machine, the condensing temperature of the refrigerant of the lower circuit of the cascade refrigeration machine $t_{cL} = 0\ °C$.

Consider cycles and calculate the coefficient of thermal transformation COP:

a) two-stage SCRM with a coil intermediate vessel; refrigerant R717; overheating on the suction of the first degree $\Delta t_{0h} = 5\ °C$;

b) cascade RM: for all cases – the upper cascade of SCRM with subcooler; refrigerant R717; hypothermia in the subcooler $\Delta t_{cu} = 5\ °C$; overheating on suction $\Delta t_{0h} = 5\ °C$; underrecuperation in the condenser evaporator $\Delta t_{E-C}^{ur} = 3\ °C$

b.1) SCRM with regenerative heat exchanger (RHE); lower cascade: refrigerant R13; overheating on suction $\Delta t_{0h} = 10\ °C$;

b.2) SCRM with RHE; lower cascade: refrigerant R23; overheating on suction $\Delta t_{0h} = 10\ °C$;

b.3) SCRM with RHE; lower cascade: refrigerant R290; overheating on suction $\Delta t_{0h} = 10\ °C$;

b.4) SCRM with RHE; lower cascade: refrigerant R744; overheating on suction $\Delta t_{0h} = 10\ °C$;

b.5) SCRM with RHE; lower cascade: R32 refrigerant; overheating on suction $\Delta t_{0h} = 10\,°C$.

For a cascade refrigeration machine with a maximum COP, investigate the choice of the optimal condensation temperature of the lower circuit refrigerant t_{cL}.

4.2. Calculation results

a) Two-stage SCRM with a coil intermediate vessel

The calculation scheme and theoretical cycle are shown in Fig. 1 and 2.

The calculation was performed in accordance with the task (see more section 4.1, item a).

Summary results of calculations are given in Tab. 2.

Tab. 2. Summary calculation's results of two-stage SCRM with a coil intermediate vessel

Parameter	π_{st}	t_2	t_5	x_9	COP
Unit of measurement	–	$°C$	$°C$	–	–
Result	5.75	76.6	121	0.134	2.07

Symbols in Tab. 2:

$\pi_{st} = p_c / p_i = p_i / p_b$ – the degree of pressure increase in the compressor stage;

t_2, t_5 – the temperature of the refrigerant after theoretical compression in the first and second stages of the compressor;

x_9 – the degree of dryness of the refrigerant before the evaporator;

COP – cycle thermal transformation coefficient.

b) Cascade refrigeration machine

The calculation scheme and theoretical cycle are shown in Fig. 3.

The calculation was performed in accordance with the task (see more section 4.1, item b).

Summary results of calculations in accordance with the item b.1 are given in Tab. 3.

Tab. 3. Summary calculation's results of cascade refrigeration machine (lower cascade – R13, upper cascade – R717)

Parameter	π_{st}^U	π_{st}^L	t_{2U}	t_{2L}	x_{5U}	x_{5L}	COP
Unit of measurement	–	–	$°C$	$°C$	–	–	–
Result	4.653	3.895	117	22.6	0.160	0.328	1.80

Symbols in Tab. 3:

$\pi_{st}^U = p_{cU} / p_{bU}$, $\pi_{st}^L = p_{cL} / p_{bL}$ – the degree of pressure increase in the upper and

lower cascades;

t_{2U}, t_{2L} – the temperature of the refrigerant after theoretical compression in the upper and lower cascades;

x_{5U}, x_{5L} – the degree of dryness of the refrigerant before the evaporator in the upper and lower cascades;

COP – cycle thermal transformation coefficient.

Summary results of calculations in accordance with the item b.2 are given in Tab. 4.

Tab. 4. Summary calculation's results of cascade refrigeration machine (lower cascade – R23, upper cascade – R717)

Parameter	π_{st}^{U}	π_{st}^{L}	t_{2U}	t_{2L}	x_{5U}	x_{5L}	COP
Unit of measurement	–	–	°C	°C	–	–	–
Result	4.653	4.272	117	41	0.160	0.288	1.80

Summary results of calculations in accordance with the item b.3 are given in Tab. 5.

Tab. 5. Summary calculation's results of cascade refrigeration machine (lower cascade – R290, upper cascade – R717)

Parameter	π_{st}^{U}	π_{st}^{L}	t_{2U}	t_{2L}	x_{5U}	x_{5L}	COP
Unit of measurement	–	–	°C	°C	–	–	–
Result	4.653	5.326	117	23.8	0.160	0.290	2.00

Summary results of calculations in accordance with the item b.4 are given in Tab. 6.

Tab. 6. Summary calculation's results of cascade refrigeration machine (lower cascade – R744, upper cascade – R717)

Parameter	π_{st}^{U}	π_{st}^{L}	t_{2U}	t_{2L}	x_{5U}	x_{5L}	COP
Unit of measurement	–	–	°C	°C	–	–	–
Result	4.653	4.194	117	63.4	0.160	0.260	1.79

Summary results of calculations in accordance with the item b.5 are given in Tab. 7.

Tab. 7. Summary calculation's results of cascade refrigeration machine (lower cascade – R32, upper cascade – R717)

Parameter	π_{st}^{U}	π_{st}^{L}	t_{2U}	t_{2L}	x_{5U}	x_{5L}	COP
Unit of measurement	–	–	°C	°C	–	–	–
Result	4.653	5.807	117	66	0.160	0.176	1.94

Symbols in Tabs. 4–7 are the same as Tab. 3.

Therefore, the results of the calculations include the following conclusion: the best value of the coefficient of thermal transformation was obtained for the ratio of

refrigerants upper stage R717 lower R290, which was 2.00. However, the value obtained is lower than the coefficient of thermal transformation obtained in the calculation of a two-stage refrigeration machine with a coil intermediate vessel, which was 2.07. In order to improve the COP for the cascade cycle, we investigate the effect of intermediate temperature (condensing temperature of the refrigerant of the lower circuit on the value of this parameter).

c) Modified cascade refrigeration cycle

In this work, calculations of a modified cascade cycle consisting of a combination of a two-stage refrigeration machine with full intermediate cooling, parallel throttling and a coil in an intermediate vessel in the upper cascade and a single-stage steam-compression refrigeration machine with regenerative heat exchanger in the lower cascade are performed. Ammonia is used as the refrigerant of the upper stage, and for the lower stage we use the refrigerant that received the highest CPC among the investigated refrigerants (R13, R23, R290, R744, R32) for the normal cascade cycle (R290).

This circuit solution has not been described in the literature. However, its implementation can theoretically have a better indicator of energy efficiency.

In Fig. 4 and 5 show the schematic diagram of the combined cascade cycle and its cycle in the *p–h* diagram.

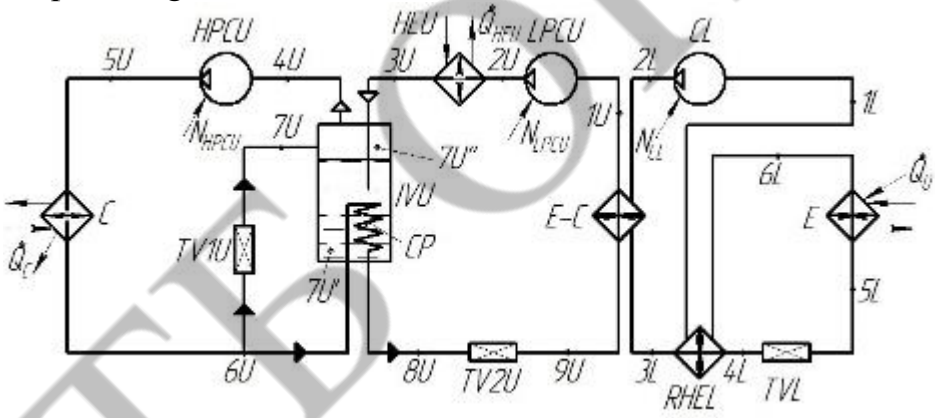

Figure 4 – Schematic diagram of the modified cascade cycle:
the upper cascade is a two-stage SCRM with a coil intermediate vessel, the lower cascade is a single-stage SCRM with RHE

Symbols for Figure 4: LPCU – low pressure compressor (first stage of the upper cascade) of the upper stage; *HPCU* – high pressure compressor (second stage of the upper cascade) of the upper stage; *HEU* – heat exchanger of the upper cascade; *IVU* – intermediate vessel of the upper cascade; *C* – condenser; *TV1U*, *TV2U* – throttle valves of the upper cascade; *CP* – coil pipe; *TVL* – throttle valve of the lower cascade; *RHEL* – regenerative heat exchanger of the lower cascade; *CL* – compressor of the lower cascade; *E* – evaporator; *E-C* – evaporator-condenser

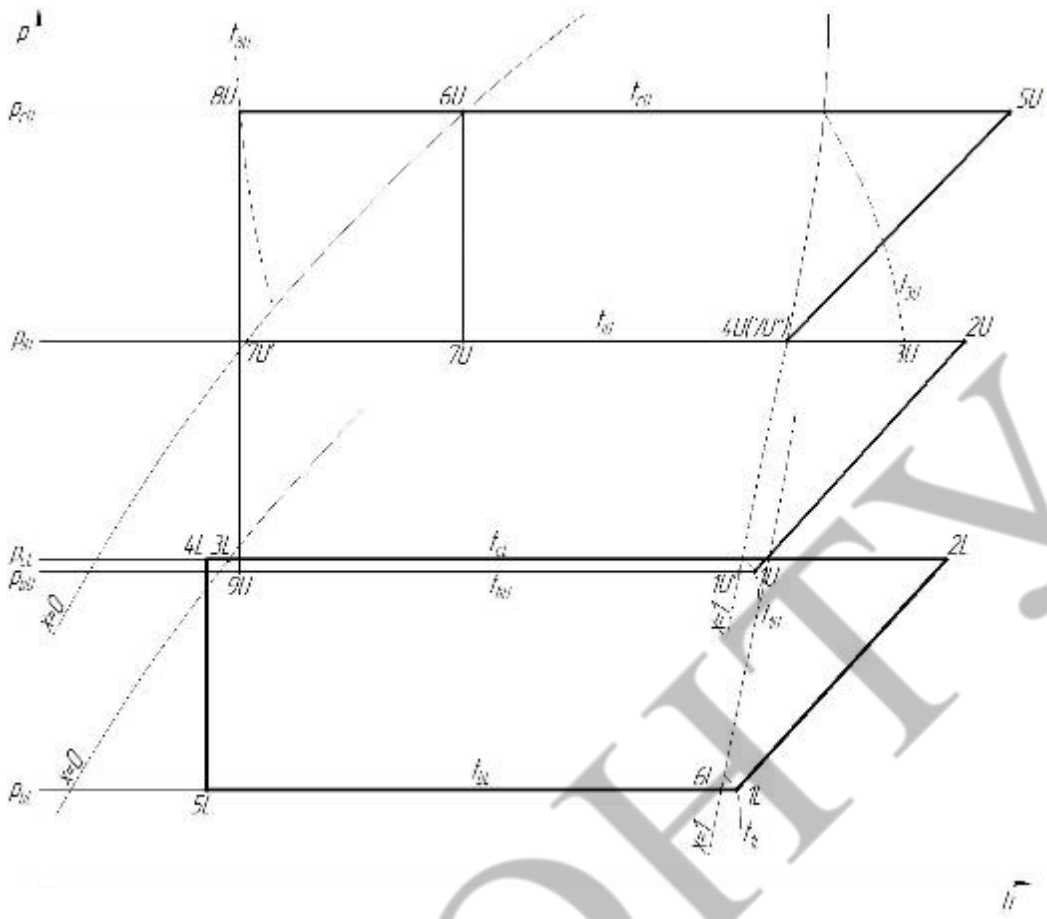

Figure 5 – Theoretically modified cascade cycle in *p–h* diagram:
p_{bU}, t_{bU} – boiling pressure and temperature of the upper cascade; p_{bL}, t_{bL} – boiling pressure and temperature of the lower cascade; p_{cU}, t_{cU} – condensing pressure and temperature of the upper cascade; p_{cL}, t_{cL} – condensing pressure and temperature of the lower cascade; p_{iU}, t_{iU} – pressure and temperature in the intermediate vessel of the upper cascade

The energy efficiency of the modified cascade cycle was determined by full or specific values in terms of:

$$COP = \frac{\dot{Q}_0}{N_{LPCU}+N_{HPCU}+N_{CL}}, \tag{5}$$

$$COP = \frac{q_{0L}}{\frac{q_{cL}}{q_{0U}}\cdot\left(l_{LPCU}+\frac{h_{3U}-h_{8U}}{h_{4U}-h_{6U}}\cdot l_{HPCU}\right)+l_{CL}}, \tag{6}$$

where $\dot{Q}_0$ – refrigeration capacity of the cycle, W;

N_{CL} – lower cascade compressor power, W;

N_{LPCU} – low pressure compressor power of the upper cascade, W;

N_{HPCU} – high pressure compressor power of the upper cascade, W;

$l_{LPCU} = h_{2U} - h_{1U}$ – specific mass work low pressure compressor of the upper cascade, kJ/kg;

$l_{HPCU} = h_{5U} - h_{4U}$ – specific mass work high pressure compressor of the upper cascade, kJ/kg;

$l_{CL} = h_{2L} - h_{1L}$ – specific mass work of the lower cascade compressor, kJ/kg;

$q_{0U} = h_{1U} - h_{5U}$ – specific mass refrigeration capacity of the upper cascade, kJ/kg;

$q_{0L} = h_{6L} - h_{5L}$ – specific mass refrigeration capacity of the lower cascade, kJ/kg;

$q_{cL} = h_{2L} - h_{3L}$ – specific mass heat load of the lower cascade condenser, kJ/kg.

Summary results of calculations are given in Tab. 8.

Tab. 8. Summary calculation's results of modified cascade cycle (lower cascade – R290, upper cascade – R717)

Parameter	π_{st}^{U}	π_{st}^{L}	t_{2U}	t_{5U}	t_{2L}	x_{5U}	x_{5L}	COP
Unit of measurement	–	–	°C	°C	°C	–	–	–
Result	2.157	5.326	55	75	24	0.10	0.213	2.07

As can be seen from the calculation results (see Tab. 8), the use of a two-stage cycle in the upper cascade did not increase the energy efficiency of the refrigeration cycle as a whole and can not be absolutely recommended for implementation due to significant complication. On the other hand, the obvious advantages of this cycle include a significant reduction in refrigerant temperatures after compression and degrees of pressure increase in each stage of the upper cascade compressor. This will increase the feed rate of the compressor, reduce its weight and size and increase its service life.

The generalized results of the coefficients of thermal transformation according to comparative schemes are summarized in Tab. 9.

Tab. 9. Comparison of COP coefficients for different circuit solutions of refrigeration machines; condensation temperature 45 °C, boiling point –45 °C

№ cf.	Schematic solution	COP	Note
1	2	3	4
1	One-stage SCRM with subcooler*	1,71	refrigerant R717
2	Two-stage SCRM with a coil intermediate vessel	2,07	refrigerant R717
3	Cascade refrigeration machine	2,00	refrigerant of the upper cascade R717; refrigerant of the lower cascade R290
4	Modified cascade refrigeration machine	2,07	refrigerant of the upper cascade R717; refrigerant of the lower cascade R290

* calculations were not performed in this work

d) Investigation of the influence of the condensation temperature of the lower curcuit refrigerant on the energy efficiency of the cascade cycle

For a cascade refrigeration machine with a maximum COP, we investigate the choice of the optimal condensation temperature of the refrigerant of the lower cascade. To do this, set the values $t_{cL} = -20; -10; 10; 20\ °C$. The refrigerant of the lower cascade is R290, the refrigerant of the upper cascade is R717.

Thermal calculations of the cycles of the upper and lower cascades are performed accordence with the scheme shown in Fig. 3. The coefficient of tremotransformation COP is determined by formula (4).

The results of the calculations are summarized in Tab. 10.

Tab. 10 The influence of the condensation temperature of the upper circuit on the coefficient of thermal transformation of the cascade cycle

t_{cL}, °C	-20	-10	0	10	20
COP	1,94	2,01	2,00	2,00	1,91

As can be seen from the calculation results, the optimal condensing temperature range of the lower stage is $-10 \le t_{cL} \le 10\ °C$. Taking into account the condensation temperatures of the upper cascade $t_к = 45\ °C$ and boiling of the lower cascade $t_0 = -45\ °C$ it can be concluded that when calculating the cascade refrigeration machine using ammonia in the upper cascade, and in the lower propane, you can set the condensation temperature of the lower cascade as the arithmetic mean

$$t_{cL} = 0{,}5\left(t_{bL} + t_{cU}\right). \tag{7}$$

This will maintain the maximum energy efficiency of the cascade cycle.

V. CONCLUSIONS

Ways to increase the energy efficiency of low-temperature refrigeration machine are considered in the research work. Two basic approaches were considered: the choice of refrigerant or their combinations and the choice of circuit design.

As shown by the results of variable calculation of different circuit solutions of refrigeration machines, given in Tab. 9, the highest value of the cycle thermal transformation coefficient (COP = 2.07) was obtained in two cases: when using a two-stage SCRM with a coil intermediate vessel and a modified cascade refrigeration machine – this is a new circuit solution not described in classic textbooks on refrigeration machines. In addition, comparing the intermediate operating parameters of these circuit solutions, it is recommended to prefer a modified cascade refrigeration machine to provide better operating conditions for its compressors, namely,

maintaining lower cascades of pressure increase and final refrigerant temperatures after compression.

Studies of the choice of refrigerant of the lower cascade from the standpoint of energy saving have shown that the largest COP will occur in the following combination of refrigerants: refrigerant of the upper cascade R717, refrigerant of the lower cascade R290. These refrigerants are environmentally friendly, which meets the conditions of the task. Refrigerants previously used traditionally in the lower cascade, such as R13 and R23, were less effective. R744, which is currently often recommended for use in cascade cycles, has shown insufficient efficacy (for details, see Tab. 3–7).

The paper also shows (for details, see Tab. 10) that when selecting the intermediate temperature of the phase transition of the cascade cycle, you can set the condensation temperature of the lower cascade, using the formula (7).

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ANALYTICAL STUDY OF THE THERMAL CONDUCTIVITY PROCESSES AT CERAMIC SINTERING

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Abstract. *The analytical study of the processes of thermal conductivity at high intensity heating of dense bodies, similar to clay and plastic materials, was conducted. The conditions of applicability for the hyperbolic and parabolic equation of thermal conductivity for the composition of mathematical models of high intensity heating were explored. It was found that for the small Fourier numbers, the solution of hyperbolic equation of thermal conductivity makes it possible to determine thickness of the thermal layer and its change over time. Based on the example of manufacturing technical ceramics, it was demonstrated that the possible heating rates are considerably below the boundary rate, within which the velocity of heat propagation may be accepted as infinitely high. The conclusion was drawn that in the course of construction of mathematical models for the processes of thermal treatment in the technologies for the production of technical ceramics and the products similar to them in the intensity of heating, it is rational to take the thermal conductivity equation of parabolic type as the basis. The analytical solution, which makes it possible to calculate temperature field of the semi-restricted array under conditions of microwave heating, was obtained on the basis of the equation of thermal conductivity with internal heat sources, taking into consideration heat exchange with the environment. Results of computational experiment testify to the correctness of the proposed dependency.*

Keywords: *thermal conductivity, parabolic type, hyperbolic type, velocity of heat propagation, microwave heating*

I. INTRODUCTION

The application of methods of high-energy influence and their combining with the traditional technologies of thermal treatment of clay and plastic materials sets the aim of obtaining the assigned working properties and characteristics: the degree of resistance to wear and cracking, resistance to the influence of high temperatures, and the required mechanical and physical internal structure. Such materials find their use in machine building, microelectronics, biomechanics, power engineering, as well as in the aerospace and transport industry [1–3]. Heating in the microwave (~~MV~~ MW) field is also referred to intensive heating technologies [4]. The application of microwave heating offers possibilities of developing fundamentally new technologies of creation of promising ceramic, compositional and semiconductor materials [5]. The efficiency of obtaining such materials depends on the special features of forming the temperature field in a body, and obtaining data about it requires reliable mathematical models. However, at present there is a problem, connected with the uncertainty of approaches to the simulation of high intensity processes, in the first place, as a result of the uncertainty of assumptions, made with the formulation of the differential equation of

thermal conductivity. The concept of high intensity heating is used widely enough; in the course of construction of models, the equations of both hyperbolic and parabolic type are permissible, depending on the specific character of the heat propagation in certain material.

Thus, the relevance of the subject matter of the study is predetermined by the need of determining correct mathematical models of thermal conductivity for the conditions of high intensity heating of material. Analytical solutions give the opportunity to carry out computational experiments and, as a result, to obtain new knowledge about the influence of a wide spectrum of parameters of the process on the thermal state of the body.

II. LITERATURE REVIEW AND PROBLEM STATEMENT

The simulation of high intensity processes of heat propagation, in the course of which the disturbance of linear connection between the heat flux and the temperatures gradient is possible, presents special complexity [6–8]. Usually, while solving the problems of thermal conductivity, differential equation is usually used, in which a temporal and spatial change in temperature is described by the equation of parabolic form, however, with the description of high intensity processes, its application can lead to obtaining incorrect results.

As was noted in [9], a certain type of isothermal surface corresponds to a specific differential operator of thermal conductivity, among which the operator of the parabolic type is a special case. It is argued [9] that the attempt to obtain temperature fields from the parabolic operator through "imposing" different initial and boundary conditions led to the problem of paradoxes and incorrect problems.

The differential equation of thermal conductivity of parabolic type, connecting temporal and spatial change in temperature for the medium with variable physical characteristics and the internal heat sources on the assumption that the velocity of heat propagation is infinitely high, takes the following form:

$$\rho c \frac{\partial t}{\partial \tau} = div(\lambda gradt) + q_v \qquad (1)$$

In [10], the hypothesis of finite velocities of heat and mass propagation was proposed. In the cases when a linear relationship between the heat flux and the temperatures gradient is disrupted, density of the heat flux is determined by the generalized Fourier ’s Law (on assumption that thermo-physical characteristics do not depend on temperature and there are no internal heat sources):

$$\vec{q} = -\lambda \nabla t - \tau_r \frac{\partial \vec{q}}{\partial \tau} \qquad (2)$$

where τ_r is the constant of time (relaxation time).

With an abrupt change of q, the reconstruction of the temperature field and the gradient of temperature occurs with the displacement in time (τ_r). The velocity of heat propagation is determined by expression:

$$w_r = \sqrt{\frac{a}{\tau_r}} \quad (3)$$

For example, for nitrogen $\tau_r=10^{-9}$s, w_r=150 m/s; for aluminum $\tau_r=10^{-11}$ s, w_r=1500 m/s.

The differential equation of thermal conductivity with regard to the relaxation processes was obtained using the equation of heat balance and generalized Fourier 's Law:

$$\frac{\partial t}{\partial \tau} + \tau_r \frac{\partial^2 t}{\partial \tau^2} = a\nabla^2 t \quad (4)$$

It is called the hyperbolic equation of thermal conductivity. The transfer to the hyperbolic operator removes some incorrect solutions of classical theory of thermal conductivity [11].

At present, considerable attention is paid to the construction of mathematical models of thermal conductivity on the basis of hyperbolic equation. In [12], the results of studying solutions to boundary-value transferring problems for hyperbolic equations were presented, in which the correctness of setting the task with boundary condition of I and III kinds was considered. In [13], the accurate analytical solution of the hyperbolic equation of thermal conductivity for the infinite plate with the boundary conditions of the first order was obtained. It was shown that warming (cooling) of a body is determined by the motion of the front of shock thermal wave, at which the temperature jump occurs. In this case, two sub–areas are obtained: in one of them, temperature varies from the temperature on the wall to the temperature on the wave front, in the other one, the unperturbated, the temperature is equal to the initial temperature. In [14], the wave heat transfer in the linear and nonlinear media on the basis of the law of thermal conductivity is explored, which considers not only the first and second derivatives of time of heat flux, but also derivatives of higher orders. This made it possible to pass over to the problem on the basis of parabolic equation with the argument delayed in time.

In [15], the solution to the nonlinear equation of thermal conductivity, based on the relaxation model of the heat transfer for quasi-stationary heating regime was obtained, which made it possible to receive dependency for the maximum heating rate, above which it is necessary to consider that the velocity of heat propagation is finite:

$$\left.\frac{dT}{d\tau}\right|_{\max} = \frac{V_r^2}{a_r - \tau_r V_r^2}\left(T_w - T_0\right) \quad (5)$$

where V_r is the linear rate of the surface (isotherm) motion, a_r is the thermal diffusivity the, T_w, T_0 are the temperatures of the surface (isotherm) and the environment, respectively.

The thermal diffusivity may be determined from the ratio for the relaxation time, given in [16]:

$$\tau_r = 3a_r / \upsilon_r^2 \qquad (6)$$

where υ_r is the speed of sound.

For evaluating the boundary rate of heating the material on condition that $\tau_r V_w^2 \le 0{,}1 \cdot a_r$ the following dependency was proposed [15]:

$$\left.\frac{dT}{d\tau}\right|_{\max} = \frac{T_w - T_0}{9\tau_r} \qquad (7)$$

The relaxation time was evaluated by different authors for different types of materials, and it was established that its value lies within the limits from 10^{-9} s for gases to 10^{-14} s for metals. The heating rate above 100 K/s is referred to as high.

With the essential dependency of thermo-physical and electro-physical properties on temperature, the analytical methods of solving prove to be ineffective. In this case, the solutions are obtained with the help of numerical methods. The drawbacks of numerical methods are connected to the fact that, underlying them, there is an error, connected with the replacement of the initial equations with approximating equations, that is, an error of computational algorithm appears, furthermore, their use is labor–intensive [17].

A separate problem of mathematical simulation of the processes of thermal conductivity is heating in the microwave field since here it is necessary to consider the conversion of electromagnetic energy to the internal energy in the volume of a body. At the same time, the technologies of obtaining materials, based on microwave heating, are becoming increasingly common [18–20]. Based on the application of theory of generalized functions through reducing the problem of thermal conductivity for a multilayer construction to the single-layer one with the variable (discontinued) physical properties of the medium in the closed form, the accurate analytical solution of the problem of non-stationary thermal conductivity with the internal heat sources varying in time, was obtained [21]. However, the proposed dependencies have their constraints and may be used exclusively for the multilayer constructions at the assigned values of internal heat sources.

As a result of analysis of literature data, it was revealed that there is no certainty in the selection of differential operator for the simulation of high intensity processes of heating bodies and there is no explicit model, which describes the non-stationary thermal conductivity of heating a semi-infinite array under the action of the microwave field.

III. THE AIM AND THE TASKS OF THE STUDY

The purpose of the work is to build up mathematical models of high intensity heating of dense bodies, the properties of which are similar to clay materials and

plastics, used in the production of technical ceramics and different compositional articles.

To achieve the aim, the following range of problems was to be solved:

– to analyze existing solutions of hyperbolic equations of thermal conductivity and to estimate their applicability for calculating the high intensity processes of production, in particular ceramics;

– to estimate the contribution of relaxation phenomena to the processes, the intensity of which is limited by requirements for the production of ceramics;

– to obtain dependencies for calculating temperature during microwave heating of a semi–restricted array for the boundary conditions of the III kind;

– to conduct computational experiment regarding the obtained dependencies for the purpose of their verification.

IV. MATHEMATICAL METHODS FOR THE ANALYSIS OF THERMAL STATE OF A BODY

4.1. Analysis of the non-stationary thermal conductivity of a body based on the model with hyperbolic equation

The study of the thermal state of a body was carried out with the use of the dependencies [13]. Fig. 1 presents the graph of the change in the excess body temperature at different values Fo. The following designations were accepted: relaxation Fourier number $Fo_r = \frac{a \cdot \tau_r}{\delta^2}$ relative coordinate $\xi = \frac{x}{\delta}$ dimensionless excess temperature

$$\theta = \frac{t - t_a}{t_0 - t_a}$$

where t_0, t are the initial and current temperatures of material, t_a is the ambient temperature.

The calculations were performed under the following conditions: $Fo_r=2{,}78\cdot10^{-11}$, $\delta=0{,}06$ m. At Fo of the order of 10^{-3} – 10^{-4}, a substantial change in temperature at the border of a body is observed, then the temperature curve begins to smooth out: in these cases, the form of curves corresponds to the results, obtained by the known dependencies, based on the differential equation of thermal conductivity of parabolic type. The heat front at $Fo=2{,}78\cdot10^{-4}$ is limited by dimensionless coordinate $\xi=0{,}97$, at $Fo=2{,}78\cdot10^{-3}$, the coordinate was displaced to the value $\xi=0{,}92$.

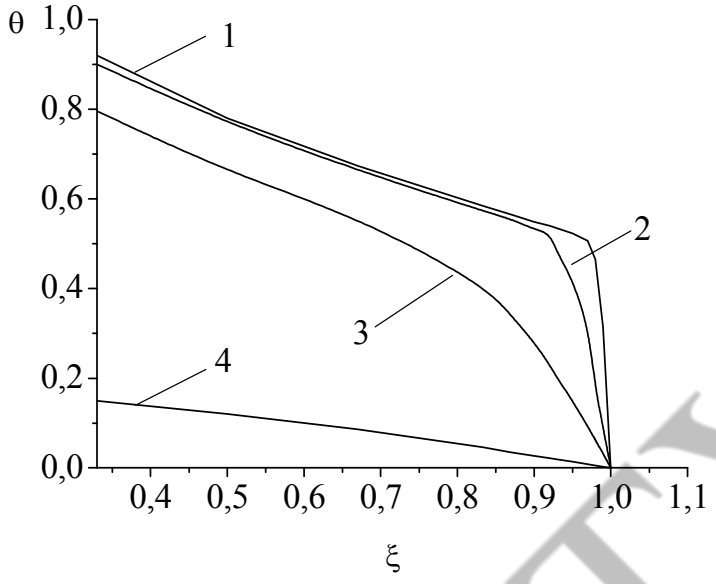


Fig. 1. Change in excess temperature of the body Θ by dimensionless coordinate ξ at different values of the Fourier number: 1 – Fo=2,78·10^{-4}, 2 – Fo=2,78·10^{-3}, 3 – Fo=2,78·10^{-2}, 4 – Fo=2,78·10^{-1}

It appears that the application of the equation of thermal conductivity of hyperbolic type makes it possible to solve the problem of the Fourier small numbers. At the Fourier small numbers, warming (cooling) of a body is determined by motion of the front of the shock thermal wave, at which the temperature jump occurs.

Analysis of the need to apply the hyperbolic equation of thermal conductivity was conducted based on the calculation data of temperature when assigning extremely high values of temperatures of the heating surface: from 3000 ºC to 4000 ºC (for example, during sintering of ceramics, the temperature does not exceed 1420 ºC). It was found that the heating rate under these conditions is 2,6 K/s –3,8 K/s. At the same time, in accordance with dependency (7) for clay materials, the properties of which were determined according to [22], the boundary heating rate was 13185 K/s (the melting point of kaolin (1800 ºC) was accepted as T_w, the starting temperature T_0=20 ºC). Thus, in the course of simulation of temperature field in the processes of ceramics sintering, there is a possibility in principle to apply the thermal conductivity equations of parabolic type.

4.2. Mathematical model of non–stationary thermal conductivity based on parabolic equation with internal heat sources

When formulating the model, the following conditions were accepted. The layer of material is considered as a semi-restricted array with the thermal insulation of lateral surface at the initial temperature t_0. Inside the rod, there acts a positive heat source, caused by the action of the microwave field, specific power of which is q_v, W/m^3. The heat exchange with the environment takes place according to the law of Newton – Richman (boundary condition of the third kind). It is necessary to find the distribution of temperature by the length of the array at an arbitrary moment of time. Mathematical

record of this problem is represented as follows:

$$\frac{\partial t(x,\tau)}{\partial \tau} = a \cdot \frac{\partial^2 t(x,\tau)}{\partial x^2} + \frac{q_v}{c \cdot \rho} \qquad (8)$$

$$t(x.0) = t_0 \qquad (9)$$

$$\frac{\partial t(\infty,\tau)}{\partial x} = 0 \qquad (10)$$

$$\alpha(t(0,\tau) - t_a) = -\lambda \frac{\partial t(0,\tau)}{\partial x} \qquad (11)$$

Here t is the temperature, x is the current coordinate, τ is the time, a, λ, c, ρ are, respectively, the coefficients of temperature conductivity and thermal conductivity, specific heat capacity and density of layer of material; α is the heat emission coefficient, q_v is the positive heat source.

It is accepted, that internal heat sources are the exponential function of the coordinate: $q_v = q_{v0} \cdot e^{-\beta \cdot x}$. Here q_{v0} is the maximum specific ~~capacity~~ power of the positive source, γ is the coefficient of attenuation of electromagnetic energy in the layer, m^{-1}.

By using the Laplace transform, solution (8) was obtained with the conditions of unambiguity (9)–(11):

$$T(x,\tau) = \left(\frac{T_a - T_0}{\lambda/\gamma} + \frac{q_{v0}}{c \cdot \rho \cdot a}\right) \cdot \left(-\frac{\lambda}{\alpha} \cdot Erfc\left(\frac{x}{2 \cdot \sqrt{a \cdot \tau}}\right) + \frac{\lambda}{\alpha} \cdot e^{-\frac{\gamma}{\lambda} \cdot \sqrt{a} \cdot \left(-\frac{\alpha}{\lambda} \sqrt{a} \cdot \tau + \frac{x}{\sqrt{a}}\right)} \cdot \right.$$

$$\left. \cdot Erfc\left(\frac{x}{2 \cdot \sqrt{a \cdot \tau}} - \frac{\alpha}{\lambda} \cdot \sqrt{a \cdot \tau}\right)\right) + \frac{q_{v0} \cdot (\alpha - \lambda \cdot \gamma)}{c \cdot \rho \cdot a} \cdot \frac{1}{2 \cdot \gamma^2 \cdot \lambda} \cdot \left\{ \frac{1}{\gamma - \frac{\alpha}{\lambda}} \cdot \left(-Erfc\left(\frac{x}{2 \cdot \sqrt{a \cdot \tau}}\right) + e^{-\gamma \cdot \sqrt{a} \cdot \left(-\gamma \cdot \sqrt{a} \cdot \tau + \frac{x}{\sqrt{a}}\right)} \cdot \right.\right. \qquad (12)$$

$$\left. \cdot Erfc\left(\frac{x}{2 \cdot \sqrt{a \cdot \tau}} - \gamma \cdot \sqrt{a \cdot \tau}\right)\right) + \frac{1}{\gamma \cdot \left(\gamma + \frac{\alpha}{\lambda}\right)} \cdot \left(Erfc\left(\frac{x}{2 \cdot \sqrt{a \cdot \tau}}\right) + e^{\gamma \cdot \sqrt{a} \cdot \left(\gamma \cdot \sqrt{a} \cdot \tau + \frac{x}{\sqrt{a}}\right)} \cdot Erfc\left(\frac{x}{2 \cdot \sqrt{a \cdot \tau}} + \gamma \cdot \sqrt{a \cdot \tau}\right)\right) \Big\} +$$

$$+ \frac{q_{v0}}{c \cdot \rho \cdot a \cdot \gamma^2} \cdot \left(e^{a \cdot \gamma^2 \cdot \tau} - 1\right) \cdot \cdot e^{-\gamma \cdot x} + T_0$$

The obtained dependency enables us to calculate the temperature of a semi-infinite array at different geometric and physical conditions, media and material.

V. RESULTS OF ANALYTICAL STUDY OF THE TEMPERATURE FIELD OF A SEMI-RESTRICTED ARRAY AND THEIR DISCUSSION

The analytical study of the temperature field of a semi-restricted array was conducted with the variation in the following determining characteristics: the the heat transfer coefficient α, the coefficient of absorption of electromagnetic energy γ, the layer thickness x, initial temperature of material t_0 and the ambient temperature t_a.

Fig. 2 demonstrates the change in temperature by the depth of material.

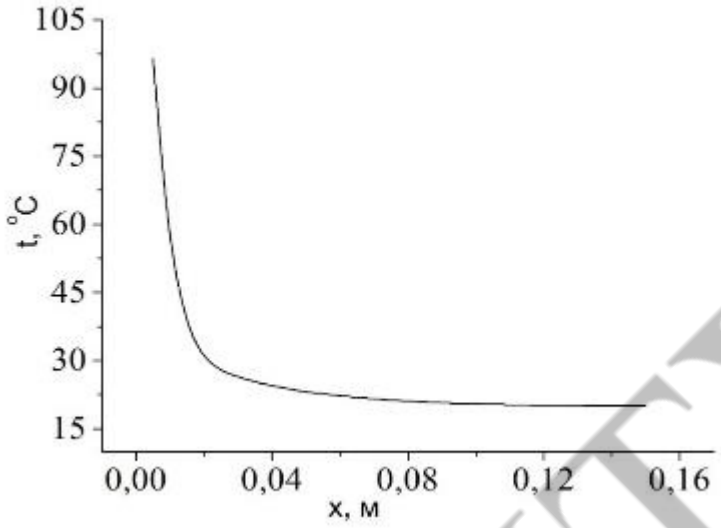


Fig. 2. Change in the temperature of material t by the depth x: τ=100 s

The data were obtained for the following conditions: α=20 W/(m^{2}K), x=0,001 m, $q_{v0}=3\cdot10^5$ W/m^3, γ=35m^{-1}, t_0=20° C, t_a=20 ^{o}C. It is evident that at a certain distance from the surface, the intensity of increase in temperature is considerably lower than in the layers, close to the surface, which is connected to the attenuation of electromagnetic energy by depth.

Effect of the heat transfer coefficient on the distribution of temperatures in the material is demonstrated by Fig. 3. It can be seen that the heat emission coefficient exerts a substantial influence on the layers, close to the surface. Low values of α lead to the fact that in the layers, close to the surface, in which the attenuation of electromagnetic energy is insignificant, the temperature grows substantially.

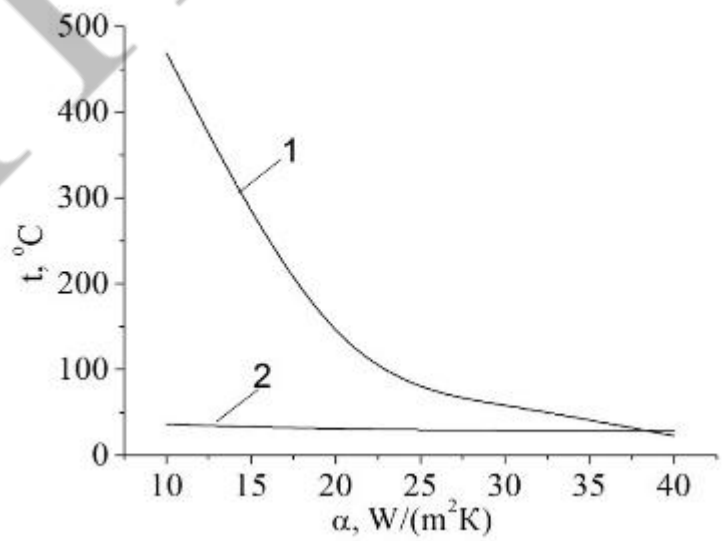


Fig. 3. Effect of the heat transfer coefficient α on the temperature of material t: τ=100 s, 1 – x=0,01 m, 2 – x=0,021 m

The absorption coefficient γ produces considerable effect on the temperature of material and on the uniformity of its heating (Fig. 4). The calculation shows that in immediate proximity from the surface at values $\gamma \leq 50$ m^{-1}, temperature of the material grows with an increase in γ, and in this case, this increase slows down. At $\gamma > 50$ м$^{-1}$, a drop in temperature is observed. At a larger depth of the array, an increase in γ leads to the monotonous decrease in temperature. This can be explained by the fact that at the low values of γ, the influence of internal heat sources is more substantial than the heat emission from the surface.

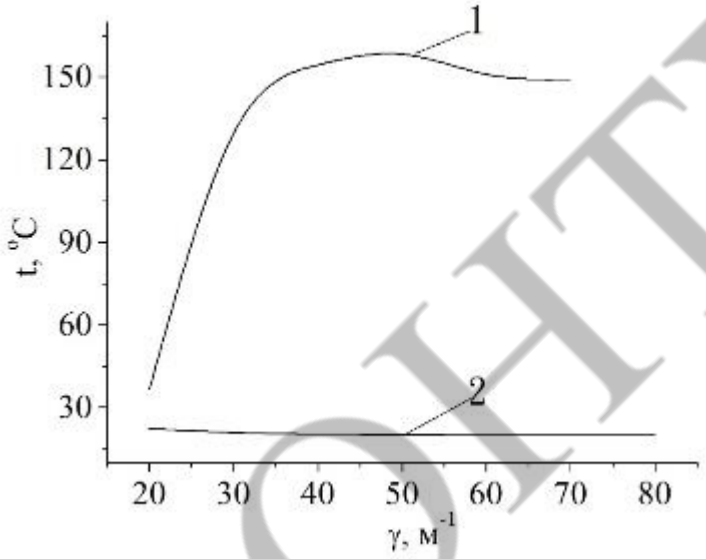
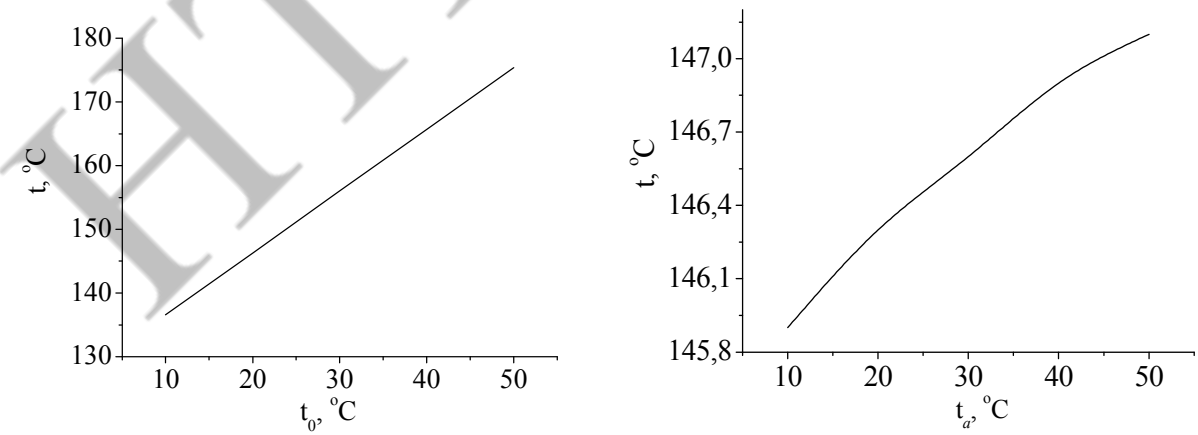


Fig. 4. Influence of the absorption coefficient γ on the temperature of material t at τ=100 s: 1 – x=0,01 m, 2 – x=0,021 m

The effect of initial temperature of the material and temperature of air on the change in the temperature of array is shown in Fig. 5. The nature of change in the body temperature correctly reflects the influence of the varied parameters.



a *b*

Fig. 5. Change in the temperature t of array depending on determining temperatures: *a* – effect of the initial temperature of array t_0, *b* – effect of temperature of air t_a, τ=100 s, x=0,001 m

Analysis of results of the calculations allows us to conclude that the obtained analytical dependency (12) may be recommended for calculating the temperature field of dielectric material, in particular, for the production of technical ceramics, under the effect of positive internal heat sources, for example, from the microwave electromagnetic field.

VI. DISCUSSION OF RESULTS OF ANALYTICAL STUDY OF THE PROCESSES OF THERMAL CONDUCTIVITY AT HIGH INTENSITY HEATING

The calculation study of change in the temperature field in the material, the thermo-physical properties of which corresponded to clay, carried out on the dependencies, obtained on the basis of the hyperbolic equation of thermal conductivity, demonstrated influence of the Fourier numbers. It was revealed that at the values Fo, commensurate with the relaxation Fo_r, two areas are formed, which correspond to a thermal layer and the layer, in which relaxation processes were not completed. It is evident from Fig. 1 that the closer the value Fo to Fo_r, the more vividly these areas are expressed. At a considerable disagreement, the nature of change in the temperature curve becomes monotonous (Fig. 1, line 4).

Thus, the solution of the hyperbolic equation of thermal conductivity, given in [13], makes it possible to obtain data for the small Fourier numbers and to determine thickness of a thermal layer at different moments of time.

By the proposed dependencies [13], obtained with with boundary conditions of the first kind, the rates of heating clay semi-array for different surface temperatures were calculated. The results show that the heating rates are considerably below the boundary rate, at which the influence of relaxation processes should be considered. Thus, when assigning the surface temperature t_0=400 ºC, the heating rate does not exceed 4 K/s while the boundary rate for the examined material is 13185 K/s. Therefore, all existing technological heating processes may be simulated on the basis of the thermal conductivity equations of parabolic type.

The microwave technologies of the production of technical ceramics and composite materials are of special interest. Due to a specific character of heating in the microwave field, the possibility of obtaining materials with the improved operational and functional properties emerges. However, there are difficulties of obtaining analytical solutions of the equations of thermal conductivity due to the need for considering the internal heat sources and special features of conversion of electromagnetic energy to internal energy. Solutions [10] are limited by the condition, at which ambient temperature must be higher than the temperature of material, which is rarely possible at microwave heating. There is a solution for the unrestricted plate with boundary conditions of the third kind [18], however, similar analytical dependencies were not obtained for the bodies of other form. This led to the need of obtaining analytical solution in the explicit form for a semi-restricted array with boundary conditions of the third kind. In the process of the model composition, we made assumptions that ambient temperature, thermo-physical and electro-physical properties (which are expressed in the value of the absorption coefficient γ) remained constant, and the initial temperature of array in all its points was identical. The solution,

obtained with the aid of the operating method, demonstrates its workability when conducting computational experiment. This allowed us to recommend it for the calculation of temperature field of dielectric material when heating under conditions of action of microwave field.

To refine the calculation results, the dependency of the absorption coefficient on the temperature of material and its structural characteristics, changing in the process of heating, should be established. Furthermore, the data on the coefficients of absorption of electromagnetic energy are very limited, which does not allow making accurate calculations for a wide range of materials. Obtaining these data requires conducting separate experimental studies. Nevertheless, the main result of the performed work lies in the fact that we obtained the dependency, which makes it possible to receive information about the thermal state of a body at its heating in the microwave field and to define influence of the determining regime parameters on the heat exchange process.

VII. CONCLUSIONS

1. The analytical study of change in the temperature field in material demonstrated that at values of the Fourier numbers, commensurate with the Fourier's relaxation numbers, two areas are formed, which correspond to a thermal layer and the layer, in which relaxation processes were not completed.

2. The contribution of relaxation phenomena to the processes, the intensity of which is limited by requirements for the production, for example, of ceramics, can be disregarded. It was shown that the possible heating rates based on the example of the production of technical ceramics are considerably lower than the boundary rates, above which it is not possible to accept the hypothesis about the infinite velocity of heat propagation. In the process of construction of mathematical models, it is expedient to take the equation of thermal conductivity of parabolic type as the basis.

3. Authors proposed a mathematical model of thermal conductivity of a semi-restricted array under the effect of internal heat sources for the boundary conditions of the III kind in the differential form. As the result of its solution, we obtained analytical dependencies for the calculation of temperature of the array at its heating under conditions of action of the internal heat sources, in particular, in the microwave field.

4. The proposed dependency for calculating the dimensionless excess temperature makes it possible to obtain information about a thermal state of a body at its heating in the microwave field and to determine influence of the determining characteristics – the heat emission coefficient, the coefficient of absorption of electromagnetic energy, thickness of the layer, initial temperature of material and ambient temperature – on the heat exchange process.

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HELIUM PRODUCTION FROM NATURAL GAS AND MARKET ANALYSIS

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Abstract: *Helium is a non-renewable gas used in emerging applications as well as in well-established industries of more than 5 decades. Because it has such unique properties, it is difficult to replace it with another element.*

Helium is obtained as a by-product natural gas purification via cryogenic distillation, therefore its production is tied to that of methane. Helium as a by- product of this process is only profitable depending on the percentage that the natural gas carries. One part of the market is supplied by natural gas producers such as Gazprom, Exxon-Mobile and Qatar gas and the other part by annual auctions of the United States Federal Helium Reserve, which sells crude gas to refineries of Linde, Air Liquide, Praxair, Air Products and Messier. This scenario is about to change due to the total privatization of the reserve in Amarillo Texas and the sale of the last public reserves.

On the other hand, electromagnetic resonances always accounted for most of the helium demand, but the machines have been modernized and consume less without sacrificing efficiency. Experts suggest that helium consumption for the production of semiconductors and optical fibers in electronics will exceed that of MRIs in the coming years.

The helium market is volatile not only due to supply and demand but also due to logistics and storage complexities: in the past 15 there were three Helium Shortages that is 6 years in which supply could not meet demand. With inelastic economic characteristics and production methods that present adversities to supply the demand, this research opts for a better understanding of the elements that influence the second most common element in the universe but of limited quantities on Earth.

Keywords: *Helium, natural gas, cryogenics, MRI, BLM, Amur.*

I. INTRODUCTION

The work that follows aims to understand technical and economic elements that influence helium as a gas for industrial and technological use. First, a detailed description of helium's unique characteristics and specific applications is described, followed by an understanding of why it is such a unique element.

Then an economic analysis based on demand, supply and the largest traders in the world is conducted. Based on historical facts, information collected by experts, relevant news and market data related to helium as a product, an attempt is made to identify the forces that affect the price and quantity in the market.

From a better perception of the market the production process is described. The different technologies that allow obtaining high purity helium from natural gas are demonstrated to obtain a summary of the critical points for its purification and liquefaction.

II. Helium

2.1. Properties

The symbol for Helium is He, it has an atomic number of 2. It is an inert gas with no color or odor [Meyer, 1926]. Its two most important isotopes are 3 2He with a natural occurrence of 0.000137%, and 4 2He with a natural occurrence of 99,99% both stable. Its density at 298 K is 0.1785 kg/m3 . This element has a boiling point of 4.15K (-269ºC) [Sicius, 2016].

For pressures below about 2.5 MPa, helium remains liquid down to absolute zero [Leyarovski et al., 1986]. Under standard conditions, helium behaves almost like an ideal gas. The weight of one m3 of helium is 179g under standard conditions. Helium as an ideal gas has a heat capacity of 5.238 kJ / (kg K). And as a gas at atmospheric pressure a thermal conductivity of 0.143 W/(m K) [Langeheinecke et al., 2020], [Winnacker et al.,]. It has a boiling point of -269ºC (4.15K), a heat of vaporization of 0.084 (kJ / mol), its triple point is -270ºC at 5.043kPa and its critical point is -267.96ºC and 227.5 MPa [Dohmann,].

In 1895, Ramsay produced helium by adding acid to uranium and isolating the gas that formed in the subsequent reaction. [Meyer, 1926]. Helium recorded the yellow line D3, which was characteristic of helium and was already known at the time, having previously separated nitrogen and oxygen. Almost simultaneously, Crookes and Cleve Langlet carried out a similar experiment. They recovered a sufficient quantity to determine the atomic mass of the gas [Sicius, 2016]. A little later, an oil well operated in Kansas delivered a natural gas that contained up to 12% by volume of an as yet unknown gas. Cady and McFarland proved in 1905 that it was helium. Almost simultaneously, Rutherford and Royds showed that alpha particles are helium nuclei [Sicius, 2016].

2.2. Sources

The first detection of He in air is based on the lines of the spectrum of crude argon. A He-Nemixture was prepared using liquid hydrogen. The content in air was first determined by Ramsay in 1905 and then in 1908 at 0.0004% by volume. Subsequent determinations showed 0.0005% volume by Claude [Meyer, 1926]. A newer study shows that the amount of Helium in the air is close to 0, according to B.M. Oliver Measurements in 1981 of the helium content of the Earth's lower atmosphere have given a value of 5.222 ± 0.017 ppm by volume [Oliver et al., 1984]. Even though it is one of the most abundant elements in the Earths air its quantities are still low compared to natural gas deposits [Littlejohn, 1993].

The helium that accumulates in the atmosphere could be the result of venting the helium separated in natural gas production but according to the study it is not really quantifiable.Helium II moves up against gravity on surfaces this phenomena is known as Ones effect [Westphal, 2013]. Helium can be obtained from liquefied atmospheric air by fractional distillation, this was done for the first time in 1900 by Ramsay and Travers. They obtained a mixture of HeNe from which pure Neon is generated, but even after laborious fractionation and the use of very low temperatures, they did not obtain pure helium [Meyer, 1926]. This shows how energy intensive and complicated

it is to extract Helium from air in comparison to its major source is: Natural Gas. Helium is separated from methane and other gases by using their physical properties of adsorption like in air separation processes. [Van Sciver, 2013]. Therefore, helium is obtained from natural gas by fractional distillation. By cooling natural gas, it is possible to separate helium from hydrocarbons and nitrogenous compounds contained in crude natural gas [Timmerhaus, 2013].

Helium is formed during radioactive atomic decay. On earth, 4 2He (Alpha-particles) is formed during Alpha-decay of various radioactive elements such as uranium or radium. Most of the Helium on earth comes from radioactive decay [Sicius, 2016]. From 1 Curie of Radium emanation in equilibrium with Radium-A, Radium-B and Radium-C, Danysz and Duane in 1912 calculated the formation of Helium of for 1g of Radium per year [Meyer, 1926]. Helium formation from Uranium. Helium can also be formed by alpha elements decay from Uranium and Thorium [Grynia and Griffin, 2016]. It is certainly a decay product of Uranium [Grynia and Griffin, 2016], [Meyer, 1926], [Yakuceni, 2009]. For 1g Uranium, a Helium formation of 2 to 4.5x10−12g per year was calculated.

III. Application

Helium is now used in a great many applications [Sicius, 2016].In welding technology, helium is used as an inert gas to protect the welding point from oxygen entering [Mohler, 1983]. In the food processing industry it is used as a packing gas [Kuhnert, 2014].

For analyzing critical products, which need to be totally hermetic, the use of gases in leakage tests has been implemented in several areas. Helium is used also for quality control of oral drug container products. If a leak is detected then the part is defective [Kossinna and Meyer, 2010] and needs a replacement or has to be fixed. In intensive care medicine, a helium-oxygen mixture (80:20) is used as breathing gas, which flows through constrictions with less resistance [Gupta and Cheifetz, 2005]. When diving, it is used as breathing gas: Trimix (oxygen, nitrogen, helium), Hydreliox (hydrogen, helium, oxygen) and Heliox (helium, oxygen) [Lettnin, 2012].

There are two ways to decrease the ohm resistance of a conductor. The first option is to change the thickness and the length of the cable. The larger the diameter of the cable and the shorter it is, the smaller the electrical resistance, but short and thick cables are not so convenient or practical. The second dependence of the resistance is on the temperature of the conductor. The colder the temperature, the lower the resistance of the conductor [Lemmer et al., 2017].In 1911 Heike Kamerlingh Onnes examined the electrical resistance of mercury with liquid helium at 4K and the resistance came down to zero. So he discovered the phenomenon of superconductivity [Huebener, 2017]. Helium plays a central role in superconductivity.

Regardless of improvement in high temperature superconductors, helium is still chosen as a coolant [Glowacki et al., 2013]. If superconductors are used, the helium used as a coolant helps to keep them below their transition temperature, e.g. in magnetic resonance imaging (MRI) [Sicius, 2016].

Nuclear magnetic resonance tomographies have shown high-resolution images from the body inside for the past decades using Helium to reduce the temperature of

the magnets [Lvovsky et al., 2013], [Heil, 1997]. This technology has been developed further the past years, for example it is possible super fast lung ventilation magnetic resonance imaging using hyperpolarized Helium-3 [Schreiber et al., 2000].The MRI with hyperpolarized 3-He enables a detailed representation of the body morphology as well as organ and internal functions. [Morbach et al., 2006].

Aside from medical applications like MRI, superconductors are also used in nuclear magnetic spectroscopy. For alloys in the magnets to even reach superconductivity they have to be cooled down at cryogenic temperatures [Styles et al., 1984]. NMR-spectroscopy has been used in chemical analysis for determining and checking the structure of small molecules. The reason Helium plays a big role in superconductivity is because when the coil is completely wound, the wire can become superconducting once the materials lowered to a temperature of 2K. The magnet is hung on a Dewar Vessel with liquid Helium and such a low temperature can be reached [R¨uterjans et al., 1996]. Nevertheless MRI technology has improved since it was invented and a lot of hospitals have transitioned from consuming one thousand liters of liquid helium per year for every machine to newer Zero boil off machines, which according to [Cockerill, 2021a] have shrunk in size and consume therefore less liquid helium than before.

In the Large Hadron Collider at the CERN research center in Geneva, two opposing beams with protons are accelerated into a 26.7 km tube. The rays cross in four places and are brought to collision after reaching the final energy. 9300 magnets keep the particle beams on the path. The magnets at CERN, which are necessary to focus the particle beams, are operated at a temperature of 1.9K, the rest of the accelerator at 4.5K. 700,000 liters of liquid helium are required to cool the material down [M¨uller, 2008].

According to [Scholes, 2011] NASA and the USA Military are the biggest consumers of helium to cool hydrogen and oxygen propulsion rockets down. In chemical rockets fuel-tank systems, two propellants are fed liquid fuel from two tanks via double injection. In case of liquid propulsion the fuel tanks must have a higher pressure than the combustion chamber. The fuels are injected by over pressure [Messerschmid and Fasoulas, 2011]. One method to deliver propellants the fuel is with pressurized gas. Neutral gases such as Helium or Nitrogen are used to push the fuel into the engine. Helium dissolves less in liquid oxygen, therefore it is the favored option [Sutton and Biblarz, 2016]. When using a pressurized gas the helium is fed into the fuel tanks and presses the fuel into the combustion chamber. Pressurized Helium can also be carried in gas phase in the same tank as the liquid fuels and be in contact with the liquids to pump them out. Another method is to use pumps to push fuels to the combustion chamber. In this case Helium replaces liquid fuel from the tank to maintain it pressurized [Ingenbergs, 2002]. Besides using He in Propulsion Systems, it is used to remove any remaining air from the engines to prevent that it freezes in the ducts [Sutton and Biblarz, 2016]. In laser technologies Helium is used as a buffer gas in Helium-Neon Excimer lasers in a range of 157nm-351nm wavelangth [Svelto and Hanna, 1998].

In high temperature nuclear reactors HTR that use graphite as main material in the reaction chamber, helium has two important roles in the process. It cools the

reaction chamber down [Wu et al., 2002] and functions as a heat carrier for generating the steam. Helium is first heated up to 700ºC and carries the heat to produce 530ºC steam [Kugeler, 2001]. When using helium for this purposes it has the advantages of being inert and having the highest thermal conductivity of all gases after Hydrogen [Van Sciver, 2013], [Sicius, 2016].

A specialized use of helium is for the manufacture of optical fibers. The gas is injected in process cooling unit after the furnace and provides sufficient cooling so that the glass fibers do not break this way the drawing speed of the fibers is increased [Park et al., 2014].

A market that might grow is the use of helium in electronics [Cockerill, 2021a]. For instance in semiconductors production the gas is used to create an inert environment around the silicon to avoid undesired reactions [Filtvedt et al., 2010]. According to [Jelinek, 2018] the revenue of the semiconductor industry is expected to keep growing in the following years and after COVID-19 the semiconductor market could rise stronger like other electronic technology materials [Bauer et al., 2020] see Fig. 1.

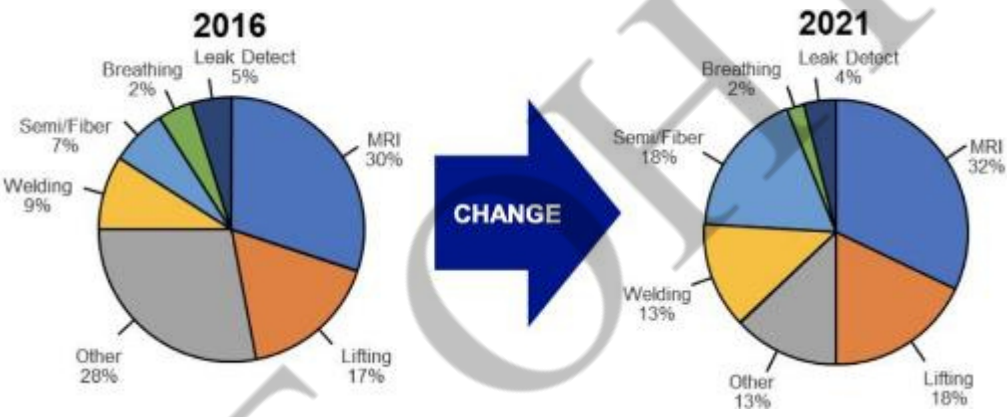

Fig. 1 Helium Transition: *High-tech usage in the semiconductor and fiber-optic segments has increased dramatically. It is expected that helium will play a significant role in the global refrigeration and transportation of COVID vaccines.*[Garvey , 2021]

IV. Supply and Demand

The helium supply chain starts with the radioactive decay and the helium mixed in the raw natural gas reserves. The first level of helium flow in the industrial supply chain consists of the natural gas extraction and processing. Helium is treated as a byproduct and is separated from the other components such as carbon-oxide and carbon-dioxide, hydrogen, nitrogen and hydrocarbons by cryogenic processes [Wilson and Newsom, 1968]. After this step crude helium is obtained with purities between 60 to 80 percent [Snyder and Bottoms, 1930].

Unpurified helium contains high amounts of nitrogen, the separation of the gases and components of crude helium to obtain high purity comprises the second level of the supply chain [Hamedi et al., 2019]. Helium refiners produce Grade-A Helium (high purity helium), they process crude helium and sell it for higher pices [Anderson, 2018], see Fig 2. This “high quality” helium can have a purity up to 99,99% purity with very low percentages of other components like hydrogen, oxygen and water [Sifrig et al., 2021].

After extraction, production and purification: the gas can be liquefied for special applications or stored as a gas at high pressures. When helium can be transported in liquid state in containers with volumes of 25000nm^3. Liquid helium distribution has technical complications and significant losses due to temperature increase during transportation it boils. The other option to store and transport helium is as gas under high pressures [Smith et al., 2004]. In the third level of the chain, helium is sold to end users by refiners and non-refiners [Bell et al., 1983] or to smaller gas distributors that commercialize the gas and transport helium with trucks and storage tanks [Dong et al., 2014].

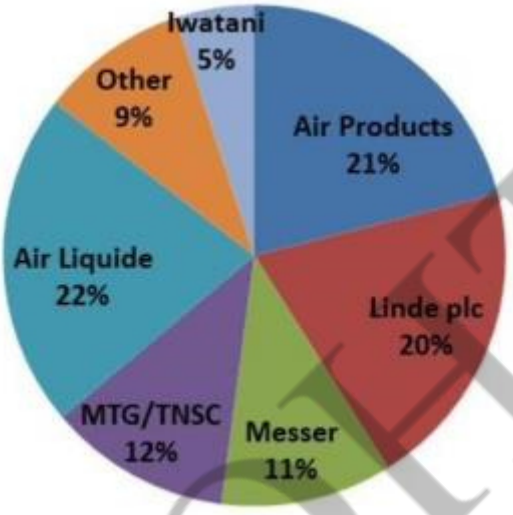

Fig. 2 World Wide refiners Share of Supply (Production)-2021: *2021 World Wide Helium Produciton 5.9 Billion Cubic Feet.* [Garvey, 2021]

For years helium has been squandered because it is treated as an undesired byproduct from natural gas production facilities. Methane producers vent helium into the atmosphere [Nuttall et al., 2012b], which is counterproductive since purifying the gas from the air is more expensive than methane 3. Regularly increase on Helium consumption and demand will presumably continue [Olafsdottir and Sverdrup, 2020].

According to [Anderson, 2018] the helium market is complex due to inelastic demand, production of the gas only as a byproduct plus only a few big helium producing companies. Since the demand is uncertain, producers only separate helium from natural gas if the they have storage facilities where the gas does not leak [Council et al., 2010]. For example refineries with access to the National Helium Reserve in Amarillo Texas. If they don't have easy access to any storage it is cheaper sometimes for the companies to vent it or leave it in a low percentage mixed with the natural gas [Clarke et al., 2013] because it is a harmless and an inert element.

After the Federal Helium Reserve (FHR) facility was completed in the 60´s the governmental consumption of helium in the united states for military rockets and space exploration increased [Sears, 2012]. Apart from these consumption increases there was not enough demand to justify the investment in another storage facility like the FHR [Anderson, 2018].

An important transition use in Helium markets according to Global Helium [Garvey and Associates, 2021] and J.R. Campbell and Associates [Gravey, 2021] took place in the past four years: semiconductors and fiber optic share of the helium users

increased from 7% in 2016 to 18% in 2021. This could influence the helium consumption regions depending on fiber optic or electrical semiconductors producers and shift the demand of helium to Asian regions [Gravey, 2021].

Another key factor on Helium demand according to Phil Kornbluth, President of Kornbluth Helium Consulting LLC, is the role that private aerospace companies such as SpaceX and Blue Origin could play in the future if they use helium for space exploration and propulsion rockets [Kornbluth, 2020b]. Other ideas like Project Loon from Alphabet to use helium to suspend balloons and have a Balloon-base communications infrastructure could influence the demand in the future [Zindel, 2020].

V. Shortages

Possible helium supply disturbances are likely to happen as they happened in the past [Cockerill, 2021b]. In the beginning of the XX century the US government developed a Helium Reserve since it was considered a crucial element for national defence and it was used for airships until the 50s [Burton, 2016]. Later in 1960 an Act was created which allowed the stored helium to be commercialized to use helium for space exploration and to buy helium from natural gas producers[Nekuda Malik, 2013].

After years in 1995 when the Bureau of Mines was not able to pay its debt to the government the U.S. Congress passed another Act to privatise helium. In 1996 they ordered BLM (Bureau of Land Management US. to sell Helium at a prize depending on the stored amount and to keep 600 million cubic feet of the crude gas in storage and the remaining debt [Lance, 2014]. The first Helium Shortage happened in 2006 because helium sources were not being developed [Kaplan, 2007]. Prices doubled due to high helium demand for supercoils of magneric resonance imaging devices during that year [Yam, 2007].

In 2010 helium shortage 2.0 lasted until 2013, the price increased particularly sharply in the following three years [Ehrensberger, 2013], due to allocation of large quantities of helium as a reserve only for Federal consumption [Lance, 2014]. Obama signed in 2013 a new helium Act to end Federal helium operations by 2021 with low market disturbance and to continue founding of the Federal Helium Reserve [US. Government, 2013].

The first helium auction conducted by the BLM took place in 2014 and the planned disposal of the Federal Helium System was scheduled for 2021 [Jolley, 2016]. Ever since the first auction in 2014 the U.S. Federal Helium Reserve has published the yearly sold quantities and prices see Appendix: A1. The average price from the first auction was 161$ per Mcf (thousand cubic feet), from 2015 to 2016 the market faced slight oversupply at a price of 106$ per Mcf. Later in 2017 the market tightened at a price of 119& per Mcf. The next Helium Shortage (Helium Shortage 3.0) hit from 2018 to 2019 with a 144% price increase from the previous year at 290$ per Mcf [Burton, 2022]. The shortage was a market reaction to the Qatar embargo which stopped helium trading in 2017 from a source that was responsible of 30% of the world supply [Anderson, 2018].

On 2020 a lot of change was expected in the market since the BLM reserve was planned to be privatised starting September 2021 [Nick Parkinson, 2020]. That same year Covid-19 hit and helium manufacturing was reduced same way other sectors did

[Nick Parkinson, 2020]. The world helium market was impacted by Covid-19 in several ways, the demand dropped after the second larges consumer of the gas, China went on lockdown. World wide social distancing impacted the balloon industry negatively, in total the market was reduced by at least 10% according to [Kornbluth, 2020a]. Helium experts suggest Covid-19 in 2020 events caused an early termination of Shortage 3.0 [Kornbluth, 2020a], [Garvey and Associates, 2021], [Cockerill et al., 2020].

In the first quarter of 2021 the helium market recovered and the demand returned, some applications like MRI and balloons had not recovered completely but others like electronics and aerospace returned stronger [Kornbluth, 2021]. Like other industries helium faced logistics and supply-chain problems [Dyatkin, 2020]. On the other side of the market, supply was also influenced that year by two key factors: first Qatar 3, Bazar´s gas plant even though uncertain wanted to produce 432MMCF per year, second the long planned Gazprom's project Amur in Russia firs production train started operating with 700MMCF (million cubic feet) per year [Quader, 2020], [Kornbluth, 2021], [Abdul Quader et al., 2018].

Qatar's embargo was lifted by Saudi Arabia that year [Adela Suliman, 2021] and was able to sell helium produced from extracted natural gas [Danabalan et al., 2022]. Since Amur's helium production plant-startup in September Gazprom was able to produce some helium before a planned shutdown in October 2021 which got prolonged because of a fire [Soldatkin, 2021]. Amur wanted to start production and include the second production train of the helium plant at the beginning of 2022 but there was an explosion and now the Natural Gas plant will shut down for at least 6 months [Kornbluth, 2022] which puts helium supply in uncertainty.

VI. Production

Helium is obtained from liquefied atmospheric air or from natural gas by fractional distillation [Gmelin et al., 1978].In this way, a He-Ne mixture is obtained from which pure Ne is obtained and after laborious fragmentation and the use of very low temperatures high helium concentrations can be obtained using the different bouing points of the gases: -161ºC for Methane and -268.93ºC for Helium [Liquide, 2017]. Since producing Helium from air costs of 1600 $ MCF (50450 e MCM) is harder than extracting it from natural gas at a cost of 7 $ MCF (220,71 e MCM helium production out of natural gas predominates in the market [Anderson, 2018] , [Nuttall et al., 2012b].

6.1. Sources

From the Earth's crust radioactive decay helium accumulates in a "natural reserve" where is mixed with natural gas. I natural gas is processed and purified, raw helium with a 40 to 50% purity is obtained [Nuttall et al., 2012a]. In natural natural gas, helium accumulates in a relatively large proportion compared to air. By cooling the natural gas, it is possible to separate helium from the hydrocarbons and nitrogen compounds contained in the natural gas [Sicius, 2016].

Natural gas is processed before being transported, raw natural gas contains a number of hydrocarbons as well as water vapor, hydrogen carbon dioxide nitrogen and helium [Devold, 2013], [Bahadori, 2014]. Nitrogen rejection is a methane purification

crucial step, it is done by cryogenic distillation which allows helium production afterwards [Jahromi et al., 2018]. Without this step separating helium from natural gas very difficult [Grynia and Griffin, 2016]. After nitrogen rejection helium is pre-treated, refined and liquefied, some LNG plants do not have such units and helium is vented into the atmosphere [Nuttall et al., 2012b].

6.2. Process

Helium removal from natural gas consists of several steps: first the gas is fed and compressed, then a sequence of acid gas, water and mercury extraction takes place before liquefying through the main heat exchanger where the heavies are removed and LNG is separated from the flow stream containing 1-3-% helium that enters the Nitrogen rejection unit [Rufford et al., 2014]. From there Helium is recovered, purified to remove the remaining N2 to reach a 99+% purity and liquefy it (see Fig. 3)

The guideline to know if the helium recovery should be included in the natural gas processing is the amount of helium contained in the reservoir, the minimum percentage of helium on a stream that was purified so far is 0.05mol% due to high amounts of liquefied natural gas production [Hwang et al., 2000]. Other conventrations of helium in natural gases vary between 0.05 and 4vol% [Conference, 1960].

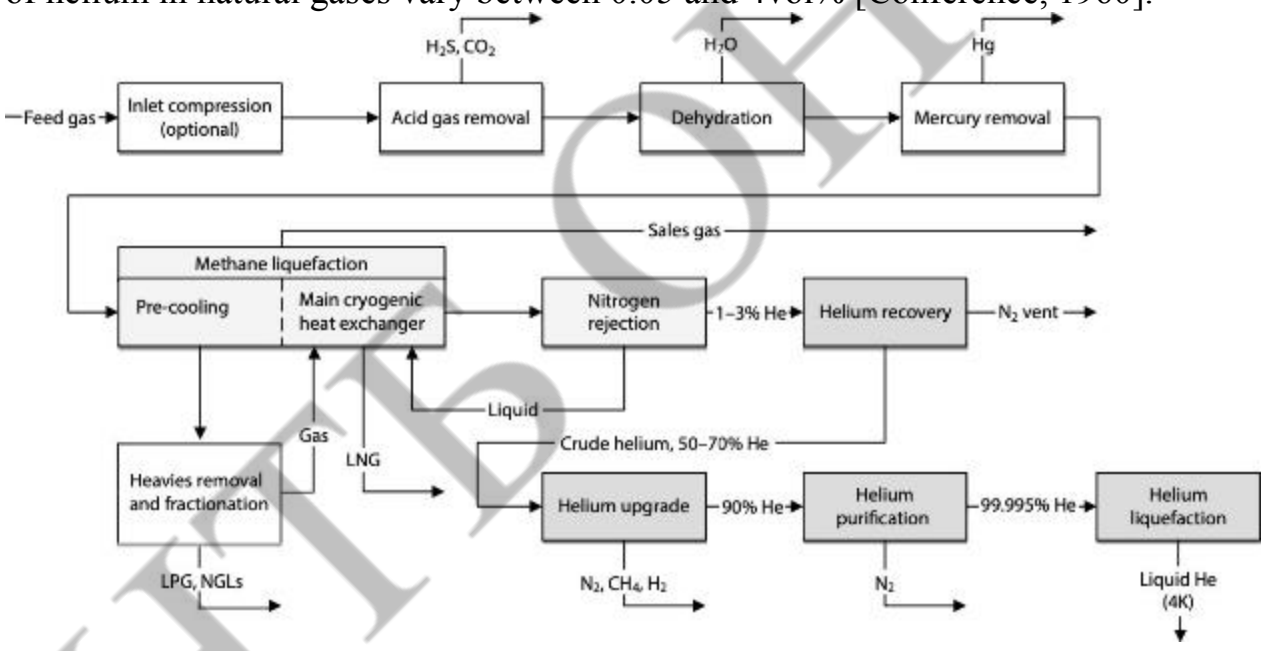

Fig. 3 LNG production with Nitrogen Rejection Schematic [Grynia and Griffin, 2016]

6.2.1. Cryogenics

Cryogenic technologies refers as engineering processes and technical applications that happen below 120K [Hwang, 2004]. The liquefaction of natural gas happens around that temperature. Cryogenic technology is used to refrigerate or cool down in processes. Another important role of cryogenics is to produce high purity gases [Agrawal et al., 2000]. Distillation has been used to process natural gas and remove nitrogen and helium. Two standard processes are single-column and double-column [Agrawal et al., 2000].

A stream of gas is cooled and fed to a high pressure column (2-2.8 MPa). Gaseous nitrogen is extracted at the top of the column and LNG at the bottom.The natural gas

is reheated in a Flash unit with previously separated nitrogen to recover refrigeration [De Guido et al., 2019].

In the double column process (see Fig. 4) the gas is fed to a high pressure column (1-

2.5 MPa). The nitrogen from the upper part of the column and a part of the crude LNG from the lower part continue to a second low pressure 150kPa column where the nitrogen is processed to complete the separation. The energy provided by the low pressure column reboiler is provided by condensation of nitrogen at the top of the high pressure column. As in the single-column process, liquid natural gas is mixed with nitrogen for nitrogen recovery [Bauer and Linde, 2009]. If the double-column process uses partial condenser crude helium can be purified and liquefied [MEHRA, 2017].

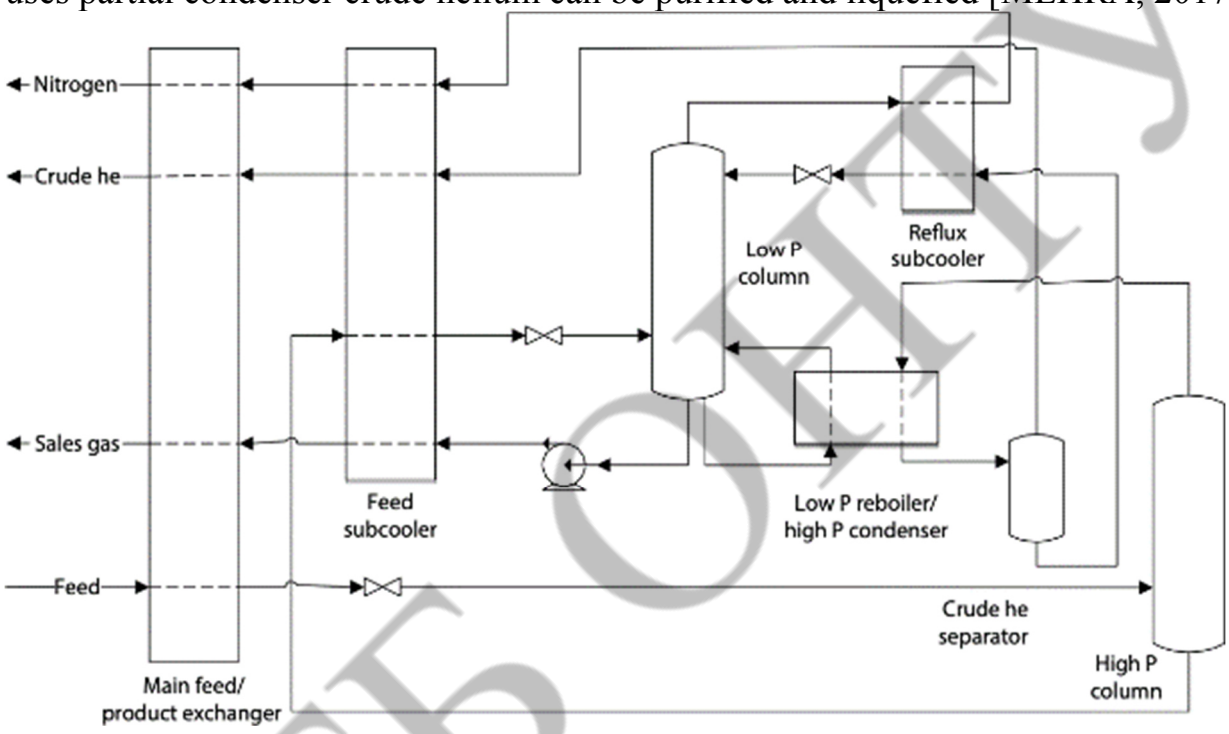

Fig. 4: Double-Column Process for Helium Processing example [Grynia and Griffin, 2016]

6.2.Purification

Helium´s boiling temperature is at 4.2K, its critical temperature is at 5.2K and at some conditions it shows properties of a superfluid [Van Sciver, 2013]. To Purify helium several steps are necessary in order to remove hydrogen and neon which are not possible to remove in the Pressure Swing Adsorption process (PSA). Therefore a cryogenic process is combined with the PSA.

Crude Helium is cooled down and combined with recycled purge gas from the PSA unit to obtain a partial-condensed flow at a purity of 90% helium. This stream goes is mixed with air so hydrogen can be removed at a catalyst [200, 2006]. Afterwards the stream is cooled down again to separate the water. Once water is removed the stream enters the PSA unit where high purity helium is obtained and can be liquefied or sold as commercial pure gas [Das et al., 2008], [Das et al., 2012], [Rufford et al., 2014].

VII. CONCLUSIONS

Since the beginning of its commercialization, helium has shown to have unique characteristics and specific properties. This attributes to helium an economic value and also to its specific applications.

The main consumers of helium choose to optimize their technologies to reduce their consumption. The market is known as a "little transparent" and with limitations such as: a low number of suppliers, logistics complications due to the reduced number of commercial sources and the volatility of gas when it comes to being transported and due to its high price.

On the other hand, helium producers are tied to the amount of helium in the natural gas field, which leads them to question whether production is profitable, knowing that its management involves highly complex technology.

The fact that the market will no longer have the Federal Helium Reserve from the BLM in the United States in the coming years causes uncertainty whether there will be enough supply or of the prices will double like they did two years ago. This causes complications and responsibilities for the refiners and comercializers of this product since they will have to buy the gas directly from a natural gas processor.

The processes for helium purification and liquefaction involve a series of devices and technologies with a high number of investment and energy consumption. That is why the price of this specialty gas could remain high in the near future, taking into account that it is a non-renewable resource and consumption increases annually.

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Apendix A1

5th Annual BLM Crude Helium Auction August 31, 2018				
Lot Number	**Volume (MMcf)**	**High Bid**	**Bidder**	**Amount**
Lot Number 1	25	$233	Air Products - 107	$5,825,000
Lot Number 2	25	$308	Air Products - 107	$7,700,000
Lot Number 3	25	$334	Air Products - 107	$8,350,000
Lot Number 4	25	$337	Air Products - 107	$8,425,000
Lot Number 5	25	$271	Air Products - 107	$6,775,000
Lot Number 6	15	$272	Air Products - 107	$4,080,000
Lot Number 7	15	$259	Air Products - 107	$3,885,000
Lot Number 8	15	$250	Air Products - 107	$3,750,000
Lot Number 9	15	$260	Air Products - 107	$3,900,000
Lot Number 10	15	$236	Air Products - 107	$3,540,000
Lot Number 11	5	$251	Air Products - 107	$1,255,000
Lot Number 12	5	$261	Air Products - 107	$1,305,000
	210	**$280**	**TOTAL**	**$58,790,000**

Average per Mcf

The average per Mcf bid is not intended to serve as a benchmark price for helium sales contracts.

4th Annual BLM Crude Helium Auction July 19, 2017					
Lot Number	**Lot Number**	**Volume (MMcf)**	**High Bid**	**Bidder**	**Amount**
Lot Number 1	1	25	$112	274 - Linde	$2,800,000
Lot Number 2	2	25	$112	271 - Air Products	$2,800,000
Lot Number 3	3	25	$113	271 - Air Products	$2,825,000
Lot Number 4	4	25	$114	271 - Air Products	$2,850,000
Lot Number 5	5	25	$116	271 - Air Products	$2,900,000
Lot Number 6	6	25	$118	271 - Air Products	$2,950,000
Lot Number 7	7	25	$113	271 - Air Products	$2,825,000
Lot Number 8	8	25	$119	271 - Air Products	$2,975,000
Lot Number 9	9	25	$121	271 - Air Products	$3,025,000
Lot Number 10	10	25	$121	271 - Air Products	$3,025,000
Lot Number 11	11	25	$122	271 - Air Products	$3,050,000
Lot Number 12	12	25	$119	271 - Air Products	$2,975,000
Lot Number 13	13	25	$124	271 - Air Products	$3,100,000
Lot Number 14	14	15	$121	279 - Weil	$1,815,000
Lot Number 15	15	15	$122	271 - Air Products	$1,830,000
Lot Number 16	16	15	$122	271 - Air Products	$1,830,000
Lot Number 17	17	15	$122	271 - Air Products	$1,830,000
Lot Number 18	18	15	$124	271 - Air Products	$1,860,000
Lot Number 19	19	15	$124	278 - Uniper	$1,860,000
Lot Number 20	20	15	$122	278 - Uniper	$1,830,000
Lot Number 21	21	15	$123	277 - Praxair	$1,845,000
Lot Number 22	22	15	$125	276 - Matheson	$1,875,000
Lot Number 23	23	5	$123	277 - Praxair	$615,000
Lot Number 24	24	5	$123	276 - Matheson	$615,000
Lot Number 25	25	5	$122	277 - Praxair	$610,000
Lot Number 26	26	5	$125	271 - Air Products	$625,000
Lot Number 27	27	5	$125	271 - Air Products	$625,000
Lot Number 28	28	5	$125	271 - Air Products	$625,000
Lot Number 29	29	5	$125	271 - Air Products	$625,000
Lot Number 30	30	5	$128	271 - Air Products	$640,000
		500	**$119**	**TOTAL**	**$59,655,000**

Average per Mcf

Bureau of Land Management Amarillo, Texas
2nd Annual BLM Crude Helium Auction
August 26, 2015, 1:00 PM Central

Lot Number	**Volume (MMcf)**	**High Bid**	**Bidder**	**Revenue Generated**
Lot Number 1	25	103	Air Products	$2,575,000
Lot Number 2	25	105	Air Liquide	$2,625,000
Lot Number 3	25	102	Air Products	$2,550,000
Lot Number 4	25	104	Air Products	$2,600,000
Lot Number 5	25	106	Air Products	$2,650,000
Lot Number 6	25	100	Air Products	$2,500,000
Lot Number 7	25	0	No Bid	$0
Lot Number 8	25	103	Praxair	$2,575,000
Lot Number 9	15	105	IACX	$1,575,000
Lot Number 10	15	104	Praxair	$1,560,000

Lot Number 11	15	104	Praxair	$1,560,000
Lot Number 12	15	105	Praxair	$1,575,000
Lot Number 13	15	105	Praxair	$1,575,000
Lot Number 14	5	104	Praxair	$520,000
Lot Number 15	5	106	Matheson	$530,000
Lot Number 16	5	105	Air Liquide	$525,000
Lot Number 17	5	105	Matheson	$525,000
Lot Number 18	5	105	Matheson	$525,000
			TOTAL	**$28,545,000**

Average per Mcf = $104.18

Bureau of Land Management Amarillo, Texas

Helium Phase B Auction
July 30, 2014, 2:00 PM Central

Lot Number	**Volume (MMcf)**	**High Bid**	**Bidder**	**Revenue Generated**
Lot Number 1	10	161	Air Products	$1,610,000
Lot Number 2	10	171	Air Products	$1,710,000
Lot Number 3	10	180	Air Products	$1,800,000
Lot Number 4	10	171	Praxair	$1,710,000
Lot Number 5	10	178	Air Products	$1,780,000
Lot Number 6	10	171	Praxair	$1,710,000
Lot Number 7	5	156	Air Products	$ 780,000
Lot Number 8	5	150	Air Products	$ 750,000
Lot Number 9	5	142	Air Products	$ 710,000
Lot Number 10	5	130	Air Products	$ 650,000
Lot Number 11	5	140	Air Products	$700,000
Lot Number 12	7.813	136	Air Products	$1,062,568
			TOTAL $14,972,568	

Average per Mcf = $161.32

INCREASING THE ENVIRONMENTAL SAFETY OF THERMAL POWER PLANTS BY COAL FLY ASH UTILIZATION

Author: Marta Zegarek
Advisors: Hanna Koshlak
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Abstract. *The paper presents the results of hydrothermal zeolitization of fly ash from hard coal combustion in one of the Polish power plants and possible further applications of zeolites. The synthesis was carried out using various NaOH fly ash mass ratio and the effect of NaOH concentration in the activating solution on composition of synthesized sample was tested. The present work proves the benefits from development of fly ash utilization and further opportunities in the use of zeolites. There exist the need for research to expand options to reduce harmful impact derived from energy production.*

Keywords *coal fly ash, utilization, thermal power plants, fusion - hydrothermal treatment process, removal, zeolite*

I. INTRODUCTION

Coal is one of the most widely use type of energy carrier. Despite efforts it is impossible to completely eliminate the demand of using coal in power plants. Great example on this field can be Poland where there is no other opportunity caused by insufficiently diversified sources of energy. In this case, it is necessary to take into account the need to eliminate harmful factors arising in the processes of coal combustion.

Fly ash is a combustion by-product constituting about 60–88% of total combustion residues from coal-fired power plants. To meet increasingly stringent limits for air pollution, the power industry has progressively improved its coal firing technology. Circulating fluidized-bed combustion (CFBC), as an advanced and clean coal technology, allows solid fuels with wide range of qualities and sizes to be burnt at lower temperature (800 – 950 °C) with high combustion efficiency, which results in considerably reduction in NOx emission compared to PCC [1]. Around 90% - 95% SO_2 reduction can also be achieved by injecting limestone in the furnace to capture the sulphur in the coal. Given all these environmental and economic benefits, CFBC has been growing steadily all over the world since its commercialization in the late 1970s [1], resulting in large amount of waste fly ash (CFBFA) discharge. Although a portion of the generated fly ash is used as fillers in brick manufacturing and road or dam construction, a significant amount is still disposed in land-fills or ash ponds with serious environmental consequences.

Coal fly ash (CFA), a by-product of coal combustion, is one of the most abundant industrial solid wastes. The emission of CFA increases annually. According to the European standard EN 450–1, fly ash is a fine grained, loose material, which is predominantly composed of spherical aluminosilicate glass particles, formed as a result of coal burning. CFA contains heavy metals, polycyclic aromatic hydrocarbons, silica, and other toxic substances [1]. If not properly disposed of, it can cause water and soil pollution, disrupt ecological cycles and pose environmental hazards (Fig. 1) [3].

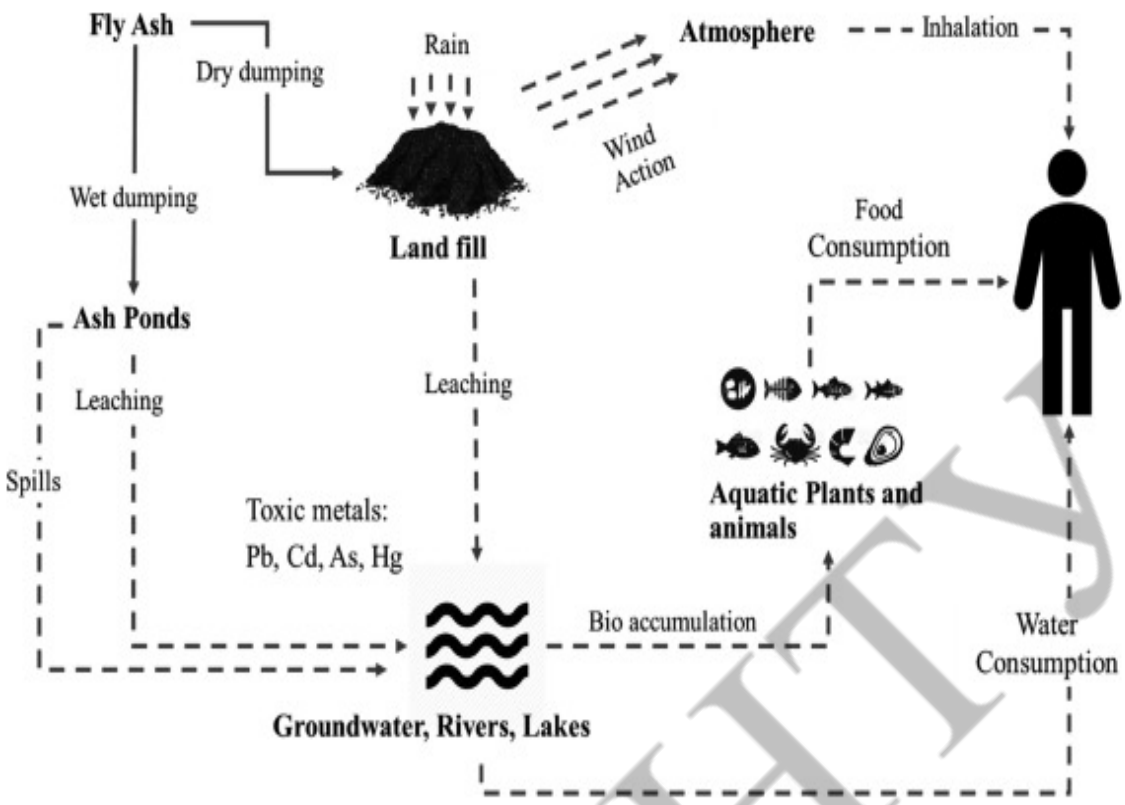

Fig. 1. Fly ash contamination pathways [3]

Carbon capture, utilization, and storage (CCUS) is one of the proposed technologies for reducing global CO_2 emissions, and it presents many opportunities for fly ash utilization. The use of cheaply available fly ash in various parts of the CCUS value chain could help reduce these costs while decreasing the environmental risks associated with fly ash disposal. In some cases, it might be possible to use the carbonated fly ash as a construction material or additive. All of which improve the economics of the capture process while benefiting the overall environmental impact of these processes. A schematic of the pathways for the application of fly ash in carbon capture, utilization, and storage (CCUS), is provided in Fig. 2 [2].

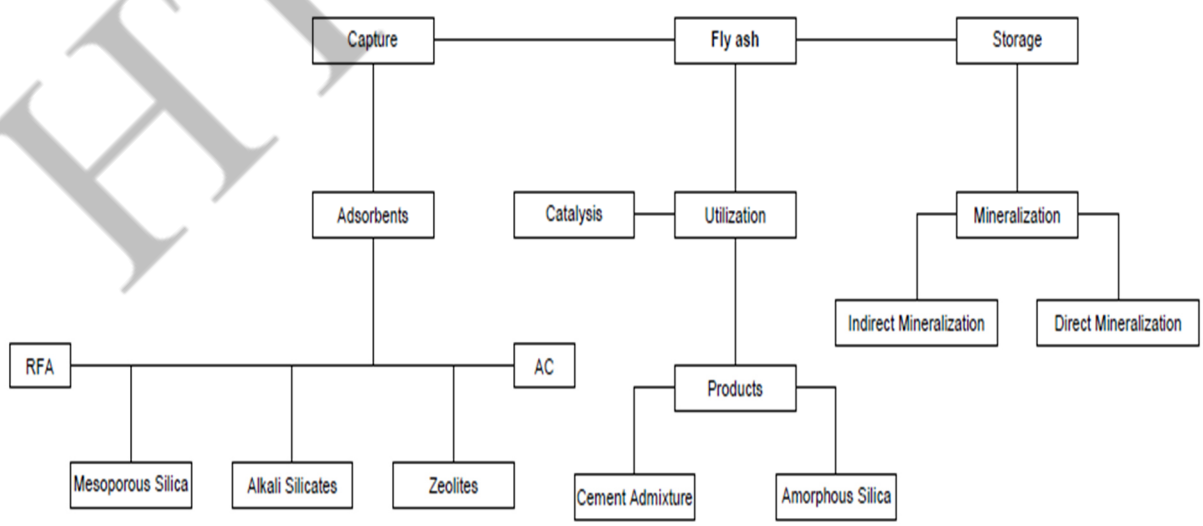

Fig. 2. Pathways for fly ash application in CCUS

Thus, there exist the need for research and development to expand options for fly ash utilization as this will result in higher utilization rates and ameliorate the harmful environmental impacts of its disposal.

II. LITERATURE ANALYSIS

2.1. Zeolite framework structures

Zeolite has broad application prospects due to its potential molecular sieving, high specific surface area, and good thermal and chemical stability. Zeolite is a kind of aluminosilicate molecular sieve crystal with uniform pores, and its skeleton contains Al, Si, and O. In Fig. 3 are illustrated common zeolite structures and in Fig. 4 are presented different zeolite structures result in distinct channels. These structural features provides a various characteristics for zeolites, of absorption selectivity, high specific surface and high ion exchange capacity [3].

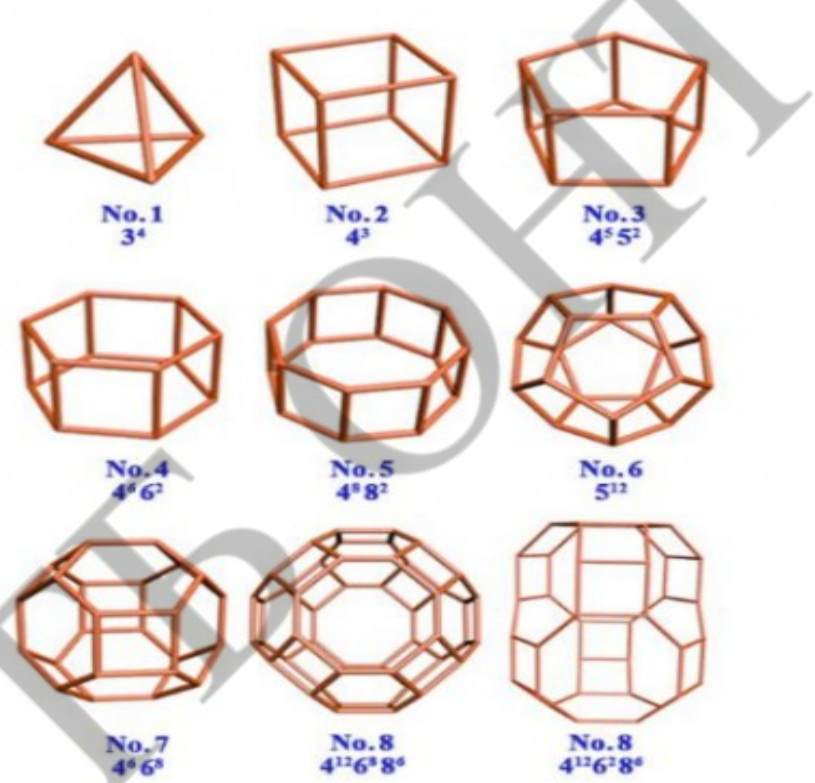

Fig. 3. Some common composite building units in framework structure of zeolite [3]

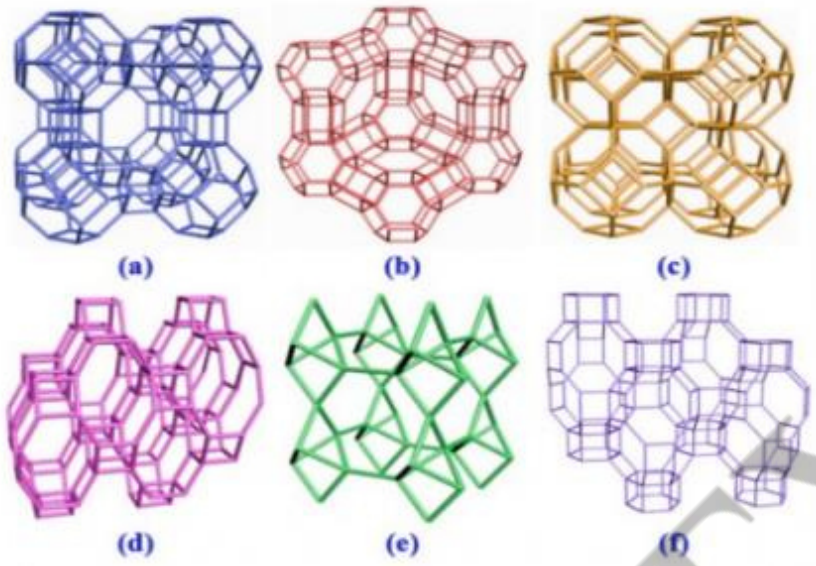

Fig. 4. Several common zeolite framework structures: (a) LTA, (b) FAU, (c) SOD, (d) GIS, (e) EDI, (f) CHA [3]

Zeolites have been widely used for air pollution control due to their excellent performance. Atmospheric aerosol is one of the main pollutants that affect the urban environment and human health, and it directly or indirectly causes haze, photochemical smog, acid rain, and other climate changes. Depending on the formation mechanism, atmospheric aerosols can be divided into primary and secondary aerosols. Primary aerosols refer to aerosol particles that are directly discharged into the atmosphere, and secondary aerosols are particles produced by the oxidation of certain gaseous pollutants (e.g., SO_x, NO_x, and hydrocarbons) in the atmosphere (e.g., from SO_2 to SO_4^{2-}).

2.2. Properties of Coal fly ash.

Fly ashes essentially consists of SiO_2 and Al_2O_3 (in both amorphous and crystalline form) [4], which have great similarity with the composition of zeolites, a valuable material widely applied in many fields related to radioactive waste management, petroleum refining, purification of gases, agriculture etc. [5]. Table 1 presents the typical chemical compositions of fly ash.

Table 1. Typical composition of fly ash from different coals

Component	Bituminous (%)	Sub-bituminous (%)	Lignite (%)
SiO_2	20–60	40–60	15–45
Al_2O_3	5 – 35	20–30	10–25
Fe_2O_3	10 – 40	4–10	4–15
CaO	1 – 12	5–30	15–40
MgO	0 – 5	1–6	3–10
SO_3	0 – 4	0–2	0–10
Na_2O	0 – 4	0–2	0–6
K_2O	0 – 3	0–4	0–4
LOI	0 – 15	0–3	0–5

Understanding the physical, chemical and mineralogical properties of coal fly ash is important, as these properties influence its subsequent use and disposal. The specific properties depend on the type of coal used, the combustion conditions, and the collector setup, among other factors. Fly ash normally occurs as fine, powdery particles with an average size of less than 20 μm, bulk density ranging from 0.54 to 0.86 g/cm^3, surface area varying from 170 to 1000 m^2 /kg band light texture. The color of fly ash is dependent on the content of unburned carbon left in ash, varying from yellow to grey to black [6]. The particle shape of fly ash also varies with the different combustion conditions applied. Fly ash produced from pulverized coal combustion (PCC), which usually operates at high firing temperature at 1300 – 1700 ℃ [7], is predominantly spherical in shape either solid or hollow. However, fly ash produced from circulating fluidized-bed combustion (CFBC), a clean coal technology known for its low NOx emission, is commonly with irregular shapes, mainly due to the relatively low combustion temperature (800 – 950 ℃) [8].

Micromorphology observation reveals that the fly ash particles are predominantly spherical in shape and consist of solid spheres, cenospheres, irregular-shaped debris and porous unburnt carbon (see Fig. 5).

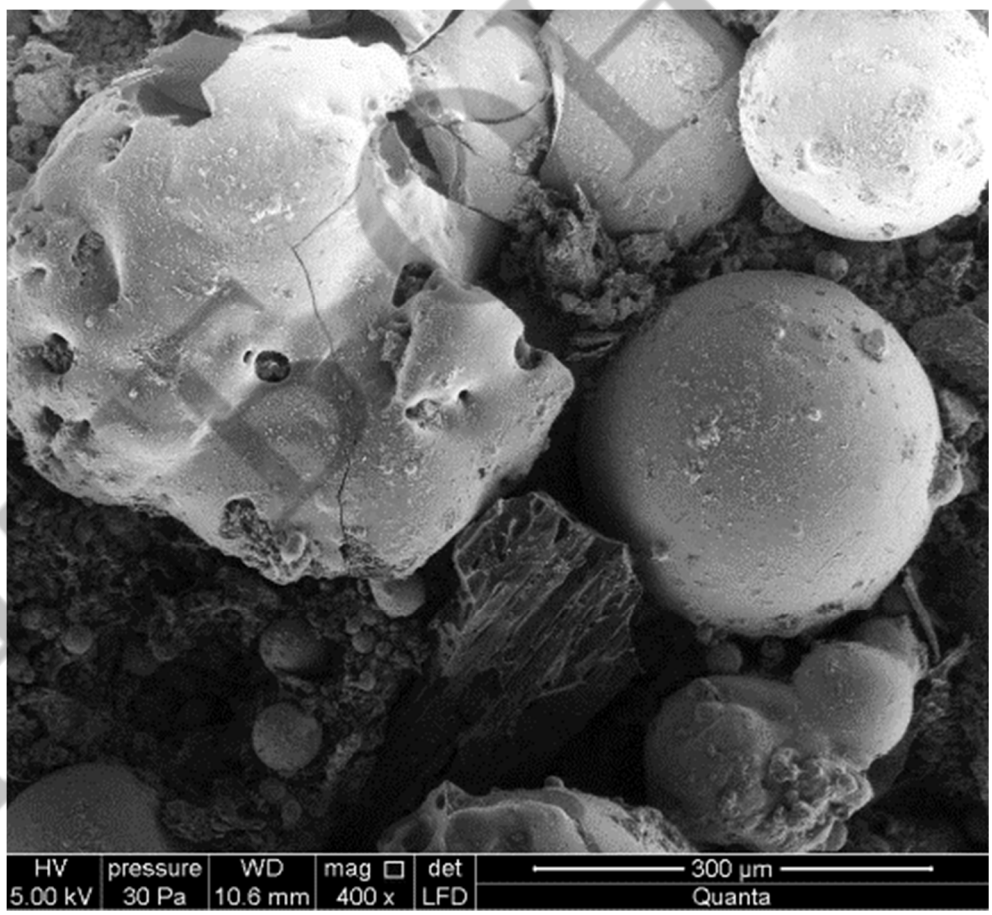

Fig. 5. Micromorphology fly ash

In FBC ash, spherical particles are rarely observed and most of the particles exhibit irregular shapes, primarily because most minerals in the coal do not undergo melting but soften only, under the relatively low boiler temperature of 850–900 °C [5]. The irregular fragments consist mainly of unburnt carbon, anhydrate and calcite.

Synthesis of zeolites, as one of the effective uses for coal fly ash, is gaining more attention, due to the compositional similarity between fly ash and zeolites. Converting fly ash into zeolite can not only reduce the waste landfills but also producing high value-added products. Thus, production of zeolites using fly ash not only convert waste into a relatively higher added value product, but also potentially constitutes one important issue of waste management. Ever since the first study conducted by Holler and Wirsching [9], many methods and process have been proposed for zeolite synthesis using fly ash and all those aim at the digestion of Si – Al containing insoluble glass phase and crystalline phases such as mullite and quartz and subsequent crystallization of zeolite [10] (Fig. 6) .

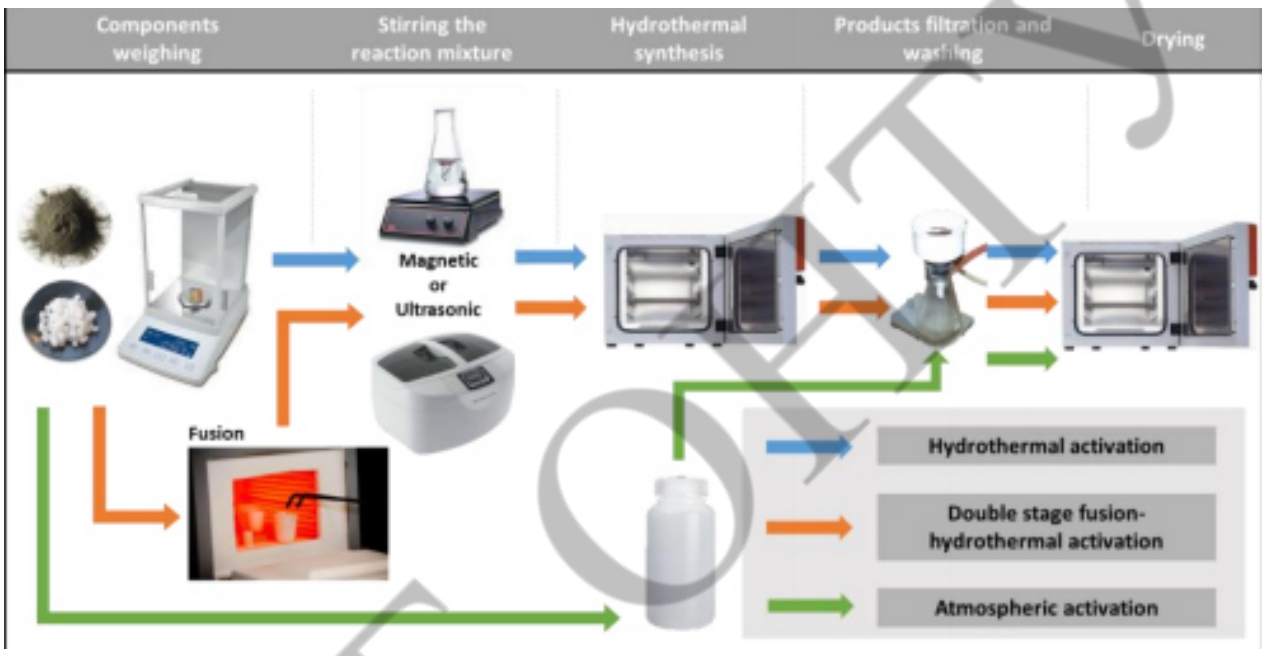

Fig. 6. - Synthesis of fly ash zeolites by hydrothermal activation, double-stage fusion–hydrothermal activation and atmospheric crystallization [12]

Simple hydrothermal process was most commonly used for direct synthesis of zeolites, where fly ash mixed with in alkaline solutions such as sodium hydroxide with different concentration at temperature from 80 to 200 °C for up to 96 hrs. However, this method usually leads to a low conversion (<75%) leaving a significant amount of fly ash residual in the products.In comparison, a two-step synthesis method proposed by Shigemoto et al. [13], where an alkali fusion stage is introduced prior to the hydrothermal treatment, demonstrated significant improvement on zeolitization process and high crystalline zeolite products were produce.

Microwave-assisted Synthesis. Microwave assisted method utilises microwave in the hydrothermal process. The microwave assists the zeolite synthesis at earlier stage due to the stimulated dissolution of SiO_2 and Al_2O_3 from fly ash and reduce its reaction time. However, it will retard the formation of zeolite in the middle to later stage. Therefore, by utilising microwave in the earlier hydrothermal process can effectively shorten the reaction time of zeolite synthesis from fly ash [14]. In the study done by Querol, application of microwave to the conventional synthesis can lead to the significant reduction of reaction time from 24 hours to 30 min.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of research The object of research is fly ash from hard coal combustion in one of the Polish power plants

The subject of research is the methods of the synthesis was carried out using various NaOH fly ash mass ratio and the effect of NaOH concentration in the activating solution on composition of synthesized sample was tested.

Methods of research: The morphology and chemical composition in the micro-area of the main mineral components of the tested materials was determined using a scanning microscope (SEM). The FEI Quanta 250 FEG scanning microscope was used, equipped with a chemical composition analysis system based on radiation energy dispersion X-ray - EDS by EDAX .

IV. RESULTS

4.1. The cycle of continuous improvement of energy services results

In the studied fly ash the dominant chemical components were SiO_2 and $Al2O_3$, while the main phase components were mullite, quartz and hematite, and a significant share of amorphous substance (glass and unburnt organic substance) (tab.2).

Table 2 Elemental analysis of coal fly ash in wt%

Component	Bituminous (%)
SiO_2	49,73
Al_2O_3	29,57
Fe_2O_3	7,15
CaO	4,65
MgO	3,19
Na_2O	1,39
K_2O	2,86
LOI	7

*Loss on ignition

Fly ash is a material that is heterogeneous in terms of its phase and chemical composition. The presence of oxide minerals - Al_2O_3, Fe_2O_3, MgO, CaO was established in the mineral composition of bottom ash; silicates and aluminosilicates - with island, ring, chain, layered and spatial structure. In terms of phase composition, the ashes are also agglomerates of various nature. The microscopic image of the surface morphology and samples of ash particles is presented in Fig. 7.

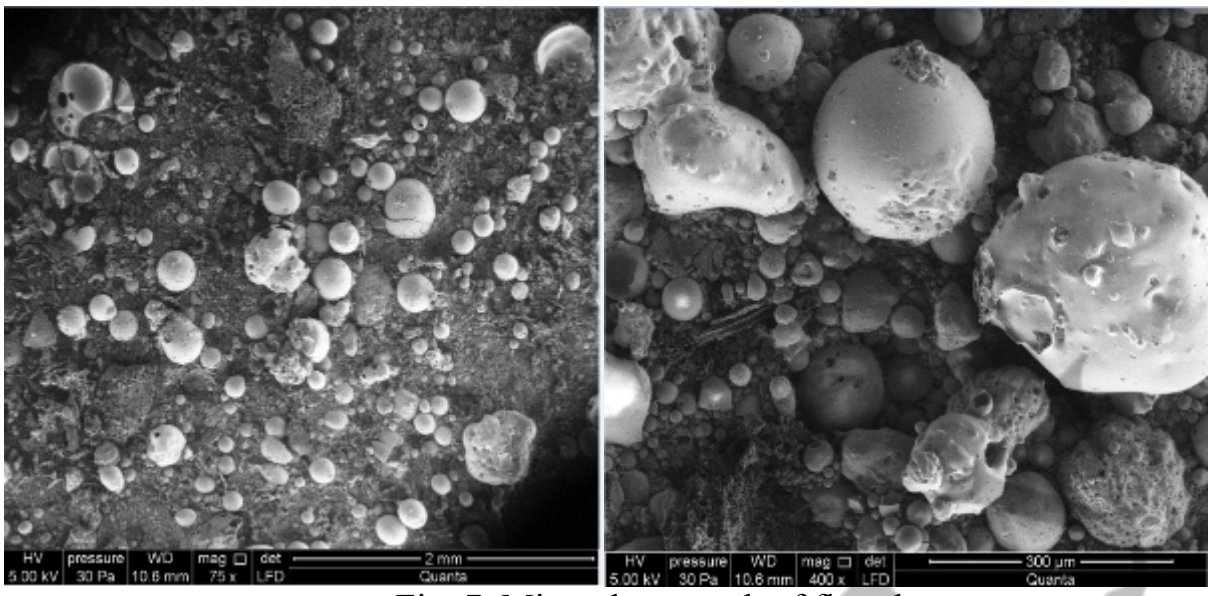

Fig. 7. Microphotograph of fly ash

The process was carried out under the following permanent conditions temperature: 80°C, time – 24 hours, water solution of NaOH (L)/fly ash (g) ratio – 1,4:1,0; 1,8:1,0. After hydrothermal synthesis, the presence of unreacted fly ash phases was found in the products, as well as new phases, the quality and quantity of which depend on the NaOH to fly ash mass ratio used for synthesis (Fig. 8).

In the products of synthesis, the share of sodium-containing phases increases with the increasing concentration of NaOH in the solution used for the process. Fly ash was examined using scanning electron microscopy (SEM). The fly ash was then subjected to an alkaline treatment with sodium hydroxide (NaOH) to carry out the process of synthesizing a zeolite-like material (Fig. 9).

Zeolites are mainly hydrated aluminosilicates of alkali, alkaline earth elements or, much less often, other cations. Very valuable are their properties (sorption, catalytic, molecular sieve, ion-exchange, etc.) are the result of the specific structure of their aluminosilicate skeleton, which forms the structure of zeolites, in which there are systems of channels and outlet chambers as a result of a series connection of parallel rings of aluminum and silicon tetrahedral.

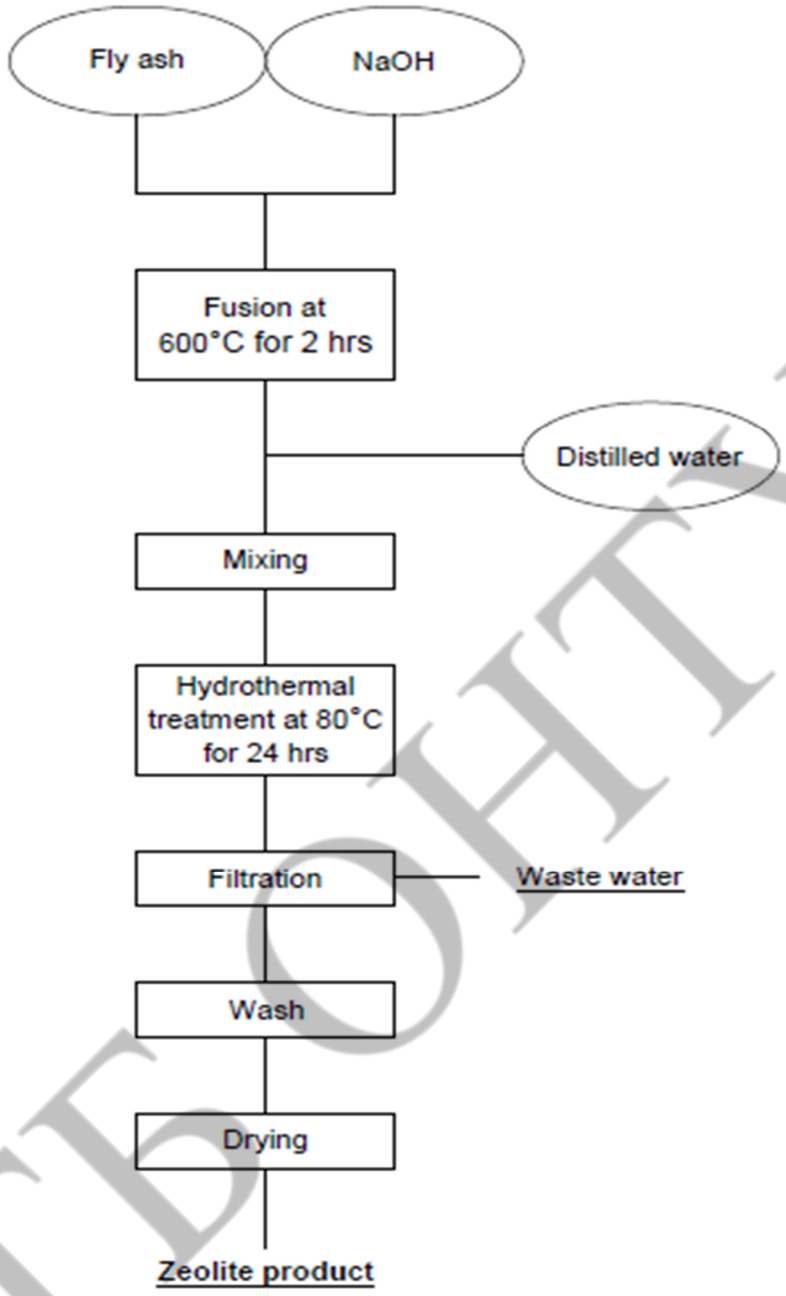

Fig. 8. High temperature fusion - hydrothermal treatment process for the synthesis of zeolites from fly ash

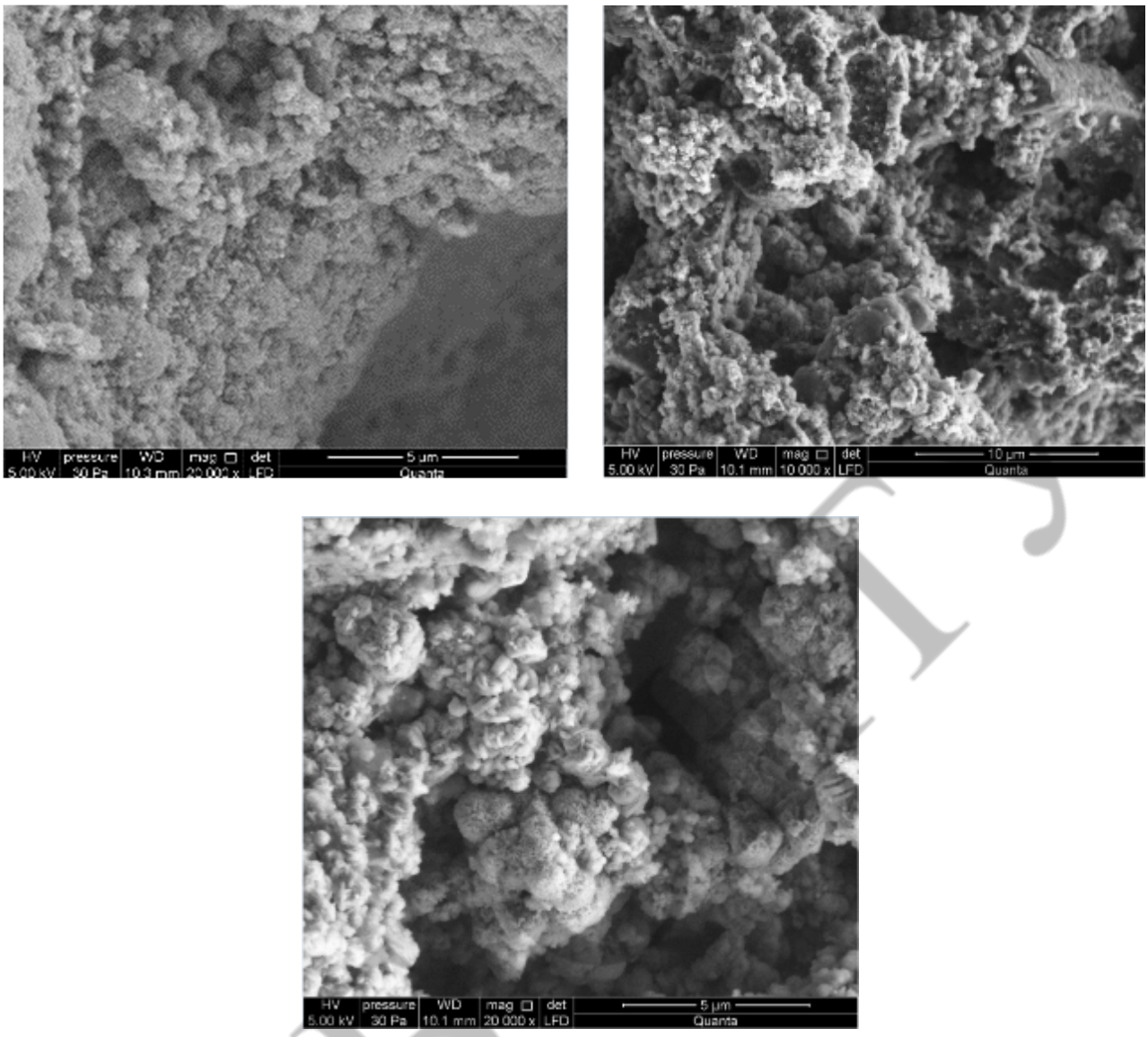

Fig. 9. Zeolite material

These rings form the so-called secondary structural divisions, which are the most common criterion for their division into various structural types.

V. CONCLUSIONS

The generation of coal fly ash is anticipated to increase for many more years, as a result of the world's increasing reliance on coal-fired power generation. Understanding the generation, characterizations and hazards provides both a background and a basis for the alternative uses of fly ash. This review has attempted to investigate the production of fly ash at the global level and covers a wide range of applications to understand the status of fly ash utilization and thus develop alternative recycling technologies. The knowledge of the various ways to use fly ash, such as in soil amelioration, the construction industry, the ceramic industry and zeolite synthesis, is essential for better management of fly ash and the reduction of environmental pollution.

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TECHNICAL COMPARISON OF INFRARED HEATERS OF LONG-WAVE RANGE

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Abstract. *An urgent problem today is the choice of economic heating in the modernization or design of a new system. The most popular type of heaters are infrared long-wave heaters. Despite its efficiency and cost-effectiveness in the brochures, it is not clear which manufacturer is really. Therefore, the work tested relatively long-wave heaters with a capacity of 600 watts, from a technical point of view, the three main Ukrainian manufacturers - Bilux, Teplov, Teplotema.*

Keywords: *infrared radiation, long-wave heaters; infrared heaters; ceiling heaters; thermal trace; Bilux; Теплов; Heat theme.*

I. INTRODUCTION

Given the situation in the fuel and economic sector, the question arises of finding alternative ways to heat production and technological, economic and other types of premises when modernizing the heating system or designing a new one. One such alternative is infrared ceiling heaters with long-wave radiation.

This principle of heating is called radiant, and has been used since ancient times. For example, in the Roman Empire in special air ducts as a coolant used flue gases from the kitchen, and later specially heated air. After the technical revolution, the types of heating also changed. So in 1985, a Hungarian scientist, Professor Mackashi, proposed the idea of using as a heat carrier air moving in a closed system and give heat to the radiators in places where it is necessary.

So radiant radiation began to be used again only 40-50 years ago. Radiant energy transfer, other things being equal, is more efficient than convective, as with radiant heating energy is easily transferred over long distances in the room, so heating devices can be placed under the ceiling and in the construction of the fence.

For clarity, it should be explained that heating is due to convective heat transfer, and radiant heaters are also heated by convection. Then why can they be better? It's simple - convective heat transfer of radiant heaters is due to radiation and heating of the surface in front of the heater. On the example of ceiling heaters, we can imagine the heating process as heating all the objects under it (floor, table, chairs, etc.) which in turn give off heat in a convective way into the surrounding space. While in traditional convective heaters heat transfer occurs due to convection into the surrounding space with a heating area limited by the physical size of the heater (eg radiator battery). It is due to this principle that infrared heaters are more efficient and have recently aroused increased interest.

Having determined that infrared heaters are the best choice for installation (at

home, in the company, in the greenhouse, etc.), there is a need for technical comparison of similar technological solutions, for example, heaters from different manufacturers.

II. LITERATURE ANALYSIS

Before starting, the existing examples of the study of radiant heaters were analyzed, and the sanitary norms of Ukraine on the indoor microclimate were analyzed for preliminary analysis of the feasibility of using radiant heaters in terms of human impact. According to the sanitary norms of the microclimate, infrared long-wave heaters can be used to heat human habitats (houses, industrial premises, etc.).

An analysis of the literature revealed that the main parameters by which you can choose an infrared heater are the thermal footprint and energy consumption. Based on these two parameters, the final efficiency can be determined.

Thermal footprint will be the most influential factor. It will affect the investment, the method of installation, as the size of the thermal trace depends on the effective location of the heaters and, accordingly, the minimum required number of heaters for a particular heated ivy. Figure 1 shows a diagram of uniform distribution of radiation from infrared heaters.

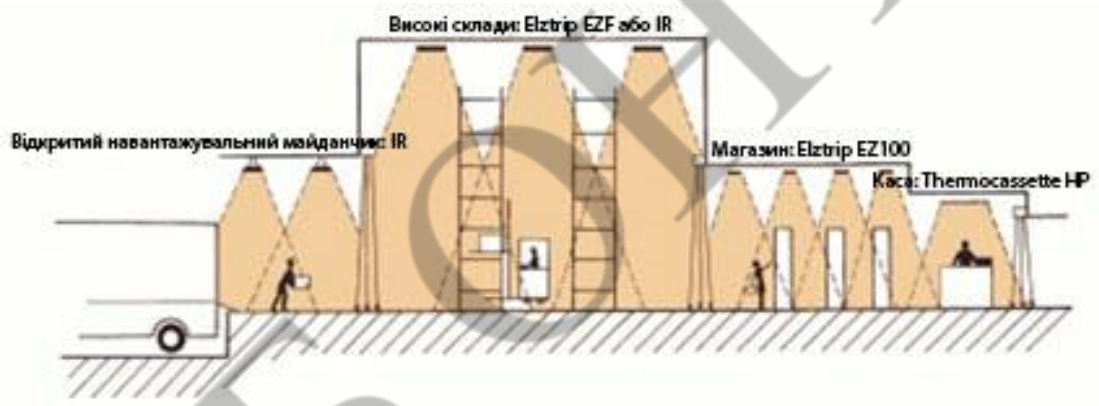


Fig. 1. Scheme of uniform distribution of radiation from infrared heaters

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Three heaters were purchased for the study:

- Bilux B600
- Heat theme Home 600
- Thermal BE 600

The sites of the represented manufacturers were analyzed, all manufacturers have certificates of conformity, but only Bilux and Teplov have European certificates of conformity and sanitary conclusions about the safety of exposure to humans, and only Bilux has a certificate of fire safety.

The technical layout of the heaters was also previously inspected (Figs. 2 - 4).

Given the available certificates and conclusions of specialists in sanitary inspection and fire hazard, as well as the layout - it was concluded that some manufacturers are copying their competitors, namely Teplotem is a copy of Bilux.

Fig. 2. Profile of the cross section

(Bilux and Teplotema - truncated trapezoid, Teplov - rectangle)

Fig. 3. Terminal connection, radiating plate connection and thermal insulation of the housing.

The basis of the study

Technical comparison was carried out in the laboratory of the Electrical Building of NTU "KhPI", Department of "Power Stations".

Research tools:

1) DALI LT7-P thermal imager - thermal trail survey;

2) Digital technical thermometer testo925 - determination of floor temperature, to determine the initial conditions of the study, measurement of room temperature for the introduction of correction factors in the thermal imager;

3) Wattmeter Etech PM300 (Energy Meter) - determination of energy consumption of heaters;

4) Measuring instrument (Roulette) - used to measure the size of the thermal trace and the height of the samples.

Room parameters - basement with a concrete floor 2 meters deeper than ground level, with a high ceiling (4 m) and a large area (80 m2), which indicates that the heat load of the room significantly exceeds the power of one heater (600 W) and its operation within 1 hour will not change the indoor air temperature. The room temperature throughout the experiment was 18.5 degrees Celsius.

The installation height of the heater is shown in Fig.5.

Thermal trace

The most important characteristics of the thermal trace are its size and average temperature.

The size of the thermal trace can be measured only after the end of the transition process, when the thermal trace does not increase in size. It was experimentally investigated that based on the parameters of the room thermal transition ends in an hour after turning on the heater. The scheme of the thermal trace is shown in Fig. 5. It was also decided to take into account the "real" heat trace - without the influence of heater radiation, namely 10 minutes after turning off and removing the heater from the stand. During this time, the thermal trace does not lose its intensity, but the effect of heater radiation is absent.

Another feature is the division of the thermal trace into efficient and scattering traces, as shown in Fig.5, and because of this there is a need to properly position the heaters on the area as shown in Fig.1.

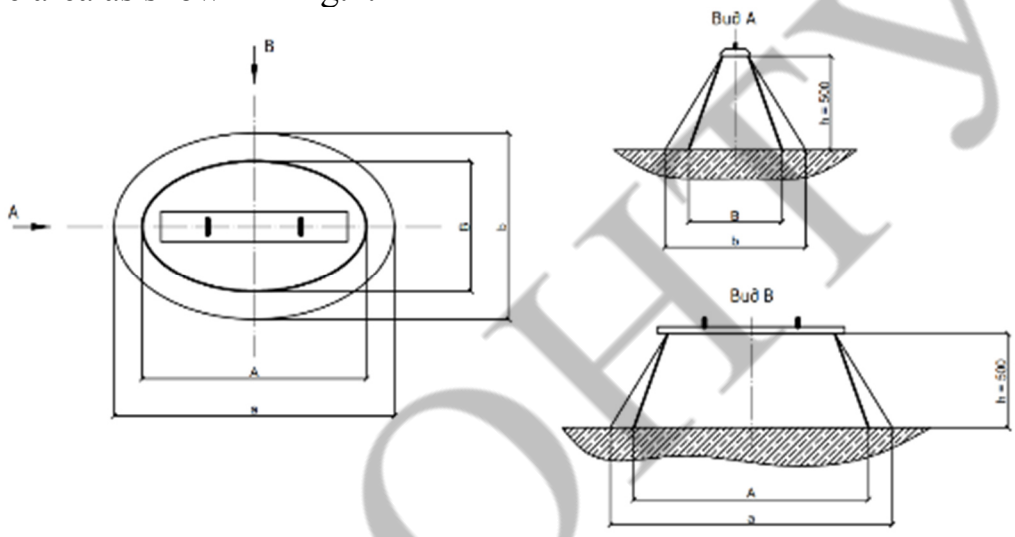
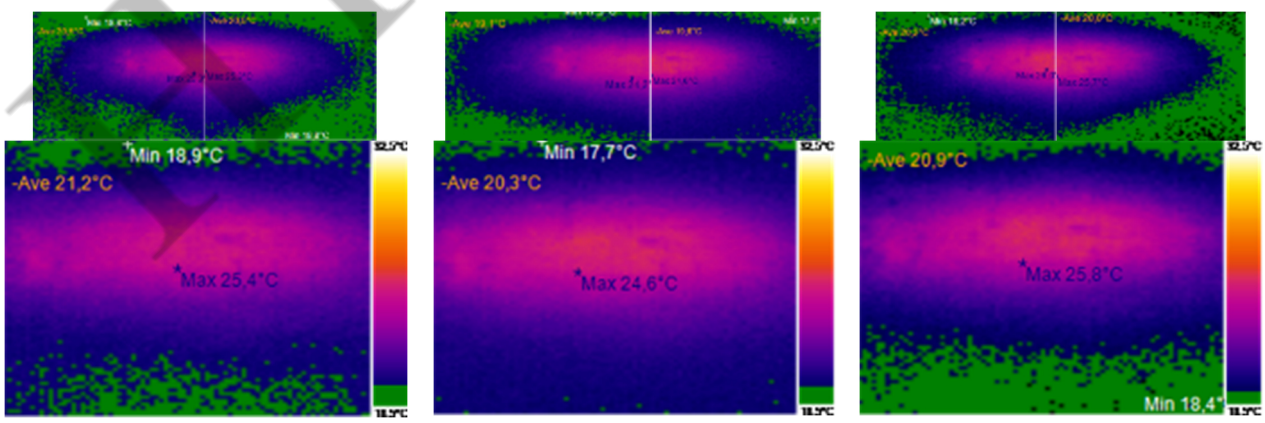


Fig. 4. Infrared heater wave distribution diagram
A × B - thermal trace of efficient heating;
a × b is the thermal trace of wave scattering.

IV. RESULTS

In fig. 5 shows thermograms of the real thermal trace of heaters.



а) б) в)

Fig. 5. Thermal trace of heaters
a) Bilux; b) Thermal; c) Heat theme

The isotherm of the cold floor measured before the experiment to determine the boundaries of the thermal trace is highlighted in green. The dimensions of the thermal trace were determined by the method of placing a hot object and then measuring the dimensions with a tape measure. Dimension measurements are presented in table.1.

Table 1. Dimensions of the thermal trace

	Bilux	**Teplov**	**Teplotema**
A, mm	1400	1100	1200
a, mm	1800	1200	1700
B, mm	1300	1000	1100
b, mm	1400	1100	1300
Spot form	a × b = 1,98м2 A × B = 1,43м2	a × b = 1,04м2 A × B = 0,86м2	a × b = 1,74м2 A × B = 1,04м2

The area of the trace shape was measured in the AutoCAD software package after full-size visualization.

During the operation of the heater, using a wattmeter, energy consumption was measured. Figure 6 shows the results of measurements, which show that the energy consumption of heaters Teplov and Teplotem is 10% higher than nominally stated.

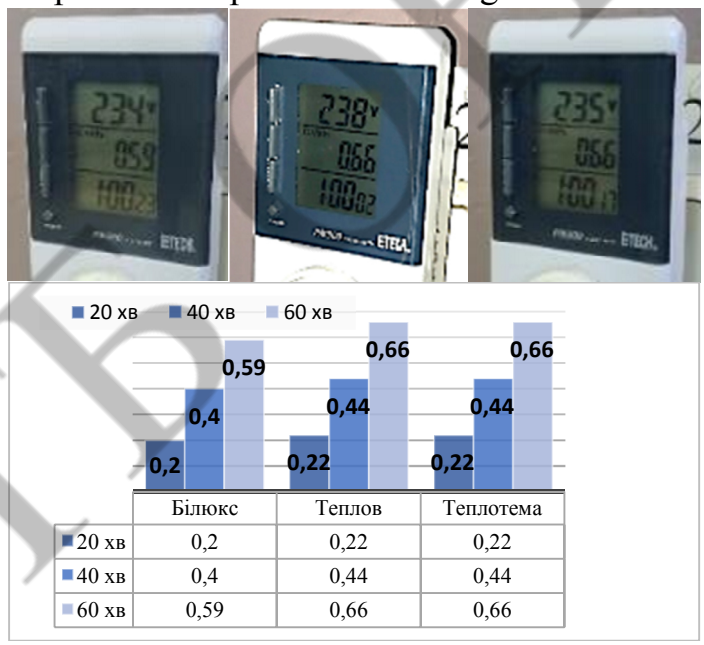
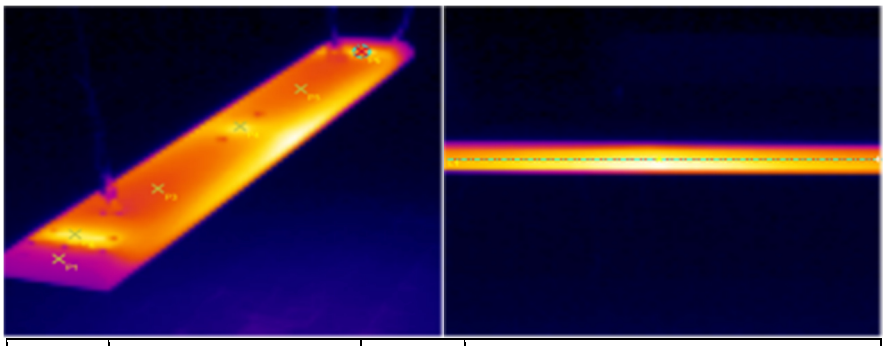


Fig. 6. Wattmeter readings and energy consumption diagram based on readings

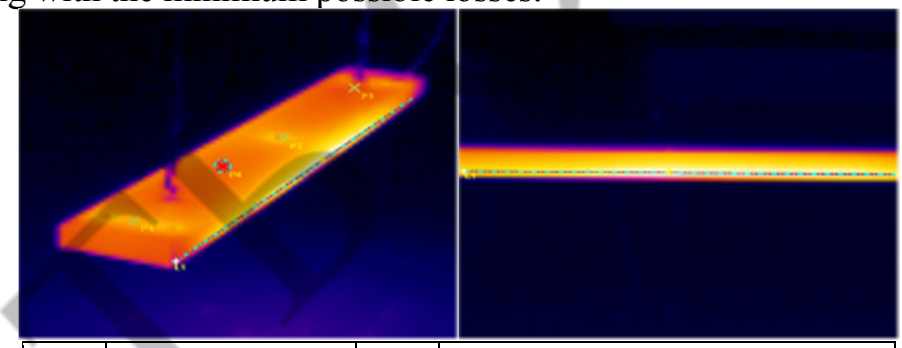
Causes of excessive energy consumption can be heat loss through the housing. As can be seen from Fig. 2 each of the samples has a different thermal insulation. So Bilux has above all a heat-reflecting plate of a streamlined form that is effective so that the energy which can be lost through the case is directed in the direction of effective heating. Teplotema and Teplov have only thermal insulation material in the upper part of the case.



Point	Temperature	№	Average temperature
P1	49,4°C	L1	77,9°C
P2	81,2°C		MAX
P3	60,4°C		83,8°C
P4	80,7°C		MIN
P5	63,4°C		70,6°C
P6	81,2°C	-	-

Fig. 7. Thermogram of the body of the Bilux heater from above on points, and on the side behind the line

As can be seen from the thermogram, the temperature of the housing is not high, and safe to install under the ceiling using any cladding. The temperature on the side of the heater is the same as the upper part, which means that the temperature is distributed evenly over the housing, which in turn indicates the correctness of the thermal insulation of the housing with the minimum possible losses.

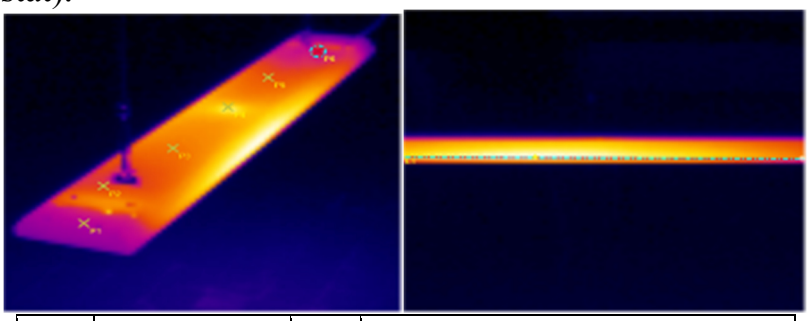


№	Temperature	№	Average temperature
P1	67,7°C	L1	88,8°C
P2	71,8°C		MAX
P3	57,1°C		91,3°C
P4	61,2°C		MIN
-	-		83,8°C

Fig.8. Thermogram of the body of the heater Teplov from above on points, and on the side behind the line

As can be seen from the thermogram, the top of the case has a lower temperature than Bilux, but the temperature on the side is significantly higher, this is due to uneven thermal insulation and the shape of the body of the Teplov heater. Temperatures indicate the fire safety of the heater. However, it should be noted that the housing on top has no ventilation holes, and such a strong insulation without ventilation holes can have a

negative impact on the long life of the heater if you need to constantly work at maximum (without thermostat).



№	Temperature	№	Average temperature
1	53,2°C	L1	95,8°C
2	65,7°C		MAX
3	73,8°C		101,9°C
4	88,4°C		MIN
5	68,8°C		79,8°C
6	57,4°C	-	-

Fig. 9. Thermogram of the heater body Heat from above on points, and on the side behind the line

The thermogram shows that despite the similarity of shape and arrangement of the heater Bilux, Teplotema made a mistake using only thermal insulation material and its uneven placement. It can be seen that the temperature at the ends is high, which creates an additional load on the terminal connection and, accordingly, on operational safety. It is also seen that high heat losses are radiated through the side surface.

Energy efficiency

Having determined the main indicators - heat footprint (namely its size) and energy consumption, you can already make a preliminary conclusion about which of the heaters is best for use.

However, any conclusion must be confirmed by mathematical calculations.

For comparative analysis of the specific energy efficiency of heaters, for thermograms obtained 10 minutes after switching off the device (real thermal trace), for each model was determined the maximum temperature difference in the field (thermal imager frame) heated floor surface, and calculated heat transfer according to Stefan-Boltzmann.

The amount of heat given off by the radiating surface according to Sephane-Boltzmann law is given in formula 1:

$$Q = C_g \cdot \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right] \cdot t \cdot F \quad (1)$$

where C_g – the coefficient of radiation is given, $C_g = 5{,}77 \cdot 0{,}9 = 5{,}193$, Вт/м2·К4;

T_1 – the temperature of the radiating surface, the average temperature of the thermal trace, *K*;

T_2 – ambient temperature, *K*;
t – time, hours;
F – the area of the radiating surface (thermal trace), m2.

$$Q_{Bilux} = 5{,}193 \cdot \left[\left(\frac{(22+273)}{100}\right)^4 - \left(\frac{(18{,}5+273)}{100}\right)^4\right] \cdot 1 \cdot 1{,}98 = 36{,}3658 \text{ Вт},$$
$$Q_{Teplov} = 5{,}193 \cdot \left[\left(\frac{(20{,}9+273)}{100}\right)^4 - \left(\frac{(18{,}5+273)}{100}\right)^4\right] \cdot 1 \cdot 1{,}04 = 13{,}0242 \text{ Вт},$$
$$Q_{Teplotema} = 5{,}193 \cdot \left[\left(\frac{(22{,}1+273)}{100}\right)^4 - \left(\frac{(18{,}5+273)}{100}\right)^4\right] \cdot 1 \cdot 1{,}74 = 32{,}8878 \text{ Вт}.$$

Next, determine the efficiency of the consumed electrical energy to obtain heat given off by the radiating surface, according to formula 2. That is, how many watts of electrical energy is used to obtain one watt of heat:

$$E = W/Q \tag{2}$$

where W – electricity consumed by the heater per hour.

$$E_{Bilux} = \frac{590}{36{,}3658} = 16{,}2241 \text{ W},$$
$$E_{Teplov} = \frac{660}{13{,}0242} = 50{,}6750 \text{ W},$$
$$E_{Teplotema} = \frac{660}{32{,}8878} = 20{,}0683 \text{ Вт}.$$

For indicative results, we express in percentage terms, taking the indication of the efficiency of the heater Bilux for 100%, then:

- efficiency of the Teplov heater = $\frac{16{,}2241}{50{,}6750}\% = 32\%$;
- efficiency of the Teplotem heater = $\frac{16{,}2241}{20{,}0683}\% = 81\%$;

The calculation shows the obvious advantage of the efficiency of the heater Bilux.

V. CONCLUSIONS

During the technical comparison of three samples of long-wave infrared heaters, a physical inspection of all samples was performed, thermal imaging of the thermal trace of each sample, thermal imaging of each sample, analysis of the obtained thermograms.

Based on the above, the following conclusions can be drawn:

1) According to the thermograms of the devices, the Bilux heater has the lowest heat loss through the housing, and the temperature modes of the device indicate reliable operation with long-term use at maximum power;

2) According to the thermograms of devices, the Teplov heater ranks second in reliability, in terms of heat loss Teplov and Bilux heaters can be compared as Teplov has less losses through the top and larger sides, so in balance they are the same in heat loss;

3) According to the thermograms of the devices, the heater from Teplotema is the least reliable and with the highest heat losses through the housing;

4) In terms of thermal trail, the most efficient heater is Bilux, and the least efficient is Teplov;

5) Structurally, the Bilux heater has the best design - the practical shape of the body, and the correct gaps. Teplov has good thermal insulation, but not enough on the side and the rectangular shape is a disadvantage for reliable operation. The heat theme in the analysis shows that it is a copy of Bilux, but not high quality, and errors in copying have made a number of shortcomings that make it unreliable and inefficient.

6) According to the efficiency calculation, Bilux heaters are 68% more efficient than Teplov heaters and 19% more efficient than Teplotem heaters.

Of the presented samples, the best option is the products of Bilux. However, this comparison is incomplete due to the fact that only 3 samples were tested. When choosing from a larger list, it is necessary to make the presented comparison for heaters from other companies.

Summing up, we can add that a quality heater can be purchased only after contacting the manufacturer with a desire to provide complete data on heaters - thermal imaging of the thermal trail, verified data on energy consumption, data on body temperature. These data provide information on real efficiency and heating capacity.

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EFFICIENCY IMPROVING OF MARINE ENGINES BY USING A CONTACT COOLING SYSTEM WITH A THERMOPRESSOR

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Abstract. *Ensuring the optimal initial parameters of the working cycle by improving the turbocharging system is one of the reserves for increasing the efficiencyof marine internal combustion engines. Reducing the power consumed by the charge air turbocharger provides a power reserve for the turbocharger turbine, which can be transferred to the engine shaft or used to drive an electric generator. There are several approaches to charge air cooling, one of them is to use thermopressor technologies in the ICE turbocharging system which allows two processes to be combined: contact cooling of the charge air and pressure increase, which reduces the compressor power consumption. A thermopressor can be used to carry out these processes. The authors of the research analyzed water spray systems and developed a scheme for improving the air-cooling systems of ship engines, which consists in the use of water injection into a thermopressor. This scheme allows to reduce the charge air temperature to 50...67 degrees, increase the relative increase in air pressure at the thermopressor outlet by 2...10%, and, accordingly, reduce the power of the engine turbocharger.*

Keywords: *turbocharger, pressure increase, water injection, charge air cooler.*

I. INTRODUCTION

There are many areas for further improvement of internal combustion engines in order to increase their efficiency, despite the high economic parameters, which are the result of a fairly high organization of the working processes of modern engines. In this case, a rational reserve for increasing efficiency is to improve systems serving the internal combustion engine, for example, the charge air cooling system improving. Today, there are several approaches to charge air cooling, on the one hand it is the use of surface air coolers. The heat exchange surface of such air coolers is a tubular-lamellar or tubular-finned structure. On the other hand, it can be applying of the contact cooling method: the forced air enters the humidification tower, in which water is injected by several nozzles to lower the air temperature and humidify it.

The authors propose to use thermopressor systems for charge air cooling. The effect of thermo-gas-dynamic compression occurs when the air is cooled in the thermopressor. This effect consists in increasing the gas pressure in the process of instantaneous evaporation of water injected into the air flow, which is accelerated to aspeed close to sonic. At the same time, heat from the charge air is removed for water evaporation, as a result of which the air temperature decreases. The thermopressor is a compact jet device, which in terms of dimensions significantly outperforms othersurface and contact type coolers, in addition, provides a certain pressure increase.

II. LITERATURE ANALYSIS

2.1. Analysis of modern methods of spraying water for air cooling systems

It is appropriate to conduct a literature review of liquid spraying methods when analyzing the contact cooling method. In many contact cooling systems, water injection will be effective if the liquid is properly atomized. This directly depends on the quality and the correct choice of nozzles (sprayers) for water, based on specific operating conditions. First of all, it is necessary to determine the type of spray and choose the type of spray torch that is most suitable for this case [1].

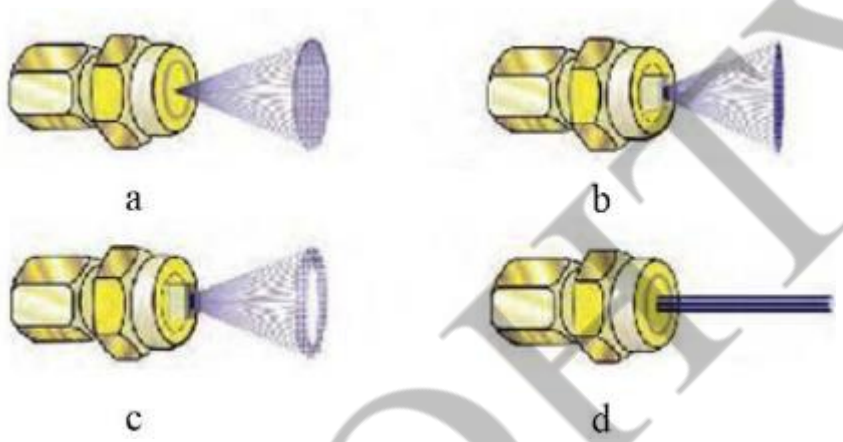


Fig. 1. Fluid spray types: full cone (a), flat spray (b), hollow cone (c), narrow spray (d)

Spraying water with hydraulic nozzles occurs under the action of pressure [1], which is pumped by the pump, which leads to the disintegration of the liquid into droplets (Fig. 2).

Fig. 2. Hydraulic water spray

In other words, passing through the spray device (nozzle), the liquid flow acquires a sufficiently high speed, turning into a form that promotes rapid dispersion (jet, film, large particles, depending on the ratio of the spray to a particular class). Thenarrowing of the nozzle cross section contributes to an increase in the flow rate, sincepotential energy is converted into kinetic energy. At the outlet of the nozzle, when thepressure

drops sharply, the laminar fluid flow breaks into drops of different sizes and creates a certain spray type.

Spraying water with pneumatic nozzles (Fig. 3) occurs as a result of the dynamic interaction of the liquid with the gas flow, that is, due to the simultaneous supply of compressed air and liquid under pressure to the mixing chamber of a two-phase nozzle [1]. In pneumatic atomization, the determining factor in the destruction of liquid continuity is the influence of a high-speed gas flow intended for additional splitting of water jets into small drops.

Fig. 3. Pneumatic water spray

Regardless of the chosen spraying method, a decrease in the droplet sizeinevitably leads to an increase in specific energy consumption, that is, a decrease in thespraying efficiency. Thus, in hydraulic spraying, in order to reduce the droplet size, it is necessary to increase the liquid pressure drop across the nozzle. For example, when spraying 1 m^3 of water at P = 0.2…0.4 MPa, the droplet size is on average 250…300 µm, and the efficiency is 0.05…0.07%. To obtain drops with a diameter of 100 µm, the pressure drop has to be increased to 1.0...1.5 MPa, while the efficiency drops to 0.02. 0.03%. If the desired particle size is 50 microns, the pressure increases to 3.0. 4.0 MPa, and the efficiency decreases to thousandths of a percent.

Obtaining the required droplet size is not an easy task. Thus, traditional mechanical and hydraulic nozzles with a working pressure even up to 30 MPa do not provide the required spray quality [2].

The original solution to the water spray problem was applied by Mee IndustriesInc [3, 4]. To supply water to the air flow, nozzles of a special design were developed,in which atomization is realized due to impact action (Fig. 4). Water under high pressure (15…20 MPa) is supplied to the nozzle head, as a result of the impact, drops with a diameter of no more than 50 microns are obtained.

Despite the relatively wide distribution of such systems, they require rather complex water supply pumping equipment and create known difficulties when operating the system under high pressure.

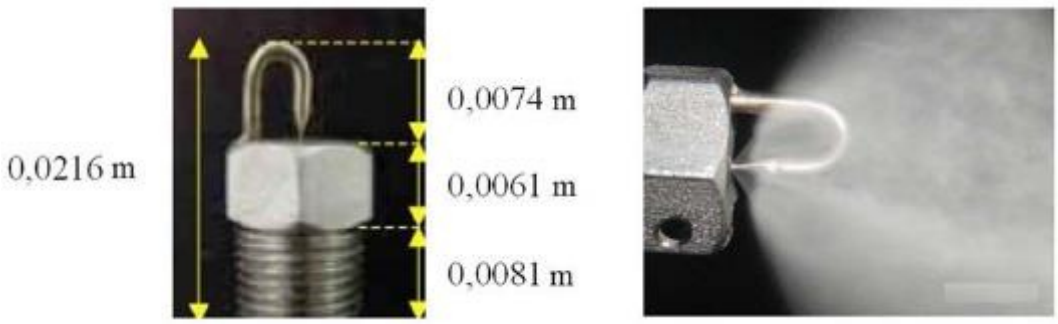


Fig. 4. The appearance of the nozzle and water spray (MeeFog)

Among the latest approaches, a particularly attractive way to improve the qualityof atomization is the use of the thermophysical properties of "explosive boiling" of water when it is overheated relative to the saturation temperature. At the end of the 90s,it was proposed to supply the nozzle with water superheated relative to the saturation temperature at a given pressure at the injection point (swirl-flash technology), when the “hydrodynamic” grinding of the swirling liquid film at the outlet of the nozzle intensifies with a sharp boiling up in its volume [5].

2.2. Analysis of modern methods of cooling the charge air of internalcombustion engines

Internal combustion engines are used as the main engines in diesel marine power plants. The charge air of the internal combustion engine is cooled in order to ensure normal operating conditions for the turbocharger and increase the mass charge of air in the cylinders. The air is cooled in heat exchangers of various designs: round-tubular, flat-tubular with corrugated common plates, with a surface made of profiled sheets, etc. Cooling of charge air for every 10 K increases the mass of air entering the working cylinder by 2.0–2.5% and leads to a decrease in the average temperature of the working cycle and the heat stress of engine parts at increased boost pressure [6].

The increase in air temperature or charge in the compressor depends on the degree of pressure increase, compressor efficiency and heat exchange with the walls, that is, on the design of the compressor. At high pressure ratios, the engine intake temperature can become high (unless charge air cooling is applied), which adversely affects the engine.

On supercharged engines, charge air cooling is the most important and simple means of increasing power, which is the more effective, the higher the pressure ratio in the compressor π_c. Along with reducing heat losses and improving mechanical efficiency (higher power without increasing the pressure level), charge air cooling also contributes to a decrease in specific fuel consumption [7, 8].

To cool the charge air in modern diesel engines, different cooling methods can be used: surface, evaporative, water contact, turbo-expander, cooling with the use of a vortex effect. With surface cooling, depending on the design, there can be plate and tubular heat exchangers (which have become more common), and by the type of coolant, coolers can be water-air and air-air [8].

The decrease in charge air temperature is typically 40–70°C. The value of pressure

losses in the exhaust gas system, according to the requirements of manufacturers for modern supercharged internal combustion engines, should be no more than 4.9 kPa. Thus, the use of charge air coolers in modern engines improves their fuel-economic and environmental performance. In this case, it is especially important to develop heat exchange systems in charge air coolers with minimal energylosses in heat and mass transfer processes.

To increase the efficiency of the piston ICE cycle, different schemes of direct water injection are used [9, 10]. In the working cycle of a piston engine, starting from the moment of ignition of the fuel-air mixture, the pressure and temperature that make it possible to organize the injection of water can be at any stage of the cycle after the start of the combustion process. There are known schemes for supplying water to the inlet pipe in order to cool the fresh air charge [9, 10].

Wârtsilâ's early designs used a Combustion Air Saturation System (CASS) to saturate the combustion air. An aqueous aerosol (dispersed stream) was injected through nozzles directly into the charge air stream immediately after the turbocharger. After heating, the mixture was saturated again by introducing an additional amount of water (Fig. 5). This solution provided a reduction in NOx to 3 g/(kW·h) [11], which is more efficient than the use of a water-fuel emulsion.

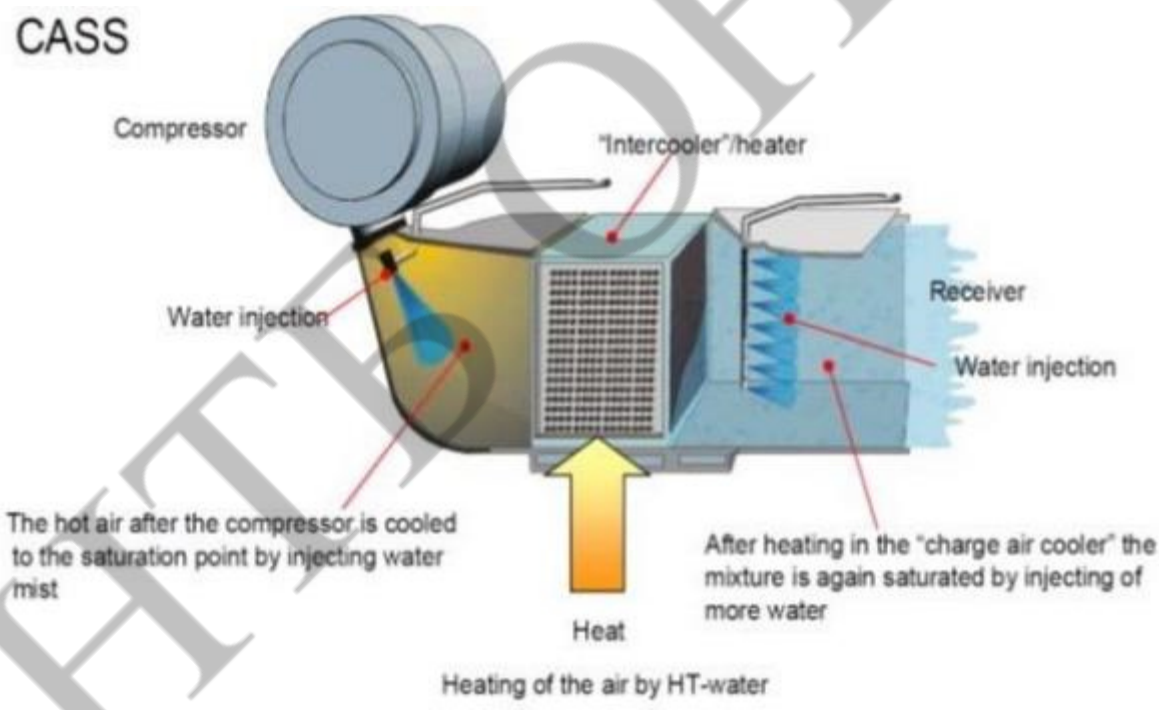


Fig. 5. Wârtsilâ charge air cooling system [101, 102]

In order to reduce NOx emissions, MAN has investigated the possibility of humidifying the charge air. To do this, the German company Munters Euroform developed a system called Humid Air Motor (HAM), which allows increasing air humidity up to 99% [12]. System testing showed that NOx was reduced by 70-80% in operational mode. The authors explain this by the fact that the increased content of steam in the charge air reduces the temperature peaks in the combustion chamber.

The disadvantage of all the considered methods is that the water injection reduces the average cycle temperature in the combustion zone and, as a result, the efficiency of the working process. This disadvantage can be eliminated by choosing the optimal method of water supply. Water injection at the beginning of the compression process not only reduces the maximum temperature of the working process, but also reduces the cost of compression work in the compressor, thereby increasing the total work per cycle [13].

III. OBJECT, SUBJECT AND RESEARCH METHODS

3.1. Goals and tasks of the research

The scientific and applied problem that is being solved in the research is the improvement of the internal combustion engine charge air system using evaporative cooling of the charge air in the thermopressor.

The object of research is ICE charge air cooling processes.

The subject of research is processes of contact (evaporative) cooling of charge air of internal combustion engines and their parameters.

Methods of research. The parameters of the charge air and the processes of its cooling in the thermopressor were calculated according to the method and program software using the equations of thermodynamics and gas dynamics of the flow, taking into account air humidity.

The goal of the research is to determine the directions of improving the fuel efficiency of the internal combustion engine by using the thermopressor systems for cooling the charge air.

Realization of the set purpose demands the solution of the following tasks.

- to analyze modern water spray systems in order to improve the cooling of the internal combustion air;
- to develop a special software based on known methods for calculating thermopressor devices, taking into account the features of the process of contact cooling of charge air;
- to develop a scheme of ICE charge air cooling systems using a thermopressor.

3.2. Methods for studying the operation of a thermopressor apparatus

In technology, processes are widely used in which the movement of gas through channels occurs under various external actions. These include a change in the cross-sectional area of the channel, the exchange of energy with the environment in the form of mechanical energy or heat transfer, the friction of the channel wall, the change in gas flow due to the supply of liquid to the flow, the process of mechanical and thermal interaction of liquid drops with a gas flow, etc.

Intensive heat supply causes an increase in aerodynamic resistance, and removal

– its decrease. With intensive heat removal and appropriate organization of the working process, it is possible not only to significantly reduce the resistance, but also to increasethe total pressure in the gas flow. In this case, due to the predominant thermal

action (heat removal), the gas flow is compressed. The apparatus is called a thermopressor, inwhich the total gas pressure increases at the outlet due to the removal of heat from thegas flow.

Heat can be removed by contact heat exchange through the channel walls and by evaporative cooling of the cooling water injected into the gas flow. The possibility of the process proceeding with an increase in the total pressure of the flow during evaporative cooling was theoretically shown for the first time by L.A. Vulis [14] in 1946. The issues of the working process theory, design and testing of a thermopressor received some coverage in the literature [15, 16].

During contact cooling of the air flow with water, a number of processes occur that mutually influence each other. The processes of heat and moisture exchange between air and water are decisive. Depending on the ratio between the vapor content of saturated air near a water droplet and the vapor content in the volume of air, either evaporation or condensation occurs [13]. In the process of contact of air with droplets of injected water, a layer of saturated air with water temperature is formed near the surface of the droplet. As a result, if the air is unsaturated, the driving force of mass exchange appears, in which the vapor formed around the surface of the droplet passes into the nearby layers of air and then, under the action of diffusion, spreads in the total volume.

The total heat flux was determined by the following equation [17, 18]:

$$dQ = dQ_c + dQ_{lat} \quad (1)$$

The wet bulb temperature of the air is the temperature of a water droplet at which the total heat exchange between air and the droplet is zero ($dQ_c = dQ_{lat}$). However, in an unsaturated air flow, heat removal does not stop and continues at a constant droplet temperature. This process is accompanied by humidification of the air, that is, the evaporation of water. The heat necessary for this evaporation is removed from the cooled air, as a result of which its temperature decreases [19].

The amount of sensible heat transferred from air to a drop was determined by the following equation [17]:

$$dQ_c = \alpha \cdot (T_a - T_d)\, dA_d, \quad (2)$$

where α – heat transfer coefficient, W/(m^2·K);

A_d – surface area of a water droplet, m^2;

T_a, T_d – air temperature and water droplets temperature, K.

Since water droplets are assumed to be spherical when evaporated, the droplet surface area is given by:

$$A_d = \pi \delta_d^2 \quad (3)$$

Accordingly, the mass of the droplet is:

$$m_d = \rho_w \pi \frac{\delta_d^3}{6} \quad (4)$$

The amount of latent heat of evaporation of a droplet is [18]:

$$dQ_{\text{lat}} = j_{\text{m}} \cdot r \cdot \left(d_{\text{a}} - d_{\text{s}}\right) dA_{\text{d}} \tag{5}$$

where j_{m} – mass flow density, kg/(m^2·s);

r – latent heat of vaporization, J/kg.

(d_{a}-d_{s}) – the difference between the moisture content of air in the main volume and unsaturated air around the droplet.

When a two-phase mixture moves in the thermopressor evaporation section, three characteristic modes can be distinguished (Fig. 6) [20, 21]:

- mode I: the influence of the drag of liquid droplets prevails over all other actions and determines the behavior of the flow;
- mode II: the determining process is the evaporation of the liquid;
- mode III: the surface friction of the air on the dry walls of the thermopressor predominates.

The diameter of a liquid droplet greatly affects the length of the evaporation section and the speed regime: with a decrease in the primary droplet size, the length of the evaporation section and friction losses are significantly reduced.

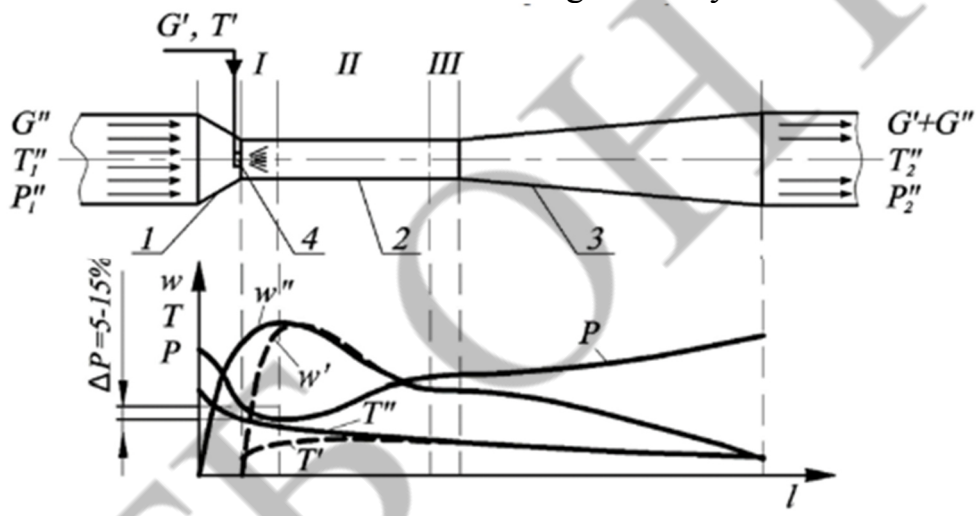


Fig. 6. The main structural elements of the thermopressor:
1 – confuser; 2 – evaporation chamber; 3 – diffuser; 4 – nozzle

Water injection increases the friction coefficient by 10...20%, so in order to avoid a further increase in losses, it is necessary to reduce the aerodynamic drag of the structural elements of the system. For this purpose, it is desirable to place injection devices in a flow with a low gas velocity (in front of the nozzle) and make them more streamlined [21].

3.3. Features of the cooling scheme application of internal combustion engines using a thermopressor

For modern marine medium-speed engines, as a rule, a three-circuit cooling system is used. At the same time, two cooling sections are used in the charge air cooler: high-temperature, in which heat is removed from the air to the water of the engine cooling system, and low-temperature, with heat removed to the fresh water circuit of

the central cooler.

A diagram using a thermopressor as a charge air cooler for the main turbocharger is illustrated in Fig. 7. Air is sucked in by a single-stage turbocharger and compressed to a pressure less than the pressure at the inlet to the internal combustion engine cylinders. After that, the air with high temperature and pressure enters for evaporative cooling in the thermopressor. At the same time, due to the effect of thermo-gas-dynamic compression, the air temperature is significantly reduced, and the pressure rises to the required value corresponding to the engine inlet. The final temperature reduction is carried out in the charge air cooler.

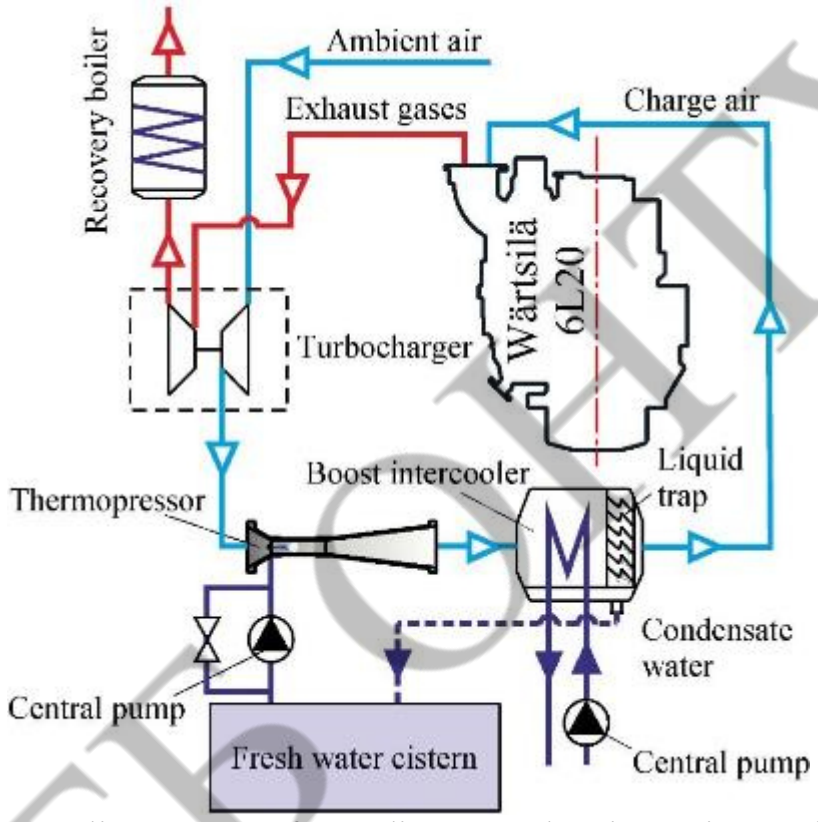


Fig. 7. Cooling system of a medium-speed main marine engine using a thermopressor

To determine the operating characteristics of the thermopressor and the main parameters of engine operation, a software package was developed based on known methods for calculating thermopressor devices [18, 21, 22], as well as taking into account the features of the process of contact cooling of the engine charge air.

IV. RESULTS

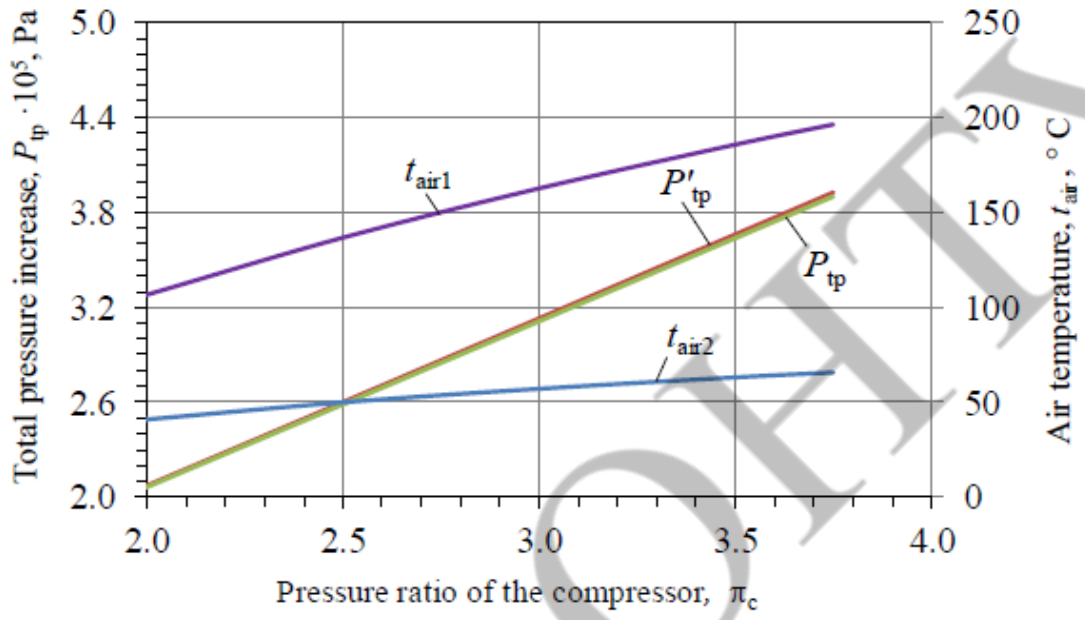
Results of research into the use of thermopressor systems for charge air cooling.

The calculation of the thermopressor system was made for the main ship's marine engine of Wârtsilâ (Finland) brand 6L20 (N_e = 1200 kW, n = 1000 min^{-1}).

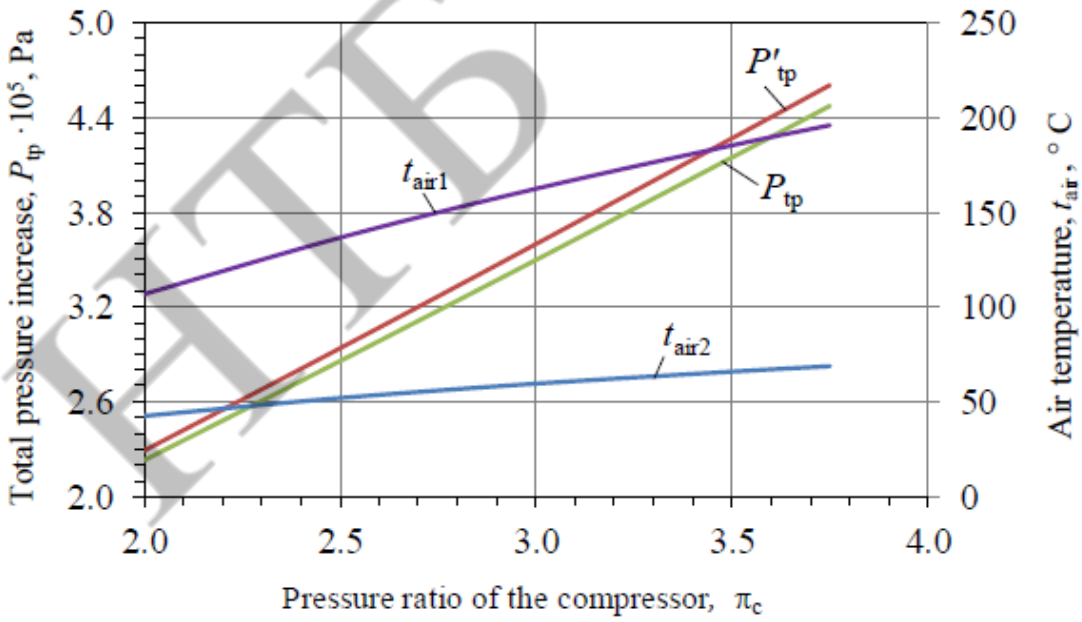
An analysis of the study results of the use of a thermopressor in charge air cooling systems (Fig. 8a, 9a) shows that the total air pressure at the "real" thermopressor outlet is P_{tp} = 2.0…3.8·10^5 Pa (up to 2.0%), and the total air pressure without friction

losses is P'_{tp} = 2.0…3.9·10^5 Pa at a water temperature for injection at the inlet of the thermopressor t_{w1} = 25 °C, at the air velocity at the inlet to the evaporation chamber M = 0.35. The air temperature at the thermopressor inlet is t_{air1} =106…196 °C, the air temperature at the thermopressor outlet is t_{air2} = 48...62 °C.

For the air velocity at the inlet to the evaporation chamber M = 0.85: the total air pressure at the "real" thermopressor outlet is P_{tp} = 2.2…4.4·10^5 Pa and the total air pressure without friction losses P'_{tp} = 2.3 …4.6·10^5 Pa. The air temperature at the thermopressor inlet is t_{air1} = 106…196 °C, the air temperature at the thermopressor outlet is t_{air2} = 50…65 °C (Fig. 8b, 9b).



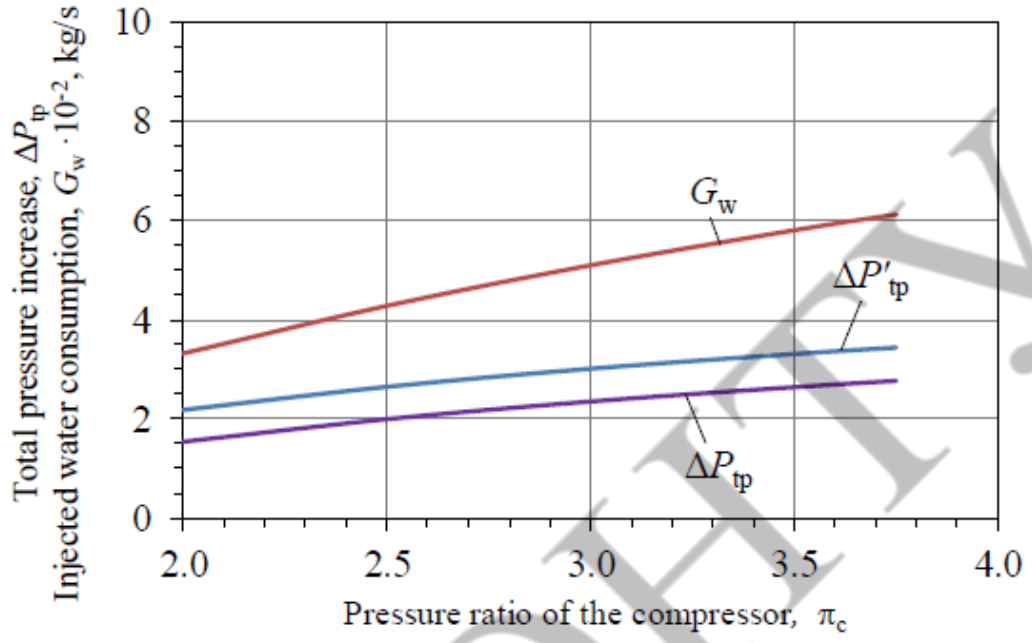
(a)



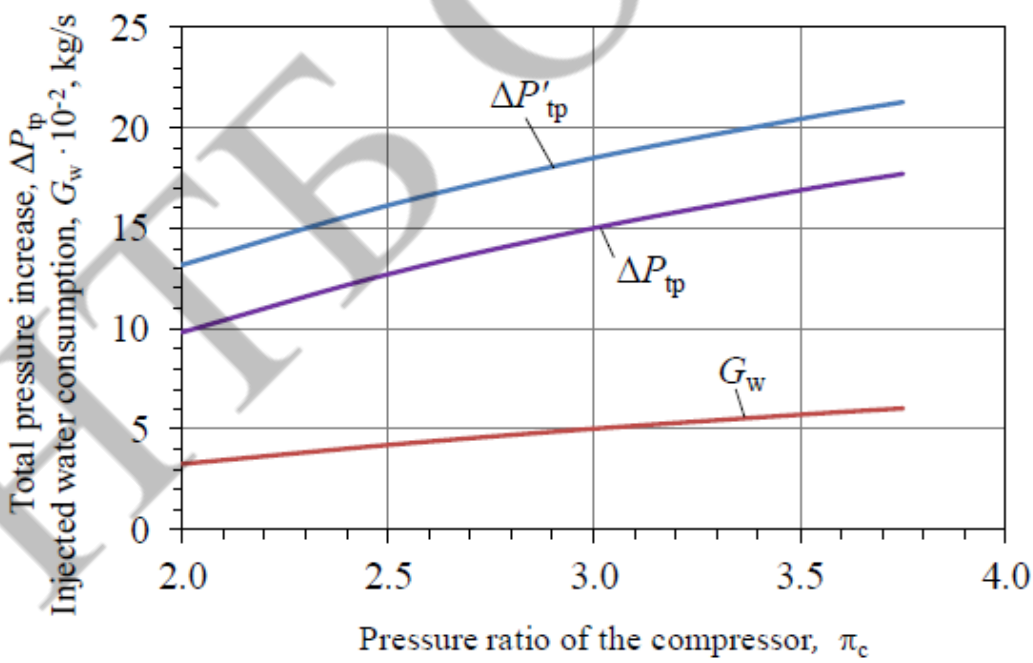
(b)

Fig. 8. Dependences of the total air pressure at the thermopressor outlet without friction losses P'_{tp}, the total air pressure at the "real" thermopressor outlet P_{tp}, air temperature t_{air} on the pressure ratio in the turbocharger π_c: M = 0.35 (a); M = 0.85 (b)

The research results show (Fig. 9a) that for the air velocity at the inlet to the evaporation chamber M = 0.35, the consumption of water injected into the thermopressor is G_w = 2.50...5.78 10^{-2} kg/s. And for the air velocity at the inlet to the evaporation chamber M = 0.85, the consumption of water injected into the thermopressor is G_w = 3.32...6.96 10^{-2} kg/s (Fig. 9b).



(a)

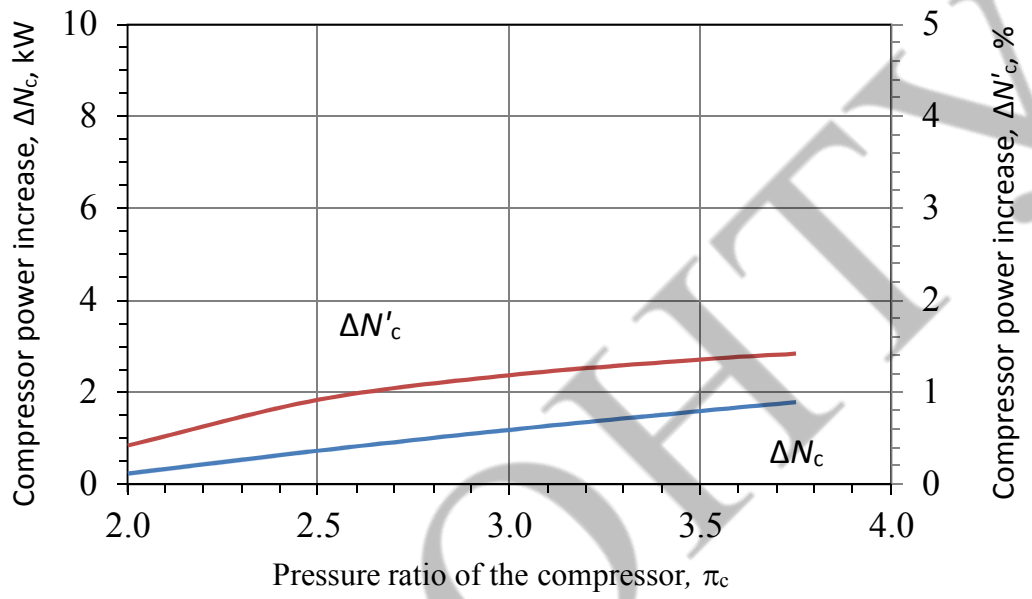


(b)

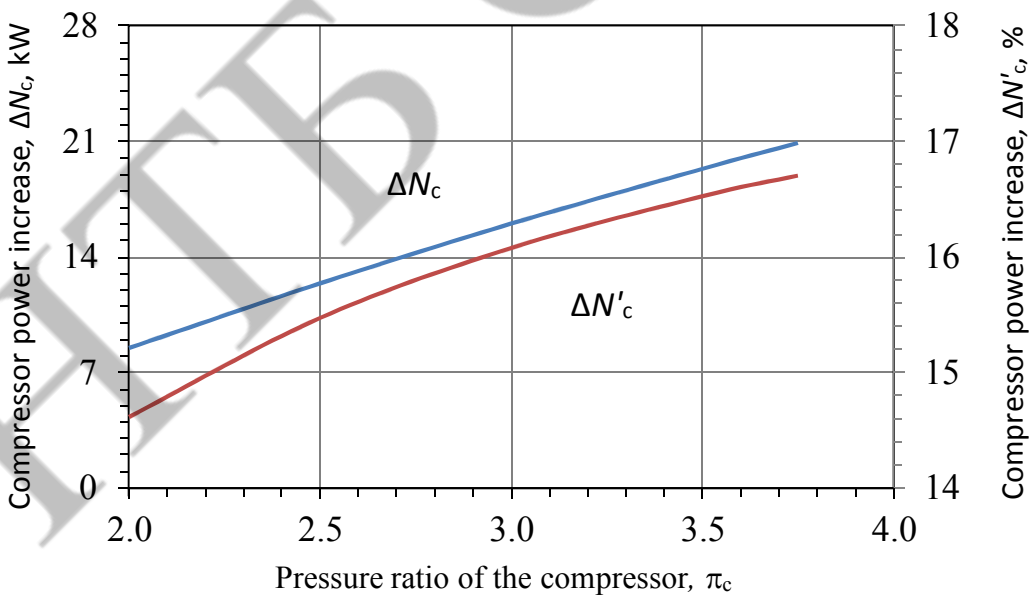
Fig. 9. Dependences of the air pressure increase at the thermopressor outletwithout friction losses $\Delta P'_{tp}$, the air pressure increase at the "real" thermopressor outlet ΔP_{tp}, injected water consumption G_w on the pressure ratioin the turbocharger π_c: M = 0.35 (a); M = 0.85 (b)

The obtained air parameters at the outlet of the thermopressor correspond to those recommended by the manufacturer for this type of engine, according to which the charge air temperature after the charge air cooler should not exceed 50 ... 70 °C.

Thus, the use of a thermopressor for cooling the charge air makes it possible to reduce the compressor drive power (Fig. 10a) by ΔN_c = 1…2 kW (0.5…1, 5 %) for the air velocity at the inlet to the evaporation chamber M = 0.35. And for the air velocity at the inlet to the evaporation chamber M = 0.85, the reduction in the compressor drive power is ΔN_c = 7…21 kW (13.0…17.5%).



(a)



(b)

Fig. 10. Dependence of the change in compressor power ΔN_c, $\Delta N'_c$ at the injected water temperature t_{w1} = 25 °C on the pressure ratio in the turbocharger π_c: M = 0.35 (a); M = 0.85 (b)

Cooling of the charge air with a thermopressor reduces the power consumed by the supercharged compressor and, accordingly, the power of the internal combustion

engine increases. Thus, the engine power increased by ΔN_e = 2…10 kW (up to 0.1%) for the air velocity at the inlet to the evaporation chamber M = 0.35 (Fig. 11a). And for the air velocity at the inlet to the evaporation chamber M = 0.85, engine power increased by ΔN_e = 38…109 kW (0.4…1.0%).

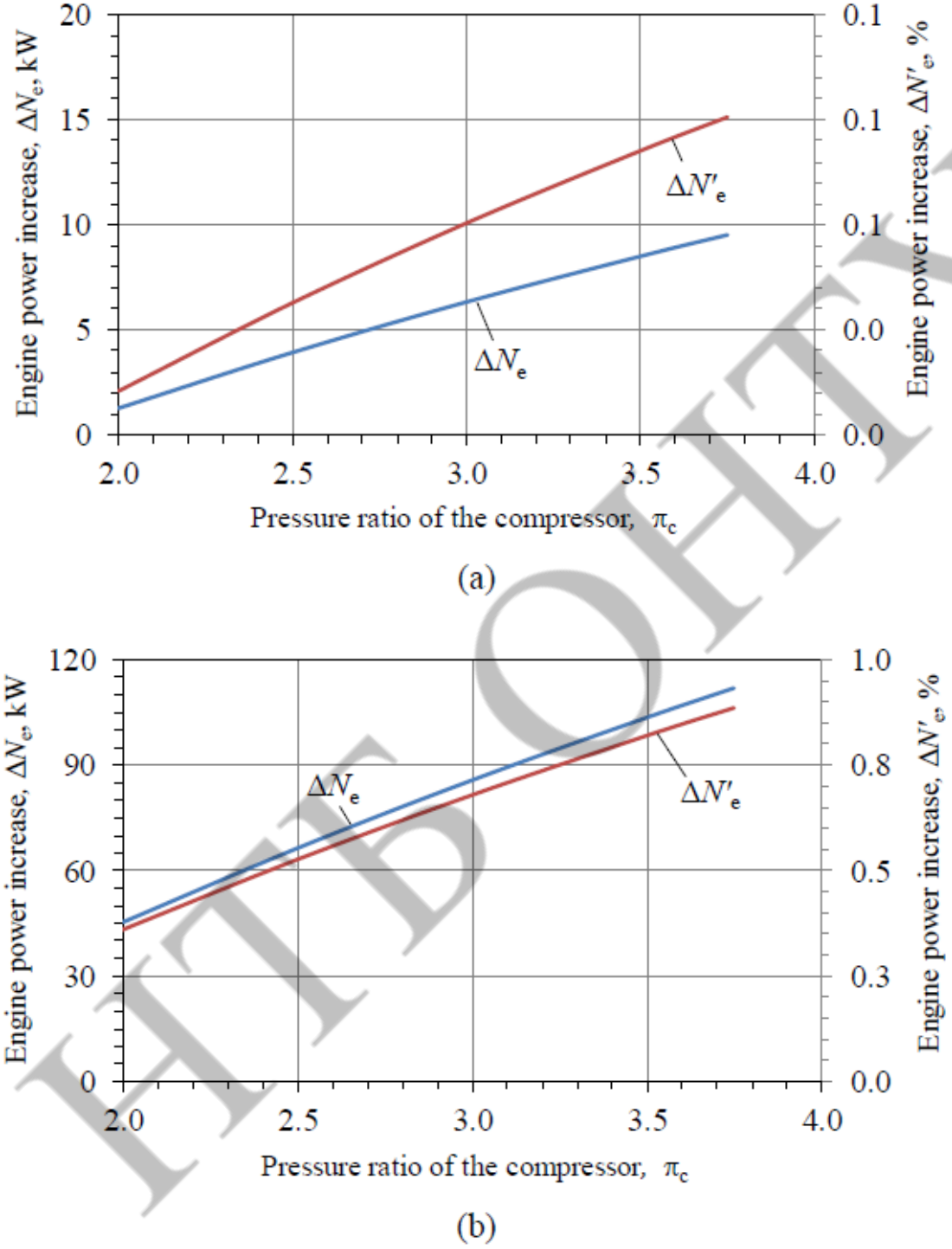


Fig. 11. Dependence of the engine power increase ΔN_e, $\Delta N'_e$ at the injectedwater temperature t_{w1} = 25 °C on the pressure ratio in the turbocharger π_c: M = 0.35 (a); M = 0.85 (b)

Thus, the use of a thermopressor in charge air cooling systems makes it possibleto reduce the power consumed by compressors by 1–17%, thereby increasing the powerof the internal combustion engine up to 1%.

V. CONCLUSIONS

1. The principle of cooling the charge air of the internal combustion engine with a simultaneous increase in pressure is proposed, which makes it possible to reduce the power consumption of the standard turbocharger while maintaining the total compression ratio πk.
2. The use of a thermopressor in charge air cooling systems makes it possible to reduce the power consumed by compressors by 1–17%, thereby increasing the power of the internal combustion engine up to 1%.
3. For the purpose of contact cooling of the charge air as well as environmental humidification of the charge air at the inlet to the ICE cylinders (in order to reduce the emission of nitrogen oxides NOx), a method of fine water spraying in the charge air by a thermopressor is proposed. This technology makes it possible to eliminate the need for complex water spray systems with nozzles located throughout the entire flow section.
4. Due to the higher intensity of heat exchange during contact cooling in the thermopressor (compared to surface cooling in traditional charge air coolers), the dimensions of the thermopressor are smaller compared to other types of heat exchangers.
5. It is proposed to use the water discharged during the cooling of moist air in the surface charge air cooler for injection into the thermopressor, which makes this system self-sufficient – autonomous.

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DEVELOPMENT OF THE AUTOMATED ELECTRIC DRIVE OF THE MINERAL FERTILIZER LOADER WITH DEVELOPMENT OF THE CONTROL SYSTEM

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Abstract. *At present, the automated electric drive is the basis of complex mechanization and automation of industrial processes. Automation frees a significant number of service personnel from constant shifts, during which in some cases there are only a few shifts per shift. The introduction of automatic control helps to improve the quality of service of the main technological process.*

At the enterprises the tendency of modernization of control systems of the old equipment has recently appeared. The control systems are outdated and the mechanical parts of the equipment remain at a sufficient level. New equipment is very expensive, and the modernization of the old is the only way out of this situation.

The purpose of this work is to replace the old control system of the electric drive of the reloader with a new one.

The peculiarities of the transmission conveyor operation are considered in the work, the electric drive capable of providing the necessary technological indicators of the installation is chosen. The calculation of the elements of the automatic control system, the calculation of the parameters of the electric drive. The MICROMASTER 420 frequency converter was chosen to control the induction motor. A mathematical model of the electric drive speed control system was developed.

Keywords: *power line, mathematical model of control system, reloader, agro-industrial complex, mineral fertilizers, automation of technological process.*

INTRODUCTION

At present, the automated electric drive is the basis of complex mechanization and automation of industrial processes. Automation frees up a significant number of service personnel from constant shifts, during which in some cases there are only a few shifts per shift. The introduction of automatic control helps to improve the quality of service of the main technological process.

At the enterprises the tendency of modernization of control systems of the old equipment has recently appeared. The control systems are outdated and the mechanical parts of the equipment remain at a sufficient level. New equipment is very expensive, and the modernization of the old is the only way out of this situation.

The paper considers the issue of replacing the old control system of the reloader with a new one. In this case, the mechanical parts of the conveyor remain and the electric drive control system is replaced with a more modern one. The modern electronics industry has great potential for new developments in the field of

automated control systems for electric drives. With the unification of the creation of automated systems has recently gained the advantage of creating complete automated drives. This increases the performance of technological equipment. New possibilities of connection or control of the batcher by means of the computer appear.

1. ANALYSIS OF THE BASIC CONTROL SYSTEM OF THE ELECTRIC DRIVE OF THE LOADER OF MINERAL FERTILIZERS

When developing automation devices for rural installations, they must rely on the broad limits of changes in environmental parameters. This will provide highly reliable tools, as the most effective measures to combat the reliability of automation devices - the choice of elements with low risk of failure and various ways to increase reliability in the design. These specific features primarily affect the primary transducers (sensors) and executive bodies of automation, which are installed directly on the objects of automation and experience all adverse environmental conditions. Other automation units can be located in separate rooms or special cabinets that eliminate adverse environmental influences.

The sequence of nodes in the RSSC (Rheostat-contactor control system) depends on their electrical connections, reflected in the electrical circuits. The electric scheme of RSSC is a graphic form of the image of RSSC. Figure 1 shows the general functional diagram of the RSSC. It shows the functional composition of the RSSC in the form of nodes and noted their relationship. As the most complete information about the control system gives the so-called schematic diagram. It lists all the elements of the control system, displayed and marked in accordance with the standard, reflect all the electrical connections of the elements [5-7].

1.1. The choice of the electric motor for the drive of the loader of mineral fertilizers

To drive a mineral fertilizer reloader, choose the engine, power, kW, which is determined by the formula:

$$\mathrm{P} = \frac{k_3 Q}{1000\eta_{\text{м}}}(cL + H), \tag{1}$$

where k_3- he power reserve factor of the conveyor, equal 1,1 – 1,25; Q – conveyor productivity, H/c; L – distance between the axes of the end drums, m; H – lifting height, m; $\eta_{\text{м}}$ - efficiency of the reducer mechanism 0,7÷0,85; c = 1,5÷2 – for scraper conveyors; c = 0,14÷0,32 – for plate conveyors.

1.2. Development of a mathematical model of an automated electric drive

In the study of transients in three-phase asynchronous motors, it is advisable to accept the following assumptions that simplify the expression of the basic parameters and coordinates of the motor: the magnetizing forces of the motor windings are distributed sinusoidally along the circumference of the air gap; losses in the steel of the stator and rotor are absent; stator and rotor windings are strictly symmetrical with a shift of the axes of the windings by 120 °; there is no saturation of the magnetic field [13].

The equations of voltage equilibrium for the windings of the three phases of the stator have the form:

$$\left.\begin{aligned} u_{1a} &= i_{1a}R_1 + \frac{d\psi_{1a}}{dt} \\ u_{1b} &= i_{1b}R_1 + \frac{d\psi_{1b}}{dt} \\ u_{1c} &= i_{1c}R_1 + \frac{d\psi_{1c}}{dt} \end{aligned}\right\} \tag{2}$$

where $u_{1a}, u_{1b}, u_{1c}, u'_{2a}, u'_{2b}, u'_{2c}$ - instantaneous values of the phase voltages of the stator and rotor engine; $i_{1a}, i_{1b}, i_{1c}, i'_{2a}, i'_{2b}, i'_{2c}$ - instantaneous values of the stator and rotor phase currents; $\psi_{1a}, \psi_{1b}, \psi_{1c}, \psi_{2a}, \psi_{2b}, \psi_{2c}$ - complete flux couplings of phase windings; R_1, R_2 - active supports of stator and rotor windings.

In the mathematical description of three-phase asynchronous electric motors, it is convenient to operate not with instantaneous coordinate values, but with their resulting vectors. If, for example, the instantaneous current values are equal i_a, i_b, i_c then the resulting current vector is determined by the equation:

$$i = \frac{2}{3}(a^0 i_a + a i_b + a^2 i_c) = \frac{2}{3}(i_a + a i_b + a^2 i_c)\,, \tag{3}$$

where $a^0 = e^{j0} = 1$; $a = e^{j\frac{2\pi}{3}}$; $a^2 = e^{j\frac{4\pi}{3}}$.

The resulting voltage vectors are determined similarly

$$u = \frac{2}{3}\cdot(u_a + a u_b + a^2 u_c) \tag{4}$$

and flux coupling:

$$\psi = \frac{2}{3}(\varphi_a + a\varphi_b + a^2\varphi_c) \tag{5}$$

Using the expression of the resulting vectors, equation (1) can be written as a single differential equation in vector form. To do this, the first equation from (1) is increased by $\frac{2}{3}\alpha^0$, second on $\frac{2}{3}\alpha$, third on $\frac{2}{3}\alpha^2$. Summarizing the obtained products, we obtain:

$$\frac{2}{3}(u_{1a} + a u_{1b} + a^2 u_{1c}) = \frac{2}{3}(i_{1a} + a i_{1b} + a^2 i_{1c})R_1 + \frac{2}{3}\frac{d}{dt}(\psi_{1a} + a\psi_{1b} + a^2\psi_{1c}) \tag{6}$$

or in vector form:

$$u_1 = I_1 R_1 + \frac{d\psi_1}{dt} \tag{7}$$

The equation of an induction motor in a coordinate system rotating at an arbitrary speed ω_k, have the form:

$$\left.\begin{aligned} u_1 &= i_1 R_1 + \frac{d\psi_1}{dt} + j\omega_k\psi_1 \\ u'_2 &= i'_2 R'_2 + \frac{d\psi_2}{dt} + j(\omega_k - p_{\ddot{I}}\psi_2) \end{aligned}\right\}, \tag{8}$$

where ω - angular speed of rotation of the rotor; $p_{\ddot{I}}$ - number of pole pairs.

When studying transients in an induction motor, which is controlled by the frequency and voltage of the stator, it is convenient to use the system

coordinates that rotate at a speed ω_k, and is equal to the angular velocity of the magnetic field $\omega_0^{'}$, which is reduced to the number of pairs of poles and is equal to 1 (reduction to a two-pole motor).

$$\omega_0^{'} = \omega_1 = 2\pi f_1, \tag{9}$$

where f_1 - stator voltage frequency, Hz;

Therefore, based on equations (7) we can write:

$$\left.\begin{aligned} u_1 &= i_1 R_1 + \frac{d\psi_1}{dt} + j\omega_1\psi_1 \\ u'_2 &= i'_2 R'_2 + \frac{d\psi_2}{dt} + js\omega_1\psi_2 \end{aligned}\right\}, \tag{10}$$

where s – electric motor slip:

$$s = \frac{\omega_0 - \omega}{\omega_0} = \frac{\omega_1 - p_i\omega}{\omega_1} \tag{11}$$

Current couplings are related to currents due to inductors:

$$\left.\begin{aligned} \psi_1 &= i_1 L_1 + i_2^{'} L_m \\ \psi_2 &= i_1 L_1 + i_2^{'} L_2^{'} \end{aligned}\right\} \tag{12}$$

To determine the electromagnetic moment of an induction motor, we use a vector product ψ_1 and i_1, then:

$$M = \frac{3}{2} p_n (\psi_1 \times i_1) \tag{13}$$

or vector product ψ_2 and $i_2^{'}$, then:

$$M = -\frac{3}{2} p_n (\psi_2 \times i_2^{'}) \tag{14}$$

Given equation (11), we can write (15) and (16):

$$M = \frac{3}{2} p_{\Pi} (i_1 L_1 + i_2^{'} L_m) \times i_1 = \frac{3}{2} p_{\Pi} L_m (i_2^{'} \times i_1) \tag{15}$$

$$M = -\frac{3}{2} p_{\Pi} (i_1 L_m + i_2^{'} L_2^{'}) \times i_2^{'} = -\frac{3}{2} p_{\Pi} L_m (i_1 \times i_2^{'}) \tag{16}$$

These equations are correct because the vector product of two equally directed vectors is zero.

To fully describe the transients in an induction motor by comparing voltages and moments, you need to add the equation:

$$M - M_o = J\frac{d\omega}{dt} \tag{17}$$

For further researches of dynamic properties of asynchronous electric motors it is expedient to present the resulting vectors in the form of projections on the complex plane and to write down them through material and imaginary parts in the following kind:

$$\left.\begin{aligned} u_1 &= u_{1a} + ju_{1\beta}; & u_2^{'} &= u^{'}_{2a} + ju^{'}_{2\beta}; \\ i_1 &= i_{1a} + ji_{1\beta}; & i_2^{'} &= i^{'}_{2a} + ji^{'}_{2\beta}; \\ \psi_1 &= \psi_{1a} + j\psi_{1\beta}; & \psi_2 &= \psi_{2a} + j\psi_{2\beta}; \end{aligned}\right\} \tag{18}$$

Combining the stator voltage vector with the real axis of the coordinate system $u_{1\beta} = 0$ ie putting we get:

$$u_{1a} = \frac{d\psi_{1a}}{dt} - \omega_1 \psi_{1\beta} \tag{19}$$

$$0 = \frac{d\psi_{1\beta}}{dt} + \omega_1 \psi_{1a} \tag{20}$$

$$u'_{2a} = i'_{2a} R'_2 + \frac{d\psi_{2a}}{dt} - s\omega_1 \psi_{2\beta} \tag{21}$$

$$u'_{2\beta} = i'_{2\beta} R'_2 + \frac{d\psi_{2\beta}}{dt} + s\omega_1 \psi_{2a} \tag{22}$$

Expressing also the electromagnetic moment on the equation (11) through components of vectors of currents and flux coupling:

$$M = \frac{3}{2} p_{\Pi} (\psi_{1a} + j\psi_{1\beta}) \times (i_{1a} + j i_{1\beta}) \tag{23}$$

and applying the rule of vector product of vectors, we obtain the absolute value of the moment: $M = \frac{3}{2} p_{\Pi} (\psi_{1a} i_{1\beta} - \psi_{1\beta} i_{1a})$, (24)

where

$$\psi_{1a} = i_{1a} L_1 + i'_{2a} L_m \; ; \quad \psi_{1\beta} = i_{1\beta} L_1 + i'_{2\beta} L_m \tag{25}$$

Using expression (2.15), we can similarly obtain:

$$M = -\frac{3}{2} p_{\Pi} (\psi_{2a} i'_{2\beta} - \psi_{2\beta} i'_{2a}) \tag{26}$$

The component currents of the rotor can be expressed through the components of the flux coupling in the following form:

$$\left.\begin{aligned} i'_{2a} &= \frac{1}{L'_2} (\psi_{2a} - k_1 \psi_{1a}) \\ i'_{2\beta} &= \frac{1}{L'_2} (\psi_{2\beta} - k_1 \psi_{1\beta}) \end{aligned}\right\}, \tag{27}$$

where k_1 - stator electromagnetic coupling coefficient.

$$k_1 = \frac{L_m}{L_1} \tag{28}$$

$$L''_2 = L'_2 - \frac{L_m^2}{L_1} \approx L_{1\sigma} + L'_{2\sigma} \tag{29}$$

Taking into account (10) and (25), the moment expressions can be written in a form convenient for outputting the transfer functions of the engine:

$$M = -\frac{3}{2} p_{\Pi} k_1 \psi_1 \times i'_2 \tag{30}$$

or

$$M = -\frac{3}{2} p_{\Pi} k_1 (\psi_{1a} i'_{1\beta} - \psi_{1\beta} i'_{2a}) \tag{31}$$

For a motor with a short-circuited rotor in equations (19), (20) $u'_{2a} = u'_{2\beta} = 0$.

Expressed from the equations (26) ψ_{2a} and $\psi_{2\beta}$ substituting them in equations (22), (23) we obtain:

$$0 = i'_{2a} R'_2 + L'_2 \frac{di'_{2a}}{dt} - s\omega_1 L''_2 i'_{2\beta} - k_1 s\omega_1 \psi_{1\beta} \tag{32}$$

$$0 = i'_{2\beta} R'_2 + L''_2 \frac{di'_{2\beta}}{dt} + s\omega_1 L''_2 i'_{2a} \tag{33}$$

$$M = \frac{3}{2} p_П k_1 \psi_{1\beta} i'_{2a} \tag{34}$$

Considering the variables in increments relative to the initial values $i'_{2a} = I'_{2a} + \Delta i'_{2a}$, $i'_{2\beta} = I'_{2\beta} + \Delta i'_{2\beta}$, $\omega_1 = \Omega_1 + \Delta\omega_1$, $s = S + \Delta s$, $M = M_{поч} + \Delta M$, we obtain equations for static mode that relate the initial values of the coordinates:

$$\frac{U_{1a}}{\Omega_1} = -\psi_{1\beta} = const \tag{35}$$

$$0 = I'_{2a} R'_2 - S\Omega_1 L''_2 I'_{2\beta} - k_1 S\Omega_1 \psi_{1\beta} \tag{36}$$

$$0 = I'_{2\beta} R'_2 + S\Omega_2 L''_2 I'_{2a} \tag{37}$$

$$M_{поч} = \frac{3}{2} p_n k_1 \psi_{1\beta} I'_{2a} \tag{38}$$

and equations for dynamic mode, which connect the increment of coordinates:

$$\Delta i'_{2a}(T_e p + 1) = \frac{s}{S_{kp}} \Delta i'_{2\beta} + \left(\frac{i'_{2\beta}}{S_{kp}} + \frac{k_1 \psi_{1\beta} \Omega_1}{R'_2}\right)\Delta s \tag{39}$$

$$\Delta i'_{2\beta}(T_e p + 1) = \frac{s}{S_{kp}} \Delta i_{2a} - \frac{i'_{2a}}{S_{kp}} \Delta s \tag{40}$$

Moment $M_{поч}$ in the second term of the numerator (41) can be written taking into account the accepted assumptions in the form:

$$M_{поч} = \frac{2M_{kp}}{\frac{S}{S_{kp}} + \frac{S_{kp}}{S}} \tag{41}$$

Expression (40) will take the following for

$$\frac{\Delta M(p)}{\Delta s(p)} = \frac{M_{П.Ф.}\left[(T_e p + 1) - \frac{(\frac{S}{S_{kp}})^2}{1 + (\frac{S}{S_{kp}})^2}(T_e p + 2)\right]}{(T_e p + 1)^2 + (\frac{S}{S_{kp}})^2} \tag{42}$$

For the working part of the mechanical characteristics of the engine can be taken:

$$(\frac{S}{S_{кр}})^2 << 1 \tag{43}$$

Representing the dependence of the slip of the motor on the angular frequency of the stator voltage in increments and performing linearization, provided that in the working area, $S << 1$, we obtain:

$$\Delta s = \frac{\Delta\omega_1 - p_П \Delta\omega}{\Omega_1} \tag{44}$$

The equilibrium equation of moments (18) can be written in increments as:

$$\Delta M - \Delta M_o = Jp\Delta\omega \tag{45}$$

block diagram of an induction motor when controlling the angular frequency of the stator voltage and provided that the stator flux is constant: $M_{П.Ф.Н.}$, $\Omega_{1Н}$, U_{1aH}, $\Omega_{0H} = \frac{\Omega_{1H}}{p_Н}$, де Ω_{0H} - synchronous angular velocity of the motor.

Then $(\frac{\Delta\omega}{\Omega_{0H}}) = \Delta\overline{\omega}$, $(\frac{\Delta\omega_1}{\Omega_{1H}}) = \Delta\overline{\omega_1}$, $(\frac{\Delta M}{M_{П.Ф.Н}}) = \Delta\overline{M}$, $\left[\frac{\Delta M_o}{M_{П.Ф.Н}}\right] = \Delta\overline{M_o}$, $(\frac{\Delta u_{1a}}{U_{1aH}}) = \Delta u_{1a}$

Taking into account (44) will be written as:

$$\frac{\Delta\overline{M}(p)}{\Delta\overline{\omega}_1(p) - \Delta\overline{\omega}(p)} = \left(\frac{\gamma}{\nu}\right)^2 \frac{(T_e p + 1) - \frac{(\frac{S}{S_{kp}})^2}{1 + (\frac{S}{S_{kp}})^2}(T_e p + 2)}{(T_e p + 1)^2 + (\frac{S}{S_{kp}})^2} \tag{46}$$

where $\gamma = \frac{U_{1a}}{U_{1aH}}$ - relative stator voltage; $\nu = \frac{\Omega_1}{\Omega_{1H}}$ - the relative frequency of the stator voltage.

Or in a simplified form:

$$\frac{\Delta\overline{M}(p)}{\Delta\overline{\omega}_1(p) - \Delta\overline{\omega}(p)} = \left(\frac{\gamma}{\nu}\right)^2 \frac{1}{T_e p + 1} \tag{47}$$

Accordingly, based on equation (41) we have:

$$\frac{\Delta\overline{M}(p)}{\Delta\overline{\omega}_1(p) - \Delta\overline{\omega}(p)} = (\frac{\gamma}{\nu})^2 \frac{1}{T_M p} \tag{48}$$

where $T_M = \frac{J\Omega_{0H}}{M_{П.Ф.Н}}$ - mechanical time constant of the engine.

A simplified block diagram of an induction motor when controlling the angular frequency of the stator voltage, built on the basis of expressions (45), (46), is shown in Fig. 2.

1.3. Development of the structural scheme of the electric drive control system

Formation of necessary static and dynamic properties of the asynchronous frequency-regulated electric drive is possible only in the closed system of regulation of its coordinates. The generalized functional scheme of such a system (Fig. 2) in addition to AM and controlled frequency converter (FC) contains regulators P and sensors D of variable electric drive.

A variant of the functional diagram of the frequency control system of the AM with feedback on the stator current is presented in Fig. 3. Here are the signals i_{sa} and i_{sc}, proportional to the instantaneous value of the currents of phases A and C of the stator windings, from the output of the current sensors $ДТ_a$ and $ДТ_c$ enter the functional current converter FT, where the output signals are formed I_1, i I_{1a}, proportional to the current value of the stator current and the active component of this current. In the nodes

Σ_1, i Σ_2 summarizes control and feedback signals from functional devices A1, A2 i A3. The A4 device provides signal transmission I_1, to the input A3 only when it is exceeded on the adder Σ_3 signal I_{1max}, proportional to the value of the maximum allowable current of the stator AM. To protect the frequency converter and the motor from current overloads, the current cut-off mode with the help of an adder is used. Σ_3 and device A4.

As the load on the shaft of the AM (from the moment M1 to the moment M_2 in fig. 5 by reducing the speed of the AM and, consequently, the signal $u_{зз}$ the mismatch signal increases $\delta_s = u_к - u_{зз.} \equiv \omega_{00} - \omega \equiv s_a$, proportional to the absolute slip of the engine. Here ω_{00} — the set speed of ideal idling BP corresponding to the initial control signal $u_к$; ω — the actual speed of the BP at a given load on its shaft. At $\delta_s \neq 0$ signal $u_{РШ}$ at the output of the slider, summing with the signal $u_{к1} = u_к$ (при $I_1 < I_{1max}$), due to the integrated component of the transfer function of the controller A5 provides such an increase in the control signal u_f a frequency converter at which the frequency of the output voltage of the inverter becomes equal $f_{10}(1 + s_a)$. Simultaneously with the change of frequency due to the functional converter FP changes in comparison with the initial voltage U10 and the output voltage of the converter U1 (see Fig. 6, b). At the same time the engine speed is restored to the set value ω_{00}, that is, the absolute rigidity of the mechanical characteristics of the BP is provided (line 1 in Fig. 6, a).

When the maximum allowable stator current is exceeded AM ($I_1 \geq I_{1max}$ i, in accordance, $M \geq M_{max}$), the slider must be switched off, for example by limiting its output signal $u_{РШ}$ on level $u_{Ршmax}$ (fig. 6, C). At the same time negative feedback on the stator current with the regulator A3 come into operation, providing at the expense of simultaneous reduction of frequency and voltage of the stator of AM to their minimum values. f_{1min} i U_{1min} limiting the moment of BP at ω = 0 on level Mmax (line 2 in Fig. 6, a). Minimum synchronous motor speed ω_{0min} will match the values f_{1min} i U_{1min}, and mechanical characteristics - line 3 (Fig. 6, a).

In fig. 7 presents a block diagram of a linearized system, the functional diagram of which is shown in Fig. 4, when operating the AM in the area of mechanical characteristics within the values of absolute slip $s_a < s_к$. The following notations are accepted in the scheme: β — the modulus of rigidity of the linearized mechanical characteristic AM ($\beta=2M_к/(\omega_{0ном}s_к)$).

T_e — equivalent electromagnetic time constant of the stator and rotor circuits of the BP, determined by the formula $T_e= 1/(\omega_{0эл.ном}s_к)$, where $\omega_{0ел.ном}$ — the angular velocity of the electromagnetic field of the AM at its nominal supply frequency $f_{1ном}$ = 50 Гц ($\omega_{0ел.ном} = 2\pi f_{1ном} = 314$ c^{-1}). Дfor BP of general industrial execution $s_к$ = 0,05…0,5 (smaller values are typical for more powerful engines), T_e = (0,006…0,06) c;

$k_{ПЧ}$ – inverter transfer factor ($k_{ПЧ} = \Delta\omega_0/\Delta u_{РШ} = 2\pi\Delta f_1/(p_п\ \Delta u_{РШ})$. When operating BP in the frequency band $f_1 \leq f_{1ном}$ = 50 Hz and the nominal control signal of the converter $u_{к.Пчном}$ correlation $\Delta f_1/\Delta u_{РШ} = f_1/u_{у.Пчном}$.

$T_{пч}$ — the time constant of the inverter control circuit, which at high frequencies modulation of the output voltage of industrial inverters (2 (50 kHz) does not exceed 0.001 s.

Transfer function PI speed controller:

$$W_{\text{РШ}}(p) = \frac{\Delta u_{\text{РШ}}}{\Delta u_{\text{к}}} = k_{\text{РШ}} + \frac{1}{T_{\text{РШ}} p} \tag{49}$$

Motor speed feedback transmission function

$$W_{\text{зз}}(p) = \frac{\Delta u_{\text{зз}}}{\Delta \omega} = k_{\text{зз}} \tag{50}$$

When the nominal control signal of the electric drive is equal $u_{\text{зсном}}$ and the corresponding nominal speed of the AM:

$$k_{\text{зз}} = u_{\text{зсном}}/\omega_{\text{ном}} \tag{51}$$

According to the structural scheme of AM, its resulting transfer function in relation to the deviation $\Delta\omega_0$:

$$W_{\text{Д}}(p) = \frac{\Delta \omega}{\Delta \omega_0} = \frac{1}{T_{\text{е}} T_{\text{м}} p^2 + T_{\text{м}} p + 1} \tag{52}$$

With $T_{\text{м}} > 4T_{\text{е}}$:

$$W_{\text{Д}}(p) = \frac{1}{(T_{01} p + 1)(T_{02} p + 1)} \tag{53}$$

where

$$\frac{1}{T_{01}} = \frac{1}{2T_e}\left(1 + \sqrt{1 - \frac{4T_{\text{е}}}{T_{\text{м}}}}\right); \quad \frac{1}{T_{02}} = \frac{1}{2T_{\text{е}}}\left(1 - \sqrt{1 - \frac{4T_{\text{е}}}{T_{\text{м}}}}\right) \tag{54}$$

If we include constants T_{02} and $T_{\text{пч}}$ to small uncompensable constants and as an assessment of their impact to take $T_{\mu} = T_{02} + T_{\text{пч}}$, then when adjusting the electric drive to the modular optimum, the integral constant and the transmission ratio of the proportional part of the RC controller will be determined as follows:

$$T_{\text{РШ}} = k_{\text{ос}} k_{\text{пч}} a_{\mu} T_{\mu}; \tag{55}$$
$$k_{\text{РШ}} = T_{01}/T_{\text{РШ}}$$

2. DESCRIPTION OF THE AUTOMATED ELECTRIC DRIVE FOR THE MINERAL FERTILIZER LOADER

Taking into account the shortcomings of the basic control system of the asynchronous electric drive of the ventilation system of the distribution station listed in the first section, it was decided to replace it with a modern one based on a frequency converter.

Frequency converter-based control systems can have any technologically necessary functions, the implementation of which is possible both due to the programmable controllers built into the converter, and additional controllers that operate in conjunction with the converters.

When operating a standard induction motor, the inverter must be selected with the appropriate power. If a large starting torque or a short acceleration time (deceleration) is required, select a converter one degree higher than the standard one.

When choosing a converter to work with special motors (motors with brakes, powerful motors, with a retraction rotor, synchronous motors, high-speed, etc.) should be guided primarily by the rated current of the converter, which should be greater than the rated motor current and features settings of converter parameters.

For the control system of the asynchronous electric drive of the loader of mineral fertilizers we will apply the frequency converter MICROMASTER 420 which general view is presented in fig. 8 [23].

The main characteristics of the MICROMASTER 420 frequency converter shown in fig. 1 [23].

The MICROMASTER 420 converter can be used to solve many tasks that require the use of drives with variable speeds. Above all, it is suitable for use in pumps, fans and conveyors. The main characteristics of the frequency converter MICROMASTER 420 are listed in table 1.

The converter differs in high productivity and comfortable use. The wide range of mains voltage allows you to use it in any part of the world.

MICROMASTER 420 has a modular design. The control panel and communication modules can be replaced without the use of any tool [23].

The connection diagram of the MICROMASTER 420 frequency converter is shown in fig. 9 [23].

Class B filter with low leakage current, it is EMC - filter for converters 1 AC 200 .. 240 V, size A and B without built-in EMC - class A filter. 1 Technical characteristics of the MICROMASTER 420 frequency converter.

Thanks to this filter, the converter meets the radiation standards EN 55011, class C.

3. CALCULATION OF ELEMENTS OF THE CONTROL SYSTEM OF THE ELECTRIC DRIVE OF THE FORKLIFT TRUCK

For the analysis of dynamics we will use the linearized block diagram received in section 1. The engine is chosen as the electric motor of a drive of system of ventilation of distributive station serial 4A90L4У3.

According to the relevant characteristics of the selected engine, calculate the values of the coefficients of the block diagram. Rated idle speed of the engine:

$$\omega_{0\text{ном}} = n \cdot \frac{2\pi}{60} = 1500 \cdot \frac{2\pi}{60} = 157 \text{ с}^{-1}$$

Rated engine speed:

$$\omega_{\text{ном}} = \omega_{0\text{ном}} \cdot (1 - s_{\text{ном}}) = 157 \cdot (1 - 0{,}067) = 146{,}6 \text{ с}^{-1}$$

Rated torque on the motor shaft:

$$M_{\text{ном}} = 9{,}57 \cdot \frac{P_{\text{ном}}}{n \cdot (1 - s_{\text{ном}})} = 9{,}57 \cdot \frac{3000}{1500 \cdot (1 - 0{,}067)} = 20{,}6 \text{ Н·м}$$

Critical moment on the motor shaft:

$$M_{\text{к}} = m_{\text{к}} M_{\text{ном}} = 2{,}2 \cdot 20{,}6 = 45{,}3 \text{ Н·м}$$

The modulus of rigidity of the linearized mechanical characteristics of AM:

$$\beta = \frac{2 \cdot M_{\text{к}}}{\omega_{0\text{ном}} \cdot s_{\text{к}}} = \frac{2 \cdot 45{,}3}{157 \cdot 0{,}279} = 1{,}03 \text{ (кг·м}^2\text{)/с}$$

Equivalent electromagnetic time constant of the stator and rotor circuits of the motor:

$$T_e = \frac{1}{\omega_{0\text{ном}} \cdot s_\text{к}} = \frac{1}{157 \cdot 0{,}279} = 0{,}023 \text{ с}$$

The parameters of the frequency converter are calculated according to the method described in [8]:

$$k_\text{пч} = 7;\ T_\text{пч} = 0{,}001 \text{ с.}$$

Speed feedback ratio:

$$k_\text{зз} = u_\text{з.с.ном}/\omega_\text{ном} = 1/157 = 0{,}0068 \text{ В·с}$$

Mechanical engine time constant:

$$T_\text{м} = (J_\text{дв} + J_\text{мех})/\beta = (0{,}023 + 0{,}388) / 1{,}3 = 0{,}399 \text{ с}$$

Additional time constants:

$$T_{01} = \frac{1}{\frac{1}{2 \cdot T_e} \cdot \left(1 + \sqrt{1 - \frac{4 \cdot T_e}{T_\text{м}}}\right)} = 0{,}024 \text{ с}$$

$$T_{02} = \frac{1}{\frac{1}{2 \cdot T_e} \cdot \left(1 - \sqrt{1 - \frac{4 \cdot T_e}{T_\text{м}}}\right)} = 0{,}375 \text{ с}$$

$$T_\mu = T_{02} + T_\text{пч} = 0{,}376 \text{ с}$$

Integral constant and transmission ratio of the proportional part of the speed controller when adjusting the electric drive to the modular optimum:

$$T_\text{РШ} = 4 \cdot k_\text{зз} \cdot k_\text{пч} \cdot T_\mu = 0{,}072 \text{ с}$$

$$k_\text{РШ} = \frac{T_{01}}{T_\text{РШ}} = 0{,}338 \text{ с}^{-1}$$

The schematic diagram of the PI speed controller is shown in Fig. 10.

Its transfer function:

$$W_{ПИ}(p) = \frac{1 + C_1 R_2 p}{C_1 R_1 p} = \frac{1 + k_{РШ} T_{РШ} p}{T_{РШ} p} \quad (65)$$

Calculate the parameters of the regulator. We set the value of the capacity C_1=1 uF. Then:

$$R_1 = \frac{T_{РШ}}{C_1} = \frac{0{,}072}{10^{-6}} = 72 \text{ кОм}$$

$$R_2 = \frac{k_{РШ} T_{РШ}}{C_1} = \frac{0{,}024}{10^{-6}} = 24 \text{ кОм}$$

3.1. Evaluation of quality management indicators of the modernized SAC

The simulation model of the electric drive for the analysis of dynamics in the MatLab environment is given in fig. 11.

From fig. 12 shows that with increasing the transmission ratio of the proportional part of the speed controller krsh the transition time decreases from 1.55 s to 1.25 s. With a decrease in krsh, the transition time increases from 1.55 s to 1.75 s.

Transitional characteristics in Fig. 13 show that with increasing the integral constant of the speed controller TRS time of the transition process increases from 1.55 s to 2.25 s When the TRS decreases, the transient time decreases from 1.55 s to 1.25 s, but the ascetic acidity increases from 0% to 10%.

From the characteristics in Fig. 14 - 15 it is seen that the designed system is able to work out any changes in the load during operation of the electric drive and provide a constant speed for the entire period of operation of the mechanism.

CONCLUSIONS

The task of scientific work was to develop an automated electric drive of a mineral fertilizer reloader with the development of a control system. In accordance with this task performed: justification of the need to automate the technological process of the agro-industrial complex; analysis of the basic control system of the electric drive of the mineral fertilizer reloader, on the basis of which the basic control system of the electric drive of the transmitting conveyor on the basis of RKSK on the asynchronous electric drive with control from the frequency converter which allows to increase reliability of the electric drive and its service life is executed.

The MICROMASTER 420 frequency converter was chosen to control the induction motor. A mathematical model of the electric speed control system and a block diagram of the electric control system were developed.

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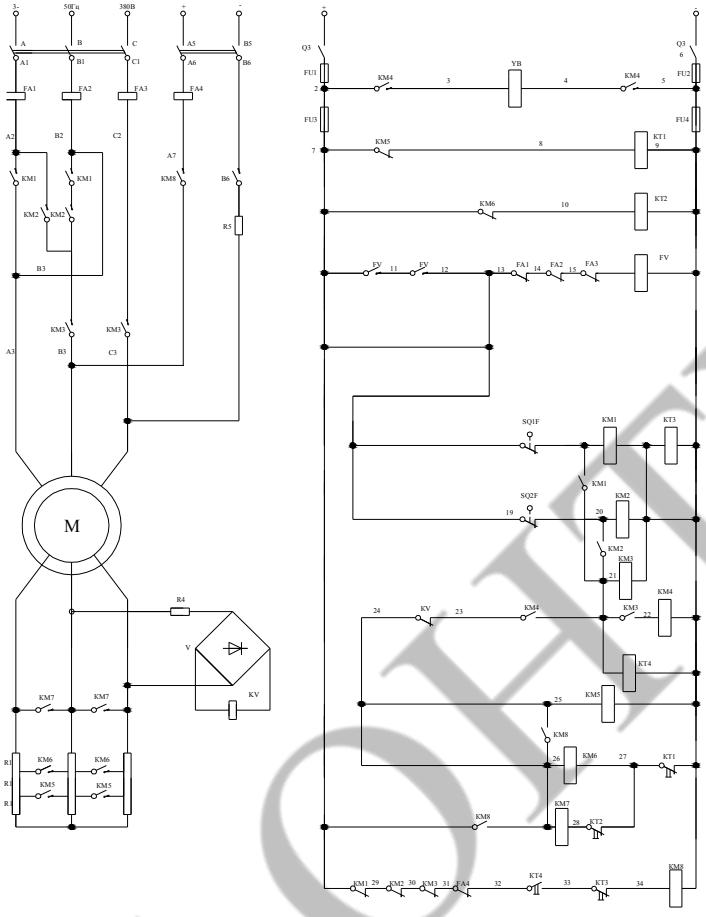

Fig.1. Schematic diagram of RCCS asynchronous motor with phase rotor

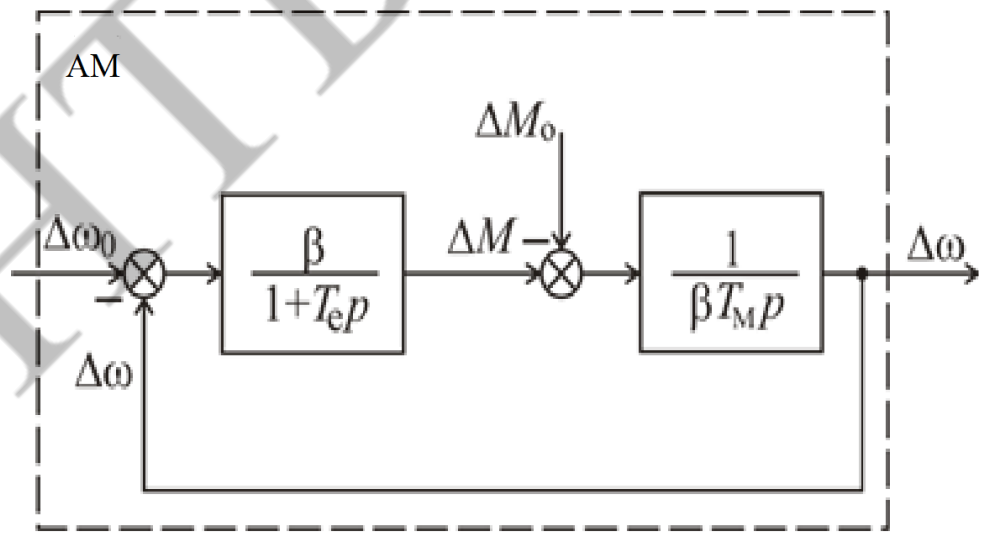

Fig. 2 Simplified block diagram of an induction motor when controlling the angular frequency of the stator voltage

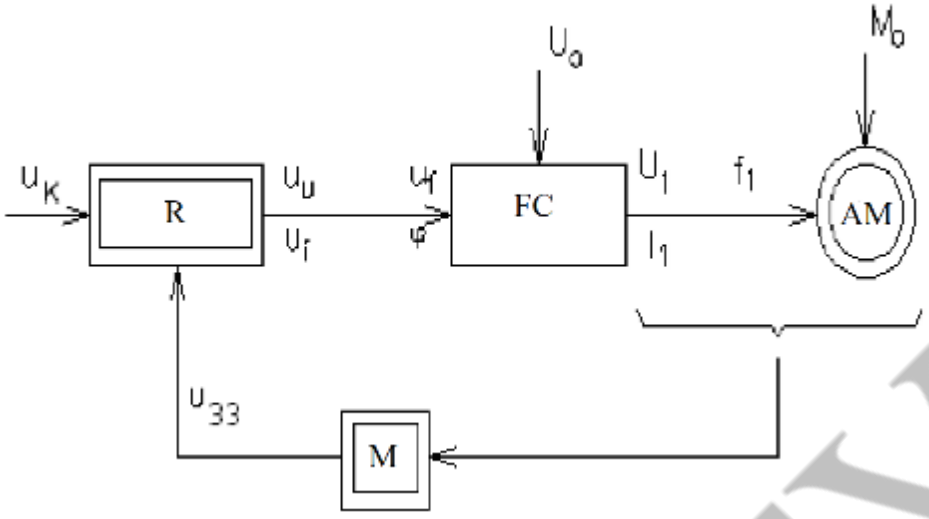

Fig. 3 Functional diagram of a closed FC-AM system with scalar control

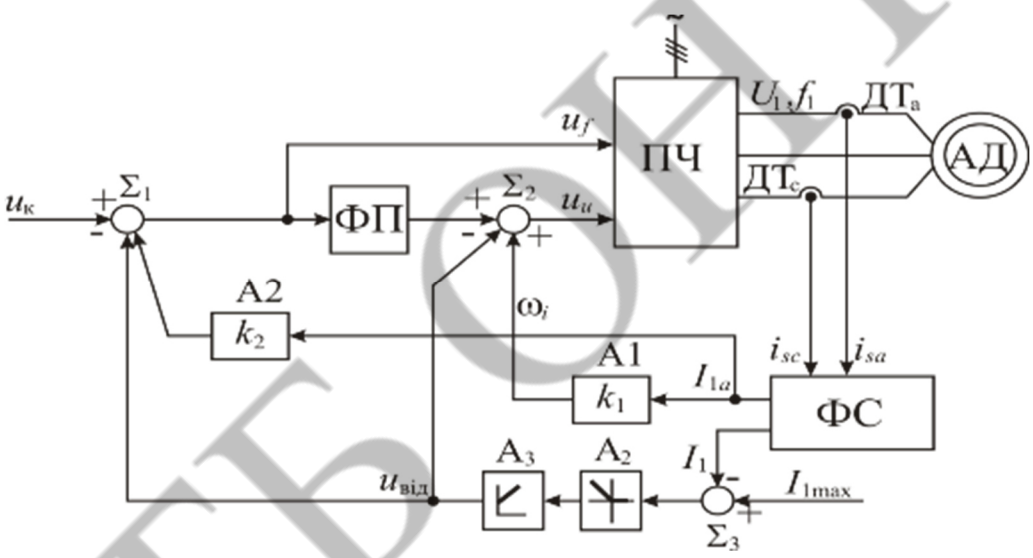

Fig. 4 Functional diagram of the FC-AM system with feedback on the stator current

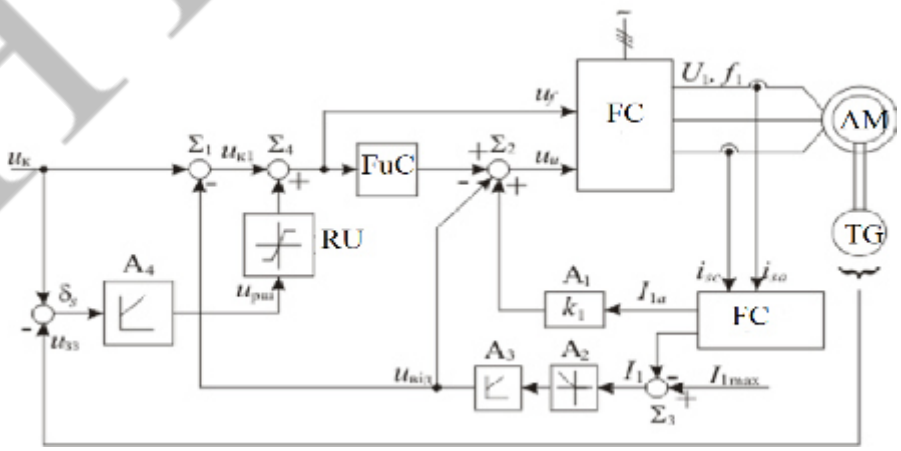

Fig.5 Functional diagram of the inverter system FC-AM with speed feedback

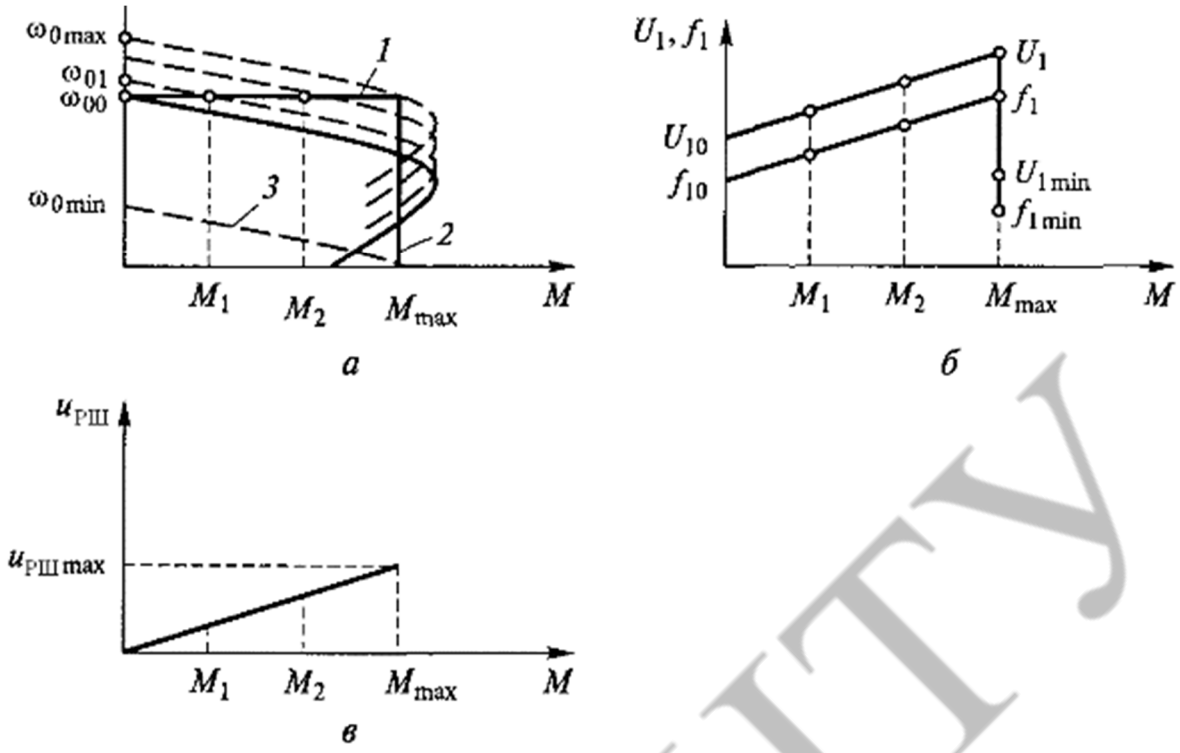

Fig.6 Mechanical characteristics (a), the dependence of the output voltage and frequency of the inverter FC (b), as well as the voltage of the speed regulator (c) from the moment in the FC-AM system with speed feedback

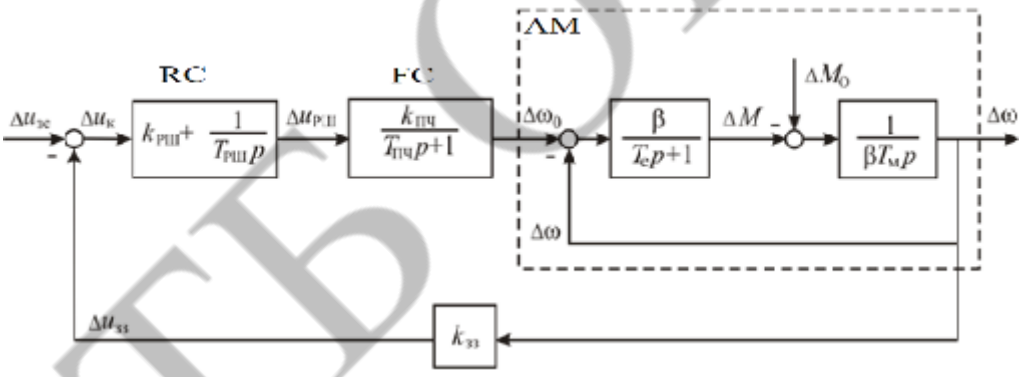

Fig.7 Block diagram of the inverter system FC-AM with speed feedback

Fig. 8. Frequency converter MICROMASTER 420

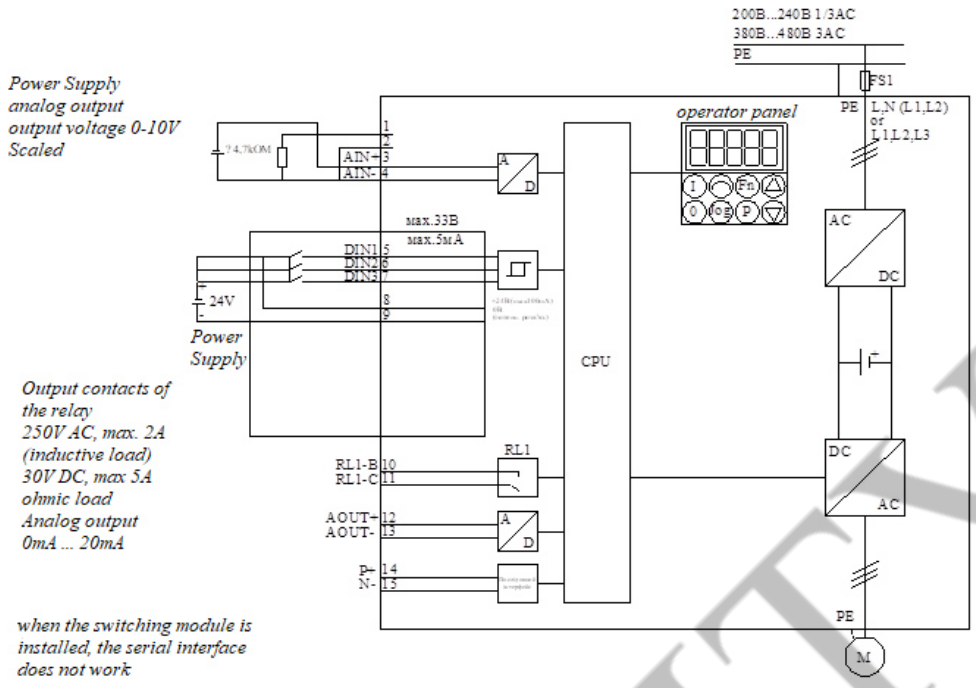

Fig. 9 Wiring diagram of the MICROMASTER 420 frequency converter

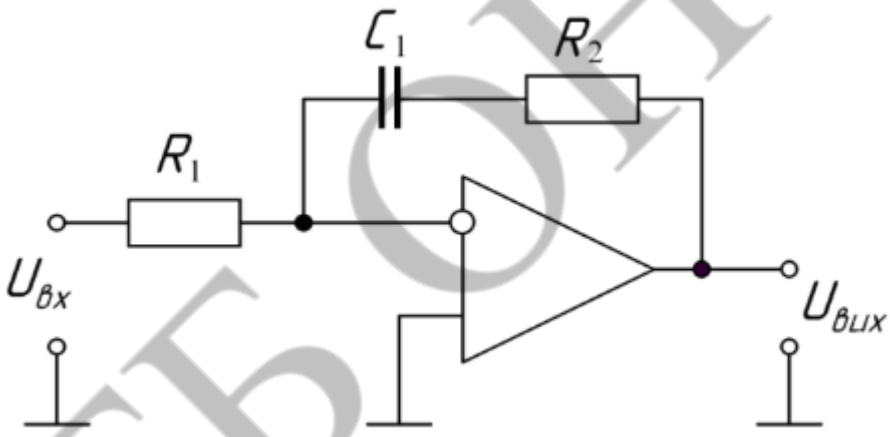

Fig. 10 Schematic diagram of the PI speed controller

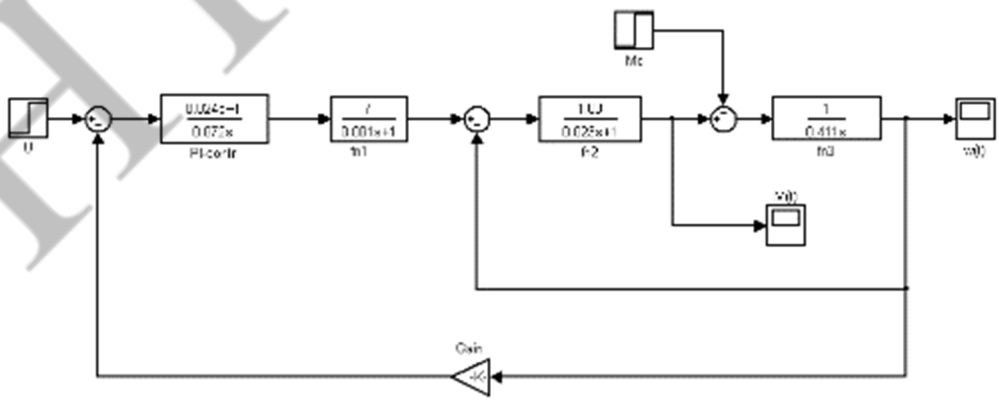

Fig.11 Simulation scheme of the modernized SAC

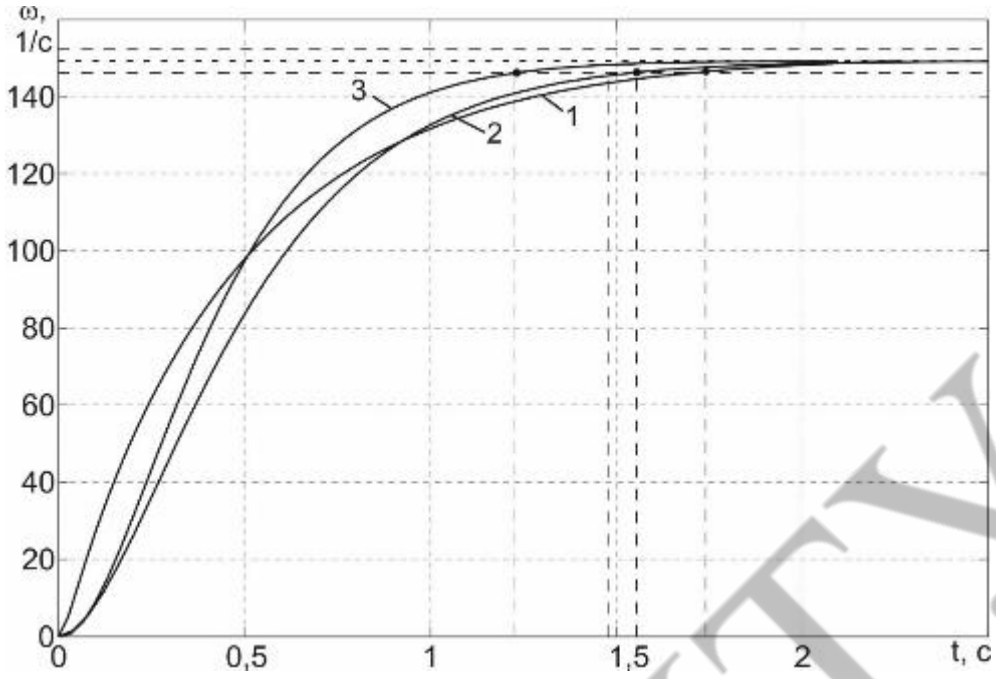

Fig.12 Transients of the system at angular velocity at $T_{РШ}$=0,072 c:
1 – $k_{рш}$=0,1; 2 – $k_{рш}$=0,338; 3 – $k_{рш}$=0,7

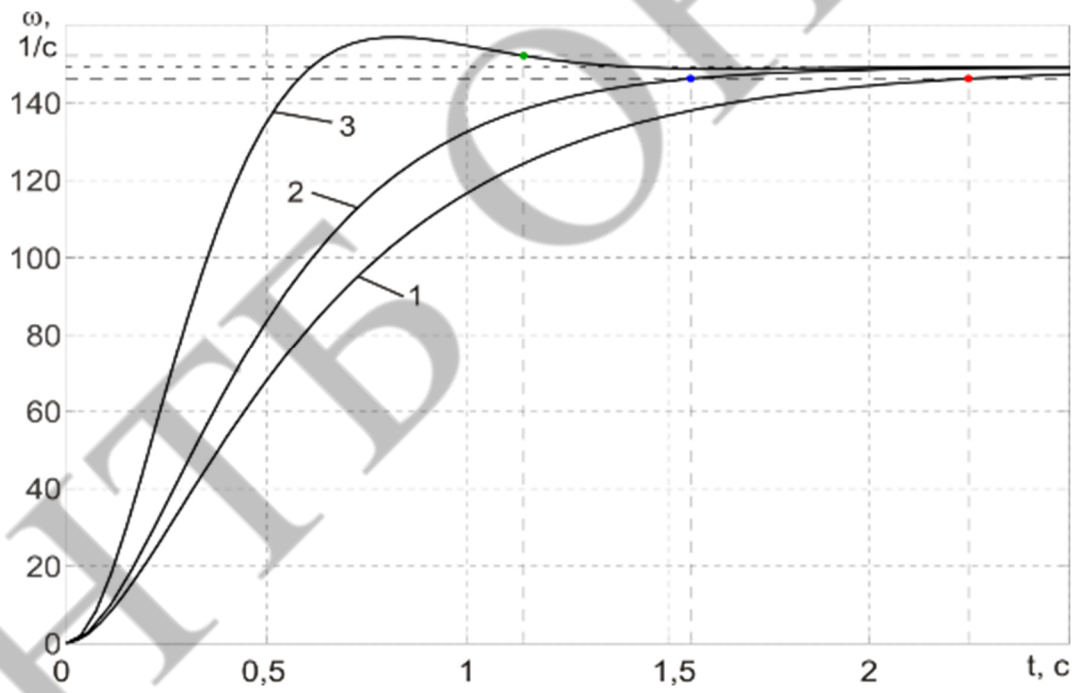

Fig. 13 Transients of the system by angular velocity при $k_{рш}$=0,338:
1 – $T_{РШ}$=0,036 c; 2 – $T_{РШ}$=0,072 c; 3 – $T_{РШ}$=0,144 c

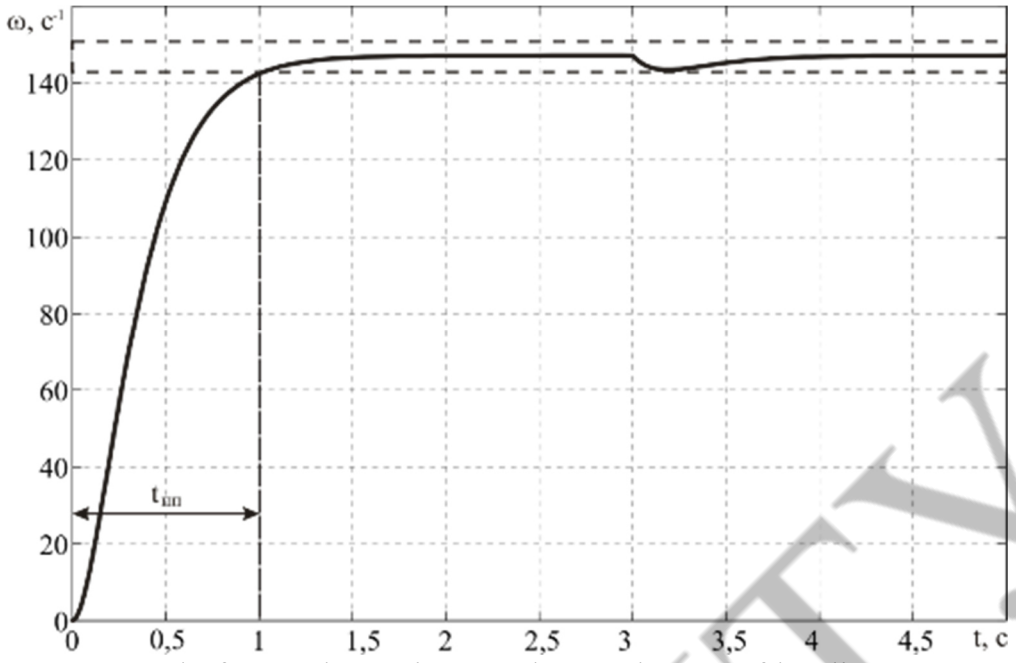

Fig. 14 Motor shaft speed transient at abrupt change of loading 100% $M_{ном}$

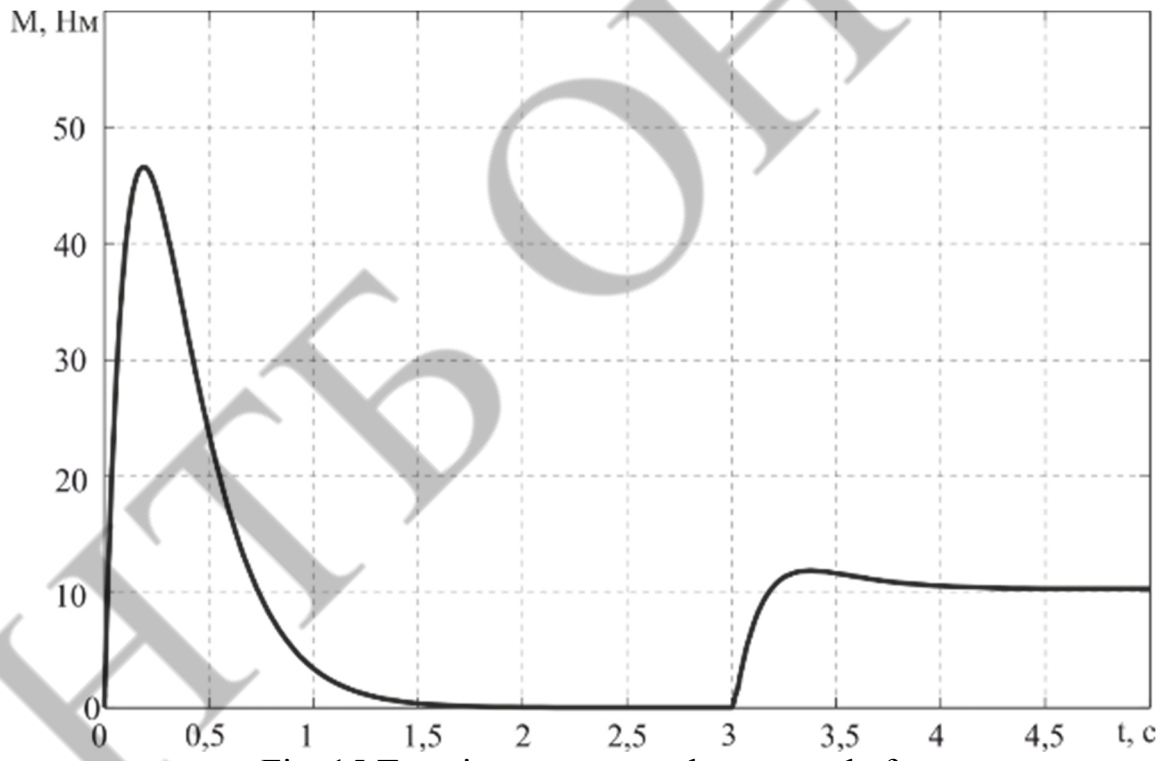

Fig. 15 Transient torque on the motor shaft
at abrupt change load 100% $M_{ном}$

Table 1

The main characteristics of the MICROMASTER 420 frequency converter

Power range	0,12 kW … 11 kW
Mains voltage	1 AC 200 V … 240 V 3 AC 200 V … 240 V 3 AC 380 V … 480 V
Laws of management	• linear dependence U/f; • programmable dependence of U/f; • direct flow control (FCC)
Technological regulator	Built-in PI controller
Digital and analog inputs	3 digital, 1 analog
Entrance	1 relay, 1 analog
Interface	Best suited for automation tasks with controllers SIMATIC S7 - 200, SIMATIC S7 - 300/400 (TIA) or SIMOTION
Additional features	BICO technology

IMPROVEMENT OF THE REFRIGERATION SYSTEM WITH RADIATIVE COOLING AND COMBINED CONDENSATION

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Abstract. *In this paper I will describe how, for what purposes and what is the most effective way to use solar radiation. As well as I will report all data on the benefits, harms and costs of this project. This paper will provide evidence of the effectiveness of the project, practical calculations and application in a real environment. In addition to all this, I will show you schematics of working installations. I will explain, show and tell you everything*

Keywords: *Radiation cooling, condensers, freons, table data, installation diagrams*

1.Introduction.

Greetings colleagues. Due to the deplorable state of the environment and the significant shortage of resources and electricity, we propose a system by which refrigeration chambers can be cooled by means of renewable energy sources, namely by means of solar radiation

Radiation cooling: Lowering the temperature of the earth's surface and objects by means of thermal radiation (i.e. temperature or thermal radiation) in the ultraviolet, visible, and infrared wavelength ranges. It is realized, as a rule, in quiet clear nights in the absence of other significant heat exchange processes in the atmosphere (turbulent heat transfer, heat exchange of water phase transitions) and in the absence (or lack in the daytime hours in winter) of solar radiation inflow. At the same time, the expenditure part of the radiation balance of the atmosphere - radiation of the Earth's surface (objects) and the atmosphere itself - becomes the prevailing value in this balance and leads to the fact that the temperature of the surfaces of objects on the ground and the ground drops below the temperature of the nearby layer of ambient air.

2. Selection of the main possible scenarios of application of refrigeration systems

Considering the uses of radiation cooling, the following classification of refrigeration systems can be proposed:

1) By cooled substance:

a) with a liquid coolant used directly for heat removal;

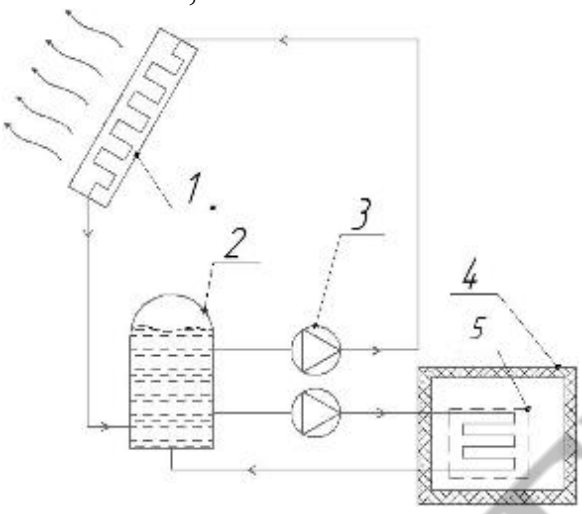
b) with a liquid coolant used for removal of condensation heat

c) with refrigerant;

d) using air as the heat transfer medium.

Figure 1 shows an example of a cooling system in which radiation cooling is used to cool the intermediate coolant, and further use it to lower the temperature of the cooled object. The disadvantage of such systems is the high cost of the system, due to the large amount of coolant in the system, a large accumulator of cold.

The cooled coolant circulating throughout the night through the radiator 1, is accumulated in the cold accumulator 2, and then used to cool the chamber.



1 - radiator; 2 - cold accumulator; 3 - pump;
4 - cooling chamber; 5 - heat exchanger
Figure 1 - The simplest scheme of the night-time radiation cooling system

Figure 2 shows a system with an intermediate coolant in which the coolant cooled by the radiator is used to reduce the condensing pressure and the energy input of the chiller.

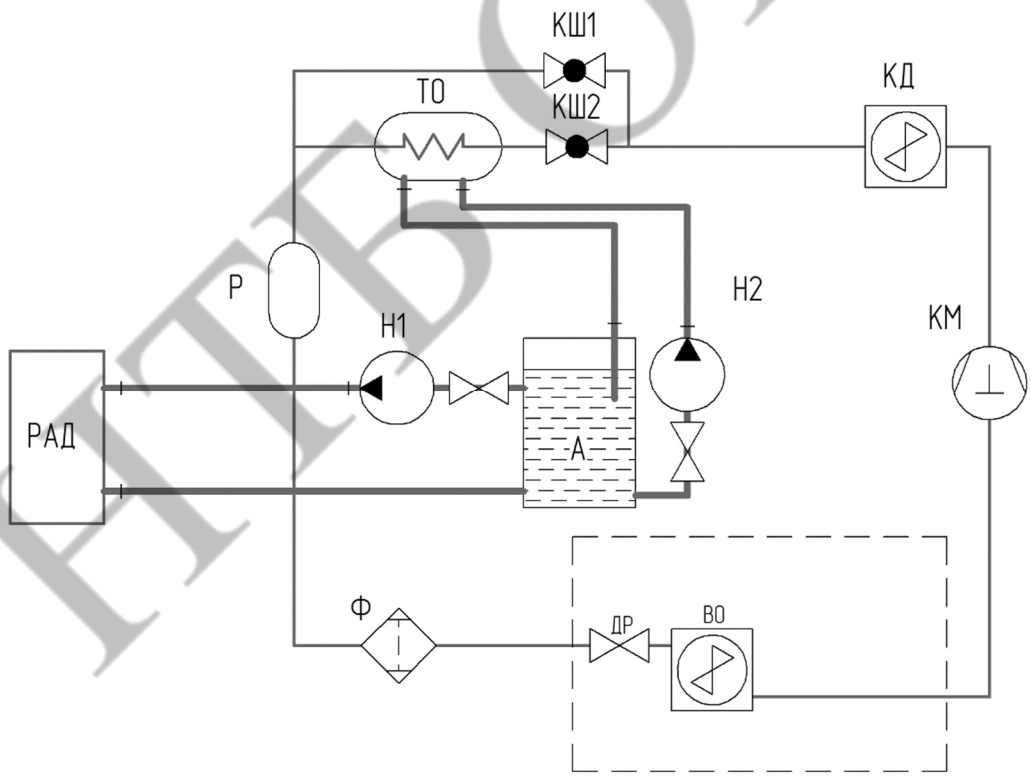
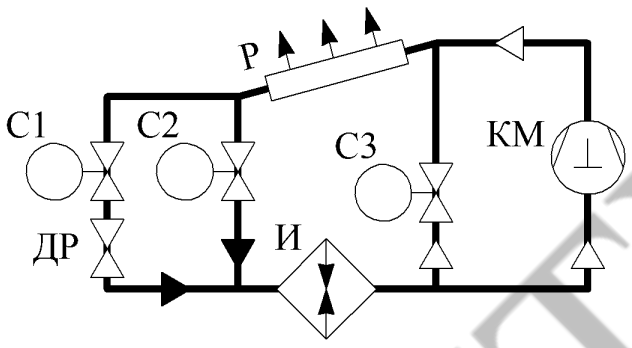


Figure 2 - Nighttime radiation cooling scheme used to reduce condensing pressure

The idea of removal of condensation heat from steam compression refrigeration machine at the expense of radiation cooling is advanced in the invention [18]. The works suggest application of combined cooling of power units [19]-[20].

If the radiation cooling is not enough for cooling to the desired temperature, the cold accumulator can also store the cold created by the chiller, or it is possible to use the chiller to cool the room directly [21].

An example of a refrigeration system in which the RO is used to condense the refrigerant in the intermediate condenser of a refrigeration machine and perform a cycle with natural circulation is shown in Fig. 3.



DR - throttling device; I - evaporator; R - radiator;
C1...C3 - solenoid valves; KM - compressor

Fig. 3 - Scheme of refrigeration system with natural circulation of the refrigerant due to radiation cooling

In this case, it is proposed to refuse a separate circuit of coolant circulation and cool directly in the radiator of the refrigerant.

Systems for air conditioning, in which the cooled air circulates directly through the radiator have disadvantages: high metal intensity of radiators, significant volumes of air ducts, large occupied areas, because the heat transfer from the air flow is much less than from the liquid flow. In this case, in such systems there is no risk of loss of coolant, they are the most simple and reliable.

According to the method of circulation of the coolant can be distinguished systems:

1) With forced circulation, as a result of pumping by a pump, compressor or fan;

2) With natural circulation, as a result of natural convection due to temperature differences.

According to the priority of the cooling method, it is possible to divide systems in which:

1) RO is used as the main source of cooling;

2) RO is an additional source of cold to the main refrigeration machine.

Classification of methods of application of refrigeration supply systems with the use of RH, the main of which are: air conditioning, refrigeration of fruit and vegetable storages; storage of refrigerated products.

Table 1 with a comparison of refrigeration systems and methods of their application is compiled.

Table 1 - Comparison of refrigeration systems

№	Reference	System name	Cold accumulator	Circulation of the working substance	Area of application
1	[22]	Refrigeration system with pumped circulation of coolant through radiators with cold accumulator	Yes	Pumping	Water cooling
2	[23]	System of natural water circulation through the panel in the form of a thermosiphon	Yes	Natural	Water cooling
3	[21]	Hybrid air conditioning system using phase transition materials	Yes	Pumping	Air conditioning and heating
4	[24]	Cooling system with air circulation in a duct heat exchanger	No	By fan	Air Conditioning
5	[25]	Cooling system with open water circulation circuit	Yes	Pumping	Water cooling
6	[26]	Refrigeration system with pumped circulation of coolant through radiators (three different designs)	Yes	Pumping	Air Conditioning
7	[27]	Refrigeration system with pumped circulation of coolant through polyphenylene oxide resin radiators	Yes	Pumping	Air Conditioning
8	[28]	Daytime radiation cooling system using spectral-selective surfaces	No	Natural	Air Conditioning
9	[15]	Refrigeration system with pumped circulation of coolant through radiators, cold accumulator for cooling condenser of refrigeration machine	Yes	Pumping	Refrigeration machine condenser cooling
10	[29]	Daytime cooling system, with pumped water circulation through radiators	Yes	Pumping	Air conditioning, getting cold water

Modeling of operation of the refrigeration system with condensation heat removal

The climate of Kazakhstan is continental. Here, in many regions, daytime atmospheric air temperatures can reach 35°C and higher in summer. In southern and western regions, given the influence of solar radiation, surface air temperature can regularly rise to 40 ... 45 ° C. Such high temperatures may affect the operation of steam-compression refrigeration machines with air-cooled condensers [30]. In them, in the

daytime, the condensation temperature can rise up to 55 ... 60°C. Such a high condensation temperature reaches the limit value for the existing models of compressors. As a result, the refrigeration machines can be switched off by the safety automatics or will work in inadmissible temperature modes, which will reduce their service life. Also in these conditions, refrigeration machines consume a relatively large amount of electricity.

In this connection, the urgent task is to find ways to reduce condensation temperature. Traditionally, evaporative condensers or condensers with adiabatic cooling of incoming air flow are used to solve the above task. However, both of these solutions require an additional constant flow of clean fresh water. In many regions fresh water can be a scarce resource [31]. Given the unfavorable forecast of reduction of available fresh water in Kazakhstan in the next decades [32], the use of fresh water for cooling condensers of refrigeration machines cannot be a recommended universal solution. In this connection it is necessary to consider other ways of condensation temperature reduction without use of fresh water.

In this section of the paper the use of radiation cooling for condensation heat removal is investigated. Radiation cooling can be used at night to create a reserve of cooled coolant. This coolant in the daytime at hours with the highest atmospheric air temperature is directed to the condenser, where it takes the condensation heat of the steam-compression refrigeration machine. In this case, it can be used to remove all of the condensation heat or only part of it. This reduces the condensation temperature and the energy consumption of the compressor.

Since the coolant (fresh water) will circulate through a closed hydraulic circuit, its losses during the annual operating cycle of the refrigeration system will be negligible.

Objective: to investigate the possibility of using radiation cooling for removal of condensation heat of a steam-compression refrigeration machine.

Objectives:

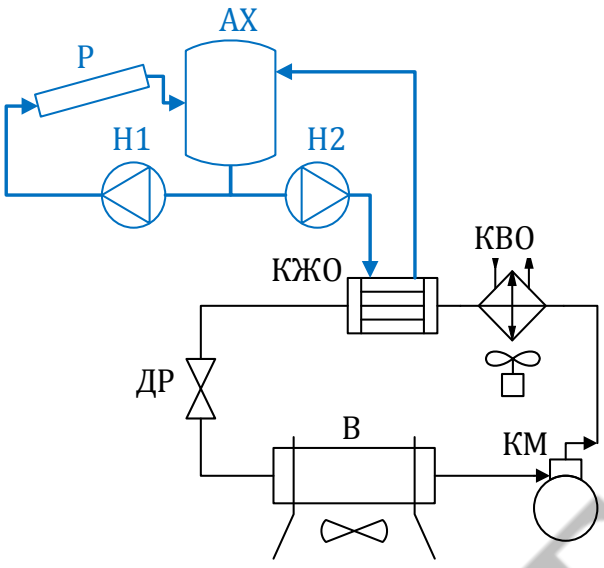
1) To develop a technical and economic mathematical model of refrigeration system with condensation heat removal;

2) To determine optimal parameters of refrigeration system having the shortest payback period.

Subject of research possesses novelty, as previously only general principle schemes of systems of this type were presented without their detailed research [15].

3.1 Principle diagram under study

Figure 4 shows a schematic diagram of a refrigeration system in which the condensation heat of a steam-compression refrigeration machine (SCRM) is removed at the expense of radiation cooling.



AX - cold accumulator; B - air cooler; ДР - throttling device;
KHE - air-cooled condenser; LCC - liquid-cooled condenser;
KM - compressor; H1 - pump supplying coolant to radiator;
H2 - pump, supplying coolant to RCC; P - radiator
Figure 4 - Schematic diagram of the refrigeration system

The system works as follows. At night time the pump H1 switches on. It takes the coolant from the coolant accumulator and pumps it through the radiator P. The coolant is cooled, and then returns to the coolant accumulator AX. At this time the SCRM operates with air cooling condenser: compressor KM is on, fan KVO is on, fan of air cooler BO is on.

In the daytime (after sunrise) the H1 pump is switched off. In the period when the atmospheric air temperature becomes high enough, pump H2 is switched on. It takes the cooled coolant from the cool accumulator AX and conveys it to the condenser of liquid cooling ClC. Here the coolant removes heat from the condensing refrigerant and heats itself. After that, the coolant returns to the AH accumulator. During this period SCRM remains switched on: KM compressor is on, KBO fan is on, B air cooler fan is on.

Rated cooling capacity of the system under consideration is 10 kW.

Characteristics of the main elements and the developed mathematical model of the refrigeration system are presented in appendix B. The mathematical model is based on the method of solving thermal balance of its elements and estimating the thermodynamic cycle of a refrigerating machine, and makes it possible to select the main elements of the refrigerating system, to determine their estimated cost and consumed electric power.

3.2 Results of modeling

Let us model operation of a refrigeration system for given values of a rated temperature head at SCC ΔtKZHO.nom (2,5...7,5 K), duration of use of a coolant from the coolant accumulator for SCC cooling τah (1...12 hours), temperature change in the coolant accumulator per cycle Δtah (2...12 K).

Let us compare the results of modeling with the results of modeling of an ordinary refrigerating machine with air-cooled condenser. This common SCRM operates on refrigerant R404, has the same dependence of compressor refrigerating factor on condensing temperature, its nominal discharge in air-cooled condenser is 10°C, refrigerant boiling point is -10°C. Its mathematical model is also presented in appendix B.

Assuming that the radiators can be used to dissipate condensing heat throughout the summer (about 90 days per year), extremely long payback periods for the system are obtained.

In the proposed range of changeable parameters, the energy consumption of the system with condensation heat extraction is 88.1...99.1 % of the energy consumption of an ordinary SCRM. I.e., removal of condensation heat in all cases leads to energy saving (by 11.9% at most). The indicated level of energy saving is lower than that indicated in [15] (up to 21%).

In the proposed range of changeable parameters, the cost of additional elements of the refrigeration system (cold accumulator, radiators, pumps, liquid-cooling condenser) is from 1492.7 to 22 842 USD.

Proceeding from the condition of minimizing the payback period we have:

1) optimal duration of liquid cooling condenser operation is 5...6 hours.

2) area of a liquid-cooling condenser shall be taken as maximally possible on the assumption, that temperature head on it will make 2,5 ... 5 °C.

3) Changing of temperature in the accumulator of cold during a day should be accepted as maximally possible at the level of about 10°C.

Table 2 - Characteristics of the system at the optimum value of the parameters to be changed

№	Parameter	Measurement unit.	Meaning
1	Liquid cooling condenser area	м2	2,26
2	Weight of cold accumulator	kg	5290
3	Heat sink area	м2	84
4	Volume flow of pump H1	m3/h	1,93
5	Volume flow of pump H2	m3/h	13,73
6	Energy consumption of the system per day	kWh	115,7
7	Liquid cooling condenser cost	USD	755
8	The cost of the accumulator of cold	USD	831,8
9	The cost of the cooler	USD	3815,6
10	Cost of H1 pump	USD	628,2
11	Cost of pump H2	USD USD	86,1
12	Cost of all additional elements of the system	USD USD	6116,7
13	Payback time	years	260,7

The payback period of the refrigeration system should have a value of no more than 10 years, due to the planned service life of the system components. So that the proposed system with condensation heat extraction could pay for itself within the allotted period if the cost of electricity was 25 times higher than the current value.

At optimal parameters (Δt_(KJO.nom)=2,5°C; τah=5 hours; Δtah = 10°C) we have the system characteristics presented in table 2.

3.3 Drainage of all condensation heat into the RAC

The FHE fan during its operation consumes additional energy. If it is switched off, the amount of heat entering the cold accumulator will increase. Consequently, the mass of the cold accumulator must increase, which will increase the cost of the system. The area of the FHE will also need to be increased. The flow rate of the coolant through the FLC, and the power consumed by the H2 pump will increase.

With optimum values of variable parameters, obtained earlier, and deactivation of the FHE during CWC operation, we obtain parameters according to Table 3.

Table 3 - Parameters of the system, if the BHE is on, when the LWC is running, and if the BHE is off, when the LWC is running

№	Parameter	Measurement unit.	EHE is on	EHE is off	Modified.
1	Liquid cooling condenser area	м2	2,25	2,75	+22%
2	Weight of cold accumulator	kg	4808	5863	+22%
3	Heat sink area	м2	76	93	+22%
4	Volume flow of pump H1	m3/h	13,74	16,75	+22%
5	Volume flow of pump H2	m3/h	1,92	2,36	+23%
6	Energy consumption of the system per day	kWh	115,72	112,82	-2,6%
7	Liquid cooling condenser cost	USD	755	863	+14%
8	The cost of the accumulator of cold	USD	831	1018	+22%
9	The cost of the cooler	USD	3815	4653	+22%
10	Cost of H1 pump	USD	628,2	682,9	+9%
11	Cost of pump H2	USD USD	86,1	140,8	+63%
12	Cost of all additional elements of the system	USD USD	6117	7362	+20%
13	Payback time	years	260,7	222,1	-17%

From a practical point of view, an increase in the area of the liquid-cooled condenser, an increase in the weight of the refrigerant accumulator, an increase in the volume flow of the pumps can be considered insignificant. Total cost of additional

elements of the refrigeration system will increase by 20%. However, the payback period of the system will decrease by 17%.

From this it can be concluded that the system should be designed in such a way that the CWC takes all the condensation heat during the daytime and the air-cooled condenser is disconnected at the same time.

3.4 Comparison of refrigerants R134a and R404a

When using R134a refrigerant, a compressor with a volumetric capacity of 32.48 m3/h is required. When using R404 refrigerant, the required compressor volumetric capacity is only 16,24 m3/hour. At that, when using hermetic Danfoss compressors at condensation temperature within the range of +30...+40°Ñ with R134a refrigerant, there is no increase of energy effectiveness as compared to R404a refrigerant.

In a system with condensation heat removal due to RO, condensation temperature will always be lower than +40°C. Therefore, in case of using hermetic compressor, R134a refrigerant is not advisable to use in the system with condensation heat removal due to radiation cooling.

While using piston semi-hermetic compressors of Bitzer 2CES and 4CES, refrigerating factor of R134a will be 6% higher than that of R404a. However, for R134a refrigerant, it requires almost a twofold increase in compressor volumetric capacity. Because of this, the compressor in the system on R134a refrigerant will be much more expensive (by 50...60%). It will also be necessary to increase the area of condenser of liquid cooling. Also in this case, energy savings per day will be only 3,6 %. As a result, the payback period of the refrigeration system will increase by 2.1 times. Consequently, using RO for condensation heat removal in the system with the refrigerant R134a is less profitable than in the system with the refrigerant R404a.

4. Conclusions

There has been made a computer modeling of a refrigeration system operation with a condensation heat removal at the expense of RH under summer climate conditions in Shymkent city. It is established that the peak condensation temperature in the daytime can be reduced to 32.5 ° C instead of 46 ° C when using an air-cooled condenser.

The shortest payback period of the developed system is observed when the temperature in the refrigeration accumulator during a day changes to 10°C, the temperature head at the liquid cooling condenser is 2.5°C and the duration of operation of the liquid cooling condenser during a day is equal to 5 hours.

At an optimum value of the system's variable parameters, the daily power consumption of the system is reduced by 5.8% compared with an ordinary PCCM, and the cost of the additional elements of the system (cold accumulator, pumps, radiators) is about 8076 USD. At the current level of electric power tariffs, the specified level of energy saving does not provide payback of a refrigeration system with condensation heat removal at the expense of RO in a reasonable time. Therefore, the proposed system can be recommended to be used only for reduction of risk of emergency shutdown of a refrigerating machine in the daytime at maximum temperature of atmospheric air on

objects, where there are no available sources of fresh water, suitable for cooling of evaporative condensers.

Long payback period of the system is due to the high cost of radiators (about 50 USD/m2) and cold accumulator.

It is also found that the air-cooled condenser fan should be turned off when the liquid-cooled condenser is running, as this will reduce the energy consumption and payback period of the system. At the same time, the liquid-cooling condenser must discharge all of the refrigerant condensation heat into the refrigerant accumulator.

Using of condensation heat removal scheme from the economic point of view is more reasonable in the systems operating on R404a refrigerant. If R134a refrigerant is charged into the system, payback period of condensation heat transfer scheme is considerably prolonged (2,1 times).

In future it is necessary to study a possibility of using radiators with selective covering of the radiating surface [29], which can provide its twenty-four-hour operation and also make it possible to reduce the mass of a cold accumulator.

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DEVELOPMENT OF ENERGY-EFFICIENT VIBRATION PLANT FOR DRYING SUNFLOWER SEEDS BASED ON INFRARED RADIATION

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Abstract. *Currently, drying of food materials by infrared (IR) radiation becomes widespread. The technology of dehydration of products and materials is far ahead of the theoretical drying conditions. Not only classical literature on problems of drying, but also special does not give concrete recommendations for the design of installations with electromagnetic energy supply. Therefore, until the only reliable way of their study is an experiment. Despite the great scientific amount of literature on drying, including on IR-installations, practical issues of designing infrared dryers have not been worked out. Well-known studies are exclusively private.*

The technological features of drying sunflower seeds by means of infrared energy supply are described, and the prospects of vibration monolayer drying of sunflower seeds are grounded. The specific energy costs are determined for the process of infra-red drying of the product.

Keywords*: sunflower, infrared irradiation, vibrolot drying.*

I. INTRODUCTION

In the system of processing operations after harvesting of sunflower, the most important place belongs to drying. Quality of drying not only ensures the storage of the harvested crop, prevents its loss, but in some cases also improves the quality of the finished product.

The freshly harvested sunflower seeds are very resistant to storage, especially at high humidity, temperature and debris. When storing seeds, chemical changes have primarily fats, and then protein substances.

High-polluted sunflower seeds are safely stored if their humidity does not exceed 7%, and the temperature is lowered to 10 ° C and lower. At humidity above the critical and the temperature of 20 ... 25 ° C, in the pile seed begins a rapid development of microorganisms, intensive hydrolytic and oxidative processes occur. Such processes lead to a rapid deterioration of the quality of sunflower seeds as an oilseed. Even a few hours of storage of freshly collected high-oiled sunflower seeds with a moisture above the critical one leads to massive self-heating and spoilage, which makes it impossible to produce high-grade oils [1].

At the present stage, with the emergence of farm and rental companies, new requirements have been created for the technology used for post-harvest treatment and, in particular, the drying of cereals and oilseeds. Farmers tend not only to grow a good harvest, but also to bring it to a state suitable for implementation or long-term storage.

The grain should have the necessary moisture, maintain its nutritional properties and seed quality. The cost and timing of drying services on elevators do not suit the farmers. Special problems arise when drying elite seed grain, which is produced in relatively small batches and requires a strict savings mode of drying and does not allow mixing with other varieties.

To solve this problem dryers with infra-red energy supply differ from the known by high efficiency and speed of drying, simplicity of structure and operation, quality of work and flexibility of technological process of drying control. When crops of grain in a farm from 100 to 300 hectares, the presence of such a dryer will increase the efficiency of the technological process after grain harvesting. The proposed type of grain dryer can also be used effectively in grain mills.

The prospects of using infrared drying of freshly harvested sunflower seeds are due to the fact that this drying method is quite high intensity, economical and allows you to maintain the nutrient and seed quality of the seeds. In addition, there is no need to use air as a thermal agent, which significantly reduces the energy consumption of the drying process. Promising in this sense is a combination of infrared heat conduction and active contact of seeds with unheated air, which provides, for example, a vibro boiling layer. The use of infrared heat removal for the drying of sunflower seeds is also facilitated by the black husk color and the relatively small thickness of sunflower seeds, which, under certain regime parameters, can provide infrared rays penetration into the central layers of the nucleus.

II. LITERATURE ANALYSIS

Analysis of recent research and publications. Infrared (IR) drying has become one of the potential applications to the general drying method because of its advantages such as the simplicity of the required equipment, the easy placement of IR drying with conductive convective and microwave methods, higher heat transfer rate, energy saving and fast transient response [2, 3].

Infrared drying implies irradiation of a moist material in the range of wavelengths of 0.8-1000 μm of electromagnetic radiation [4]. Many researchers have been studying IR drying as a potential method for obtaining high quality dried fruits, vegetables and grains [5, 6]. Numerous studies have been conducted to improve the efficiency of heating and obtaining high quality dry food products [7, 8, 9].

When using infrared radiation to dry the moist materials, the rays pass through the material, penetrate into it, and the radiation energy is converted into heat [10].

The energy efficiency of infrared dryers is directly related to the absorption characteristics of the material, which determines the economic feasibility of the dryer [11]. Infrared drying is a method of dehydration that has high-energy efficiency. This means that the energy savings of an IR dryer are greater than that of convection and other drying methods. Given the distance between the heating source and the material, the air flow rate and temperature, as well as the material speed (if a continuous IR dryer) can have a significant effect on energy efficiency.

The transmission of infrared energy is carried out without heating the ambient air so there is no need for a heating medium between the source of energy and the material in IR dryers. Because of the rapid and uniform heating, the infrared radiation

penetrates directly into the inner layer of the material without heating the surrounding air, and the energy consumption of infrared drying is lower than other methods [12, 13]. Summing up and analyzing the experiments of other researchers, we can conclude that an increase in the power level of infrared radiation leads to a reduction in the drying time, while an increase in air velocity leads to an increase in drying time and energy consumption. By increasing the air speed, the surface layer becomes cool and requires longer drying time. Thus, the air velocity must be adjusted to provide better results. The power level of infrared radiation should also be adjusted, since increasing power can lead to loss of quality. In addition, there are other factors that were not considered by the researchers such as the effect of vibration on the drying process in IR dryers.

Researchers of the Institute of Cold and Biotechnology in St. Petersburg [14] conducted a study of the process of drying sunflower seeds of the seed fund with infrared radiation of the selected wavelength when reaching the specified moisture content and temperature, which does not exceed 44-46 °C on the surface of the layer of the treated material, depending on the height the product layer, the density of the heat flow, the distance from the infrared emitter to the product. From the analysis of experimental curves it can be seen that the moisture content of sunflower seeds during the whole drying process decreases with time over linear law, while the temperature in the center of the product layer does not exceed 44-46 °C. However, the researchers [14] did not apply the vibratory effect of grain transfer along the tray dryer.

The work [4] studied the drying characteristics of three varieties of high-volatile rice varieties (slenderness, shankar and basmati) using serial vibration infra-red dryer with a radiation intensity of 3100 and 4290 W /m^2 and a depth of 12 and 16 mm grain layer. They found that the drying rate depends on the intensity of the radiation, the drying occurred during the fall, and the period of constant velocity was not observed. At a given temperature of air for drying (40 ° C), the increase in the intensity of infrared radiation reduced the drying time in both fixed and vibration modes.

Researchers in the work [15] also emphasized that one of the methods of rapid and uniform drying of grain is vibration.

In the work [16], the processes of radiation-convective heat and mass transfer between all the defining objects inside the vibration dryer with IR-power supply are theoretically substantiated. On the basis of thermal and material balances, the equations that describe the main dynamic characteristics of the drying conditions of oily grain material in a continuously operating IR dryer are determined. Due to the fact that the exact analytical solution of the presented mathematical model in the form of a system of differential equations in partial derivatives does not exist. The proposed solution allows to identify dependencies of temperature distribution and moisture content of grain and oil-bearing material on the length of the dryer at any time.

The work [17] proposed technologies of targeted energy delivery for the intensification of heat and mass transfer during the processing of food raw materials. The basis of the proposed hypotheses is the wave technologies of the combined electromagnetic and vibrational action. Mechanisms, effects and mathematical models of barodiffusion and actions of vibration fields are grounded. The numbers of wave similarity are proposed, on the basis of which the bases of experimental data on drying are summarized.

Many studies have been carried out on thin-layer drying of food products using different methods of dressing and drying methods such as soya [18], crushed rice [19], hybrid rice seeds [20], but very little information for vibration infrared drying sunflower seeds.

In spite of the fact that air in IR-drying is not a coolant, it has a significant impact on the efficiency of heat exchange radiation. The lower the temperature difference between the air and the irradiated surface, the lower the temperature gradient in the material and its uniform heating. A large temperature gradient inside the drying body (seeds, grains) often causes its destruction - the appearance of cracks, deformations, and the like. Therefore, as a rule, in installations for radiation drying the temperature difference between the air and the material to be dried should be limited.

We conducted research on a "vibration thermo radiation" monolayer "oscillating" heating dryer, using which, according to laboratory studies, it is possible to achieve a lower specific energy consumption in comparison with traditional dryers by about 1.5-2 times [21]. In it to reduce humidity of products by 6-8%, with its one-time heating, in the chamber over the thermal tray it is necessary to create sufficiently high temperatures (up to 200-250 ºC), while the particles of products are warmed up to a temperature of 140-180 ºC, which is unacceptable oh for many kinds of grain products, especially for seed grain. Therefore, in further studies, for the reduction of the temperature of the heating of the product particles, with the least decrease in its moisture content, it was proposed [22, 23] to use "oscillating" heating with infrared rays. In it the heating periods alternate with the periods of cooling by cold air, and an electromechanical debalanced vibration drive is used to excite oscillations.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The purpose of the work is to study the kinetics of the technological process of drying sunflower seeds by infra-red irradiation in a vibrolot mono dryer.

Object of research: the process of drying sunflower seeds in a vibrating dryer with infrared energy supply.

Subject of research: vibration tray dryer and regularities of change of parameters of drying of sunflower seeds in the conditions of a vibroweighted layer of production.

Materials and methods of research. Experimental-industrial sample of a vibration machine (fig. 1) for drying sunflower seeds, allows a wide range of drying temperature control (from 20 to 180 ºC), the air velocity varies within 0, 5 ... 2.5 m / s, oscillation amplitude of the vibrolot (from 0.5 to 6 mm).

Technical characteristics of laboratory vibration dryers

Productivity, kg / h.	110;
Power of the electric car, kW	5,0;
Power vibration drive of the lot, kW	0,5;
Amplitude of oscillations of the vibrolot, mm	0-6;
Frequency of rotation of the driving electric motor, rpm.	910;
Temperature in the thermocouple, ºC	20-180;
Weight, kg	230;
Overall dimensions, mm	1400x600x3000;

The basic scheme of such a drying machine is shown in Fig. 1. The machine consists of a closed shell housing 1, on the sites 2 of which with the help of elastic elements 3 installed thermal 4 and grate 5 lots. The work path of the thermal tray 4 is made of heat-resistant sheet steel. The working path of the grate tray is formed by longitudinal vertical strips 7 welded to the brackets 8 so that there is a longitudinal clearance δ = 1.5 ... 2 mm between them. In the middle of each tray mounted vibration drive, containing two centrifugal vibro-accelerators mounted on the sides of the lot.

Each centrifugal vibrator has a shaft with unbalanced loads 9 which, by means of an elastic muffle 10, is connected to an actuating asynchronous electric motor 11. Moreover, in each vibration drive, the electric motors 11 are connected in such a way that, when connected to the network, their rotors are rotated toward each other. Shafts with unbalanced loads 9 are installed on the bearings parallel to each other at an angle β to the planes of the work tracks of the trays. Above the surfaces of thermal trays 4 fixed heat generators 12 (infrared emitters). At the top and on the sides, the thermal tray 4 is covered with thermal insulation 13. Above the start of the thermal tray 4, the feed bottle 14 is fixed, and at the end of the impeller 15, at the beginning of the grate tray 5, there is a discharge nozzle of the fan 16, and above the grate pan 6, the outlet pipe 17 with the adjusting the shaft 18. At the end of the grate tray 5, the receiving hopper 19 was installed.

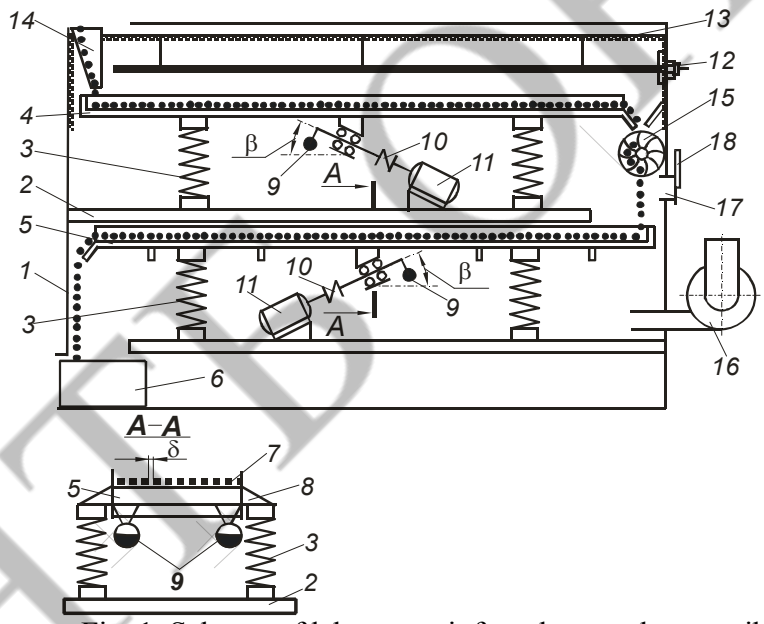

Fig. 1. Scheme of laboratory infrared monochrome vibration dryer:

1 - body; 2 - site; 3 - elastic elements; 4 - thermal lot; 5 - Grain lot; 6 - receiving hopper; 7 - longitudinal vertical stripes; 8 - bracket; 9 - debalanced cargo; 10 - elastic coupling; 1- - electric motor; 12 - thermogenerators; 13 - thermal insulation; 14 - feed throat; 15 - impeller; 16 - fan; 17 - outlet pipes; 18 - adjusting sider.

The machine works this way. When actuating electric motors 11, their rotors begin to rotate towards each other in each vibration drive, which leads to a dynamic synchronization of their rotation, resulting in the translational vibrations of trays 4 and 5 at an angle β to the planes of their work paths. Bulk products are fed through the loading neck to the surface of the lots, where the vibration is distributed by a mono layer. Under the influence of the vibrations of trays between their surfaces and particles

of bulk products there is an asymmetry of frictional forces, which leads to the directed movement of particles of bulk products (vibration transport) along the surface of the lots. At the same time, the points of the surface of the trays fluctuate relative to some center without directed motion in general for the period of one oscillation. By changing the static moments of the unbalanced cargoes 9 relative to the rotation axis, a vibration transport mode is established with the continuous dumping of the particles of bulk products during their movement along the trays. Continuous pouring of product particles leads to their chaotic scrounging when moving along thermal trays 4 above which there are thermogenerators 12 and contributes to their uniform irradiation on all sides with infrared rays, which leads to intense, rapid and uniform heating of sunflower seeds.

Fig. 2. Photo of experimental vibroplot infra-red dryer
(impeller, outlet pipes, regulating sider on the photo not shown)

After passing the thermal lot, the heated products (sunflower seeds) are fed through the drum impeller 15 to the grate lot 5, which is blown by the atmospheric air from the fan 16. In this case, the continuous chaotic throwing and turning of the product particles also improves the uniformity of their air by blowing. It leads to disturbance of the equilibrium state of moisture in product particles, when the pressure of water vapor in them becomes greater than the partial pressure of water vapor in the air, as a result of which moisture begins to intensively evaporate [22, 23]. The processed products, after passage of the grate tray 5, are fed into the receiving hopper 19. The drum impeller 15 prevents access of the cold air from the fan 16 to the high temperature chamber over the thermal lot 4 and at the same time allows the product to wake from the heat lot 4 to the grate 5. The airflow intensity is controlled by a sider 18. The speed of vibration transport of bulk products, and therefore the time of its location on the tray surface is regulated by changing the static moments of unbalanced cargoes 9 relative to and their rotation or angle β. Since the infrared radiation of the thermogenerator 12 can create a very intense heat flux, which facilitates the rapid heating of the product particles, and the process of evaporation from them requires more time, the speed of vibration transport on the grate tray 5 is set higher, and it is made with wider work paths.

The infrared heater consisted of 20 infrared lamps of 250 W (OSRAM, Slovakia), located in a drier in a chess manner. The distance between the lamps, at which the maximum uniformity of the energy irradiance of the surface of the dried material is achieved, is 0.12 m. The lamps are powered by a 220 V power supply. The infrared lamps can be located 5 ... 15 cm away from the surface of the lot.

Humidity of sunflower seeds is determined by drying the samples to a constant mass. Samples were taken before and after infrared irradiation and airflow.

The product loading bin is equipped with a gateway that regulates the thickness of the product monolayer on the lot within the range of 7 ... 22 mm, depending on the size of the grain and the speed of its movement on the lot.

The intensity of the infrared radiation varied by changing the distance between the lamps and the surface of the reception. Also, to achieve the required uniform levels of intensity of infrared radiation, the aforementioned distance was regulated manually, changing the height of the suspension of the lamp body. To ensure the uniformity of infrared radiation over sunflower, preliminary measurements were made prior to the main tests.

The weight of the grain was determined by the electronic weights TWE-0,21-0,01. The temperature of the product was measured remotely by the Laserliner pyrometer. The change in the mass of grains before the study and after determining the mass of sewage.

The experiments recorded the length of the process, the temperature and mass of sunflower in the beginning and at the end of the treatment. Specific mass of material (g) shows the mass (m) of the product per unit surface treatment (F), and specific power - the IR-energy, which is spent on 1 m2 of the treated surface.

Experiments were conducted at room temperature of 20 ° C, relative humidity of 65% in the room. The influence of the energy of the energized energy on the average speed of the drying process was studied. Experiments were carried out at a rate of grain movement per lot 0.025 m/s, and a specific load of 4.11 kg/m^2. The amount of moisture was determined by the initial and final humidity of sunflower. The drying rate was calculated based on the amount of moisture and the time during which sunflower was affected by infrared radiation.

Table1. Range of the process of IR – drying study

Raws	**Specificpower IR, kW / m^2**	**Temperature, T, ° C**	**Download, *g*, kg/m^2**	**Duration process t, min**
Sunflower seeds	**2,0…5,0**	**33…43**	**4,11…8,22**	**30…60**

The mass flow rate of the inlet air was provided by the fan and controlled by an electric inverter (N50-007SF, Korea). Air velocity for all experiments was measured using TESTO Anemometer 425 (Germany) with an accuracy of ± 0.03 m/s. The speed of air varies within 0.5 ... 2.5 m/s by adjusting the fan engine speeds. The initial moisture content of sunflower seeds was 17 ± 0.5%. In total, 34 experiments were performed on combinations of three levels of infrared radiation (2000, 3000, 5000 W/m^2) and vibration (24 Hz)). To measure the change in humidity during drying, the vibrolot dryer was stopped and samples were taken at a time interval of 7 minutes.

IV. RESULTS

Any modernization of the dryer can be considered quite effective if the reduction of specific energy consumption (with the obligatory preservation of product quality) is achieved.

Parameters of IC-drying sunflower seeds recommended by OSRAM lamps on the basis of experimental studies should be considered: height of hanging infrared emitter during drying of grain h = 0,1 m; t_{min} = 35 °C to t_{max} = 43 °C. With an increase in specific power by 2.5 times (Fig. 3), the drying process decreases in proportion.

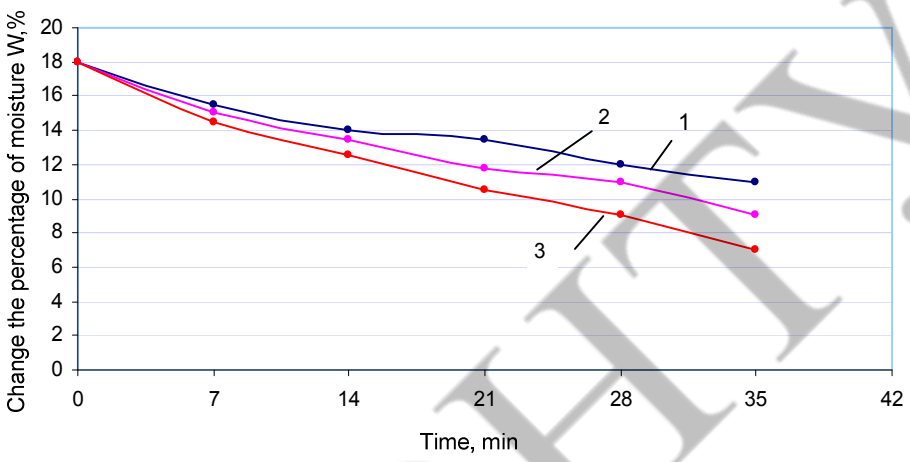

Fig. 3. Effect of specific power on kinetics of drying
where, 1 - N = 2000 W / m^2; 2 - N = 3000W /m^2; 3 - N = 5000W / m^2.

The drying time to the relative humidity of the product in 6-7% takes 35 ... 60 minutes. The data (fig. 3) determined the values of the drying rate (Fig. 4).

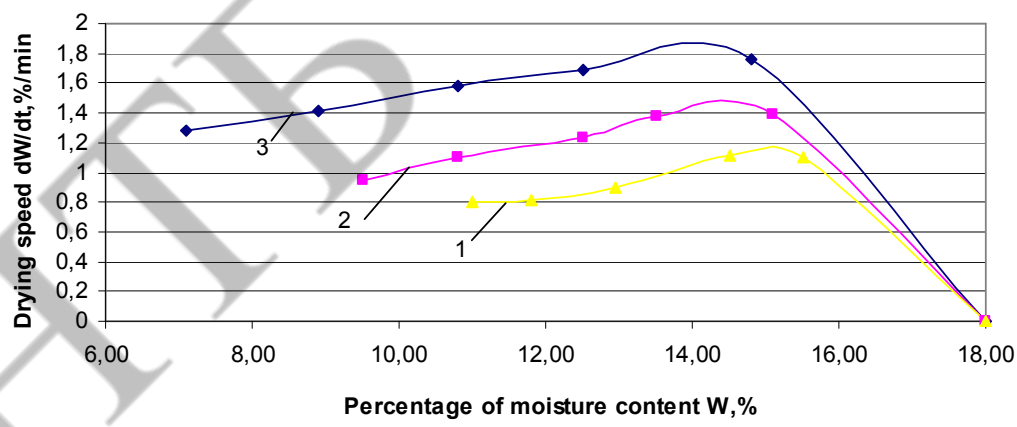

Fig. 4. Effect of specific power on the speed of drying
where, 1 - N = 2000 W / m^2; 2 - N = 3000 W / m^2; 3 - N = 5000 W / m^2.

It can be seen (Fig. 4) that when the amount of energized energy is increased by 2.5 times, the drying rate increases by 50%. The drying rate varies within 1 ... 2,15% / min. The productivity of the installation in a loading mode of 4,11 kg / m^2 at a rate of grain movement per tray 0,016 ... 0,025 m / s was 80 ... 110 kg / h of dry grain with a moisture content of 6,5%. At the same time, at an increase in the power of 2.5 times the increase in the temperature of sunflower seeds at the outlet does not exceed 43 ºC (Fig. 5), which is very important in the process of drying sunflower seeds.

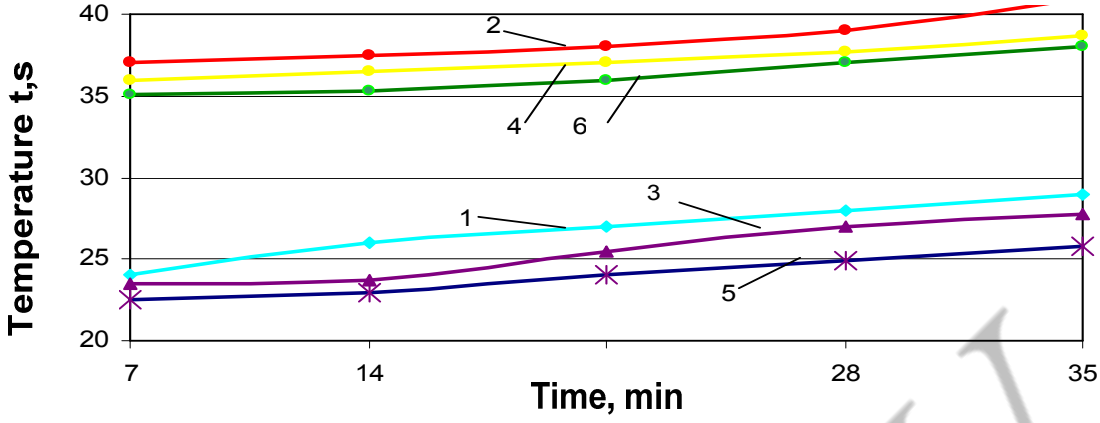

Fig. 5. Effect of specific power on product temperature.

where, 1 - the product temperature at the input to the dryer at N - 5000 W / m^2;
2 - the product temperature at the outlet of the dryer at N -5000 W / m^2;
3 - the product temperature at the entrance to the dryer at N -3000 W / m^2;
4 - the product temperature at the outlet of the dryer at N-3000 W / m^2;
5 - the product temperature at the input to the dryer at N -2000 W / m^2;
6 - the product temperature at the outlet of the dryer at N -2000 W / m^2;

The drying machine described above reduces the specific energy consumption by approximately 1.5-2 times compared with convection shaft driers, retains all the advantages of the laboratory infrared monochrome vibration dryer described above. At the same time, the maximum temperature of the heating of particles of products is 1.5 - 2 times less with larger limits of their humidity. This allows for higher quality production of products at lower heat costs.

However, since the output moisture content of loose products may fluctuate within very wide limits, in order to regulate the speed of vibration transport of bulk products along the vibrolots, and therefore the time of their processing on each tray, it is necessary to adjust the parameters of the vibrations of the lot by changing the magnitude and frequency of oscillations of the force to provide energy saving resonance mode of vibration drying. To solve this problem, it is possible to use [24] or an debalanced controlled vibration drive with an adjustable magnitude of static imbalance, or an unbalanced vibration drive in which a wide-pulse frequency governor of a three-phase alternating current is used for feeding the electric motors. It allows you to adjust the angular speed of the drive motors (and therefore, to maintain the resonant frequency of oscillations of the vibrocolots and to adjust the magnitude of the force of the vibrational stimulator).

V.CONCLUSIONS

1. Complex experimental research on the influence of regime parameters (specific load and power) on the kinetics of IR drying of sunflower seeds in a vibration laboratory infrared monochrome vibration dryer was performed.

2. With an increase in specific power in 2,5 times the drying process decreases in proportion. The drying time to the relative humidity of the product at 6-7% takes 30

... 60 minutes. The average temperature of the product was within 35-43 ºC. There was no cracking of the husk.

3. Parameters of IC-drying sunflower seeds recommended by OSRAM lamps on the basis of experimental studies should be considered: height of hanging of infrared emitter during drying of grain h = 0,1 m; t_{min} = 35°C to t_{max} = 43°C.

4. Vibration monolayer dry intermittent infra-red heating allows to reduce the specific energy consumption approximately in 1,5-2 times, in comparison with the convection dryer, retains all the advantages of laboratory infrared monochrome vibration dryer. At the same time, the maximum temperature of the heating of particles of products is 1.5 - 2 times less with larger limits of their humidity. This allows for higher quality production of products at lower heat costs.

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5. ECOLOGY AND ENVIRONMENTAL PROTECTION

MODIFICATION OF ANAEROBIC DIGESTION USING RICE HUSK

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Abstract. *The current rate of development of grain-processing and meat-processing industries makes effective and cost-effective waste disposal more actionable. The reprocessing of waste from the meat processing industry, which includes waste water, formed directly in the production of meat and from cattle manure, requires special attention. Biotechnological methods of processing are considered a promising form of recycling food production wastes. One such method is anaerobic digestion, which is a continuous multi-component process that transforms organic material into finished products, such as biogas containing methane, water vapor and carbon dioxide, through microbial activity.*

The aim of this study was to investigate the joint utilization of rice husks, manure and sewage from a meat processing plant by anaerobic digestion in a laboratory anaerobic batch bioreactor for 10 days. During the study, parameters of influence of the substrate composition on the efficiency of decomposition of organic matter, biogas and methane yield were identified. A series of experiments investigating anaerobic fermentation of substrates was carried out with different weight ratios of manure, waste water and rice husks at mesophilic temperature conditions (36 ± 1°C). After benchmarking fermentation mono-substrates and mixtures, the use of mixed substrates for methane was proved to increase the degree of biodegradability of organic substance waste.

Keywords: *wastewater, anaerobic sludge, rise husk, cattle manure, biogas.*

I. INTRODUCTION

Requirements of the modern market dictate the implementation in production processes of technologies with low power, resource and capital intensity. Such technologies enable high-quality and competitive products. One of the strategic directions of development in the food and processing industry is providing the population with food products in a necessary quantity, while also actively greening the industry. Today, upgrades of production capacities in the move towards closed cycle production is considered as one of the fundamental directions to take in solving the problems of rational use of natural raw material resources and environmental protection. Gradually, producers are considering their accumulated world experience of waste recycling, understanding that it creates by-products, and thereby provides an additional source of financial income and also improves their ecological image. Given world growth rates in the prices of raw materials for food, questions of further reduction and effective utilization of food waste and the emergence of processing industries acquire increasing relevance in ecological and economic plans. Manufacturers pay

considerable attention to these aspects as their products are oriented to the European consumer market with strict requirements for environmental protection. The choice of methods for waste recycling considers the physical and chemical parameters of waste, the features of the manufacturer, and indicators of and energy efficiency.

In this work, the joint recycling of meat-processing waste and waste from rice cleaning is considered. For the period 2014-2016, 3884 thousand cattle a year were produced in Ukraine's livestock industry. Around 192 thousand were reared in the Odessa region [1]. Manure waste from cattle production for nongrazing time (220-240 days) in Ukraine and the Odessa Region amounts to 34.9 million tons and 1.7 millin tons respectively. Wastewater from the meat-processing entities amounts to 188 800 000 m^3 and 3760000 m^3 a year for Ukraine and Odessa, respectively.

Manure is the mix of excrement and urine from animals mixed with a straw or peat layer. Manure can be categorised as either covering (solid) or bespodstilochny (liquid) manure. The composition of manure depends on parameters such as the breed and age of animals, the type of feed and type of a layer. The second object of the research is wastewater from the meat-processing industry. This wastewater has many components and high level of COD (chemical oxygen demand), content of the weighed substances and fats, increased content of biogenous elements, neutral pH values, temperature within 20-30ºC, and organic substances are in both colloidal and soluble forms.

II. LITERATURE ANALYSIS

According to a statistical year-book of public service of statistics of Ukraine in recent years [1] the productivity of rice in Ukraine was 50 centners per 1 hectare. For Odessa region for the period of 2014-2016, on average 4.5 thousand tons of rice a year were imported by processing plants. This leads to theformation of rice husk waste amounting to 828 tons annually, on average. The rice husk is a by-product of grain cleaning. The husk is characterized by a considerable content of cellulose and mineral substances. There are three main methods of treating rice husks: burning, creating special dumps and conversion to produce silicon. As rather small amounts of rice are cultivated and converted in Ukraine, burning remains by the dominant method of waste treatment of rice and does not conform to modern requirements for low-waste and wasteless technologies. Therefore, to improve the profitability of the grain processing and meat-processing industries, effective waste recycling with the subsequent generation of by-products is the priority direction of development of policy for these industries.

Anaerobic fermentation is considered one of the most efficient paths of utilization of multicomponent effluent. Biochemical and microbiological aspects of the process of anaerobic fermentation depend on the composite conditions. According to the commonly used scheme, anaerobic fermentation consists of four phases: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Courses of each of these phases provide corresponding development of a microbiological community. Bacterial activity results in various products of disintegration of the complicated molecules which are a substrate for microorganisms for the following phase. The bacteria for the reactor are divided into three common groups [2]. The first group includes hydrolytic

bacteria, referred to as acidogenic, and which provide initial hydrolysis of a substrate to low-molecular organic acids and other small molecules. The second group is represented by heteroacetogenic bacteria which produce ethanoic acid and Hydrogenium. The third group includes metanogenic bacteria which form a methane. The last group can be divided into subgroups: consumers of Hydrogenium – lithotrophs, and consumers of ethanoic acid – acidtrophs. Synergism of these groups occurs, for example, various growth rates can be explained by common cultivation and appear as a result of interaction between trans-species type of hydrogen transfer. Substrates, which are partly Sulfur and Nitrogen, can cause increases in two additional groups of microorganisms: sulfate-reducing bacteria and denitrifying bacteria [2]. These symbiotic microbial communities can change the characteristics of fermentation, and function as self-regulating systems which maintain pH value, redox potential and thermodynamic equilibrium at optimum levels for growth, thereby providing stability of fermentation.

Courses of anaerobic reactions substantially depend on environmental temperature because of the sensitivity of bacteria to temperature jumps of an anaerobic system. There are three various temperature ranges which affect functioning (activity) of anaerobic bacteria: psychrophilic (18-20 °C), mesophilic (25-40 °C), and thermophilic (50-70 °C). It is known that when keeping a psychrophilic temperature regime, the process of a substrate's fermentation takes place very sluggishly and does not provide a sufficient degree of destruction of organic matter. During the mesophilic mode, stable growth of the metanogenic bacteria occurs, and the biomass increases. This mode positively influences biodegradation of substrate components. Keeping a thermophilic temperature regime stimulates a more intensive course of processes of anaerobic fermentation in the reactor. However, expenses on energy for heating and maintaining a thermophilic temperature regime are not compensated in full.

Activity of bacteria depends on pH level as each group of microorganisms has specific levels of pH for optimum growth. Monitoring of the pH parameter is fundamental to maintaining optimum bacterial growth. It is known that accumulation of volatile fatty acids in the bioreactor causes sharp jumps in pH level, which causes serial atrophy in methanogenic bacteria [3]. It, in turn, leads to a decrease in the effectiveness of removal of pollutants and formation of biogas. For acidogenic bacteria the optimum pH level is from 5.2 to 6.5 pH units, while the optimum pH level for metanogen is in the range of 7.5 to 8.5 pH units. Low pH values promote restitution of a proton to Hydrogenium, then its restitution into methane. A wide range of types of acidogenic bacteria entering the hydrolytic group provide their resistance to changes of conditions of cultivation, partly becoming acidophilic. It is known that the mean time of regeneration for such bacteria is 2-3 hours, which is a rather short time term for anaerobic processes [4]. However, this group of bacteria is negatively influenced by low pH values and a redox potential. In the conditions of a sharp increase of Hydrogenium concentration, microorganisms choose the alternate metabolic path for Hydrogenium removal, thereby regulating its concentration [2]. In cases of increased substrate concentrations in the reactor, a bacterium immediately reacts by formation of an excess amount of Hydrogenium and ethanoic acid, thereby reducing the oxidizing potential and pH. If this process continues further, then the substrate in the reactor

"turns sour" and finishes the work. However, acidogenic bacteria use feed-back and choose alternate metabolic paths, such as formation of propionic and butane acids that helps to restore the stability of operation of the reactor. The role of Hydrogenium in management of emergence and consumption of the intermediate products explains the formation of some long-chain fatty acids which leading to accumulation or an expenditure of Hydrogenium.

An important aspect in regulating the operation of the bioreactor is availability of nutrients which are important for efficient anaerobic microorganisms' growth [5]. In addition to the main content of macronutrients, organization of a microbiological community demands availability of micronutrients and minerals, such as Nitrogen, Phosphorus, Sulfur, Potassium, Calcium, Magnesium, Iron, Nickel, Cobalt, Zincum and Copper for ensuring optimum microbial growth. These nutrients have to be present at very low concentrations, however, their absence general negatively influences microbial growth and activity of microorganisms. Existence of ions of ammonium plays an important role in anaerobic fermentation. For an optimum process of anaerobic fermentation, the level of ions of ammonium have to be supported at the level of 80 mg/l. It is known from research that a stable course of anaerobic fermentation processes needs the maintenance of ammonium ions at the level of 50-150 mg/l under mesophilic conditions. Higher concentrations of ammonium lead to serious violations of reactor operation because of the resulting decrease in growth rates and specific activity of methanogenic bacteria [6]. In addition, a sulfide concentration is necessary for stable methanogenic organisms' growth, but it should be noted that depending on the pH level of the reactionary environment, sulfides can show toxic properties. Numerous research has shown that sulfide toxicity in relation to methanogenic bacteria, namely acetate consumers and H_2 consumers, inactivates and suppresses transformations of the intermediate products. This process depends on accumulation of volatile fatty acids that cause a decrease in the exit of methane.

From literary data it is known that the presence of heavy metals on a substrate in many cases causes toxic or inhibiting effects on the process of anaerobic fermentation. However, despite this, their presence at a very low («trace») concentration is necessary for microorganisms' growth. The toxicity of heavy metals (Cadmium, Chlorine, Copper, Nickel and Zincum), have been estimated through results of research. It has been revealed that acidogenic, acetogenic and metanogenic microorganisms are characterized by different resistances to the toxic influence of heavy metals [7].

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The laboratory tests are executed by fermentation of a substrate in a UASB bioreactor (Upflow Anaerobic Sludge Blanket reactor) of periodic action with a volume of 50 dm^3 (figure 1, image 1). We investigated anaerobic substrate fermentation with different weight ratios of components in mesophilic conditions with a temperature regime of 36±1°C and pH units of 6-7±5. During the laboratory tests we controlled the amount of the emitted biogas, methane and degree of biodegradation of organic matters on an index of the chemical oxygen demand (COD) and pH. Considering design features of the anaerobic reactor, it should be noted that the effectiveness of the process will be affected by the generation rate of easily settling

bacterial floccules. Thus, the waste of rice purification is used as a biological additive in anerobic process of sewage fermentation [8]. At the beginning of each cycle a component of a substrate was moved into the reactor, then the crane was hermetically closed. Working mix substrates were heated to 35-37 °C automatically. A stable temperature of working mix substrates was provided by a water-jacket with a temperature sensor. Hashing of a substrate was carried out by an automatic mixer. Biogas was gathered and measured in a water gasholder with a total amount of 13 dm^3.

The pH meter Hanna HI2210 was used to determine pH units. The pH range was from -2 to 16±0.01 units pH, and the temperature range was -0.9 to 120±0,5 ° C. The amount of methane in biogas was determined using the Signalling-explosimeter thermochemical device CTX-17-90, and measurements range from 00.0 to 99.9%. The COD indicator was determined according to standard gain 211.1.4.021-95. "Methods of determining the chemical oxygen demand (COD) in surface water and wastewater". The amount of total nitrogen was determined according to the standard gain 211.1.4.031-95 "Methods titration determination of total nitrogen in wastewater". The quantity of VFA (volatile fatty acids) was determined in accordance with "Methods of measuring fat mass concentrations by thin layer chromatography (TLC) ".

The aim of this work was anaerobic digestion of wastewater from meat processing enterprises with different substrate weight ratios of components (Table 1). The first three samples were monosubstrates (S1, S2, S3). The first sample consisted of meat processing wastewater after the mechanical treatment stage, the second consisted of cattle manure and the third was rice husks produced as a by-product of rice cleaning. The other substrates were mixtures and consisted of various components and weight ratios of manure and rice husks as follows: 3:1 (S4), 1:1 (S5), 1:3 (S6).

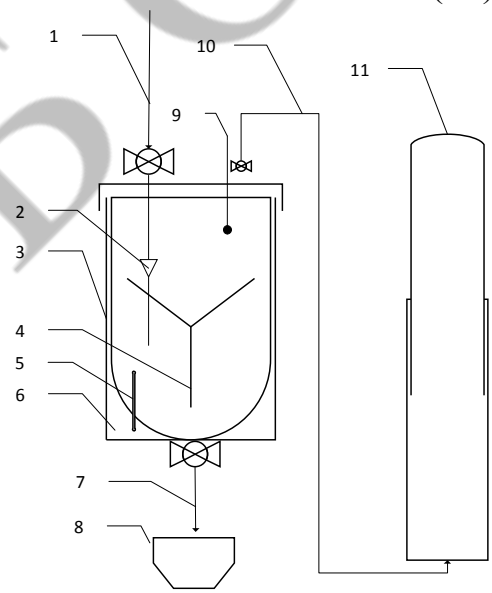


Figure 1. Equipment-technological scheme of anaerobic digestion of sewage, where 1 - supply of waste water; 2 - flow of sewage; 3 - bioreactor; 4 - electric mixer; 5 - heating element; 6 – water-jacket; 7 - sludge effluent: 8 - capacity to collect the sludge; 9 - temperature sensor; 10 - biogas stream; 11 - water gasholder.

Image 1. Photo of laboratory scale anaerobic bioreactor

Each substrate was added to 0.5 l of excess sludge from the previous anaerobic digestion of cattle manure with the addition of ordinary water, which contains the necessary microbial community to start fermentation and decomposition of organic matter. The temperature of the mixture was maintained at 35-36°C in the tests. The value of the redox potential fluctuated in the range of -260-140 mV; conditions for anaerobic transformation of organic matter below this range are not optimal [9]. Fermentation of each of the substrates was carried out for 10 days.

Table 1. Characteristics of substrates

Indicators		Unit	Sewage (S1)	Cattle manure (S2)	Rice husk (S3)	Weight ratio of manure : rice husk		
						3:1 (S4)	1:1 (S5)	1:3 (S6)
Waste	m	kg	-	7,73	-	3,52	2,38	1,37
	r.h.	kg	-	-	5.3	1,28	2,52	3,41
	s	l	28,9	20	20	20	20	20
Active sludge		l	0,5	0.5	0.5	0,5	0,5	0,5
Dry organic matter		%	5,8	11.65	25.2	15,1	18,6	20,4
s - meat processing wastewater sewage, m – cattle manure, r.h. – rice husk								

IV. RESULTS

According to the research, fluctuations in pH during anaerobic digestion of different substrates occurred in the range of 6.2 pH units in the substrate S2 (cattle manure) to 7.3 pH units in the substrate S1 (waste water). All substrates were characterized by optimum pH levels for microbial community functioning.

After the 10 day cycle of fermentation, substrates were observed to decrease in dry matter content by about 2 times the biggest indicator of removal of solids reported in the substrate S1 (sewage) – 56% and in mixed substrate S6 (1m : 3r.h.) – 54%. There

was also a marked decrease in COD of substrates before and after fermentation, reflecting the degree of decomposition of organic matter. Figures for COD decrease were as follows: S1 (sewage) – 42%, S2 (manure) – 58%, S3 (rice husk) – 37%, S4 (3m : 1r.h.) – 66%, S5 (1m : 1r.h.) – 64% and S6 (1m : 3r.h.) – 65%.

The amount of total nitrogen in the substrates after anaerobic digestion did decreased slightly, by 5-10% in all substrates. The content of VFA after anaerobic digestion of substrates for S2 (manure), S4 (3m : 1r.h.), S5 (1m : 1r.h.) and S6 (1m : 3r.h.) decreased by 49%, 55%, 61% and 54%, respectively. In substrates S1 (sewage) and S3 (rice husk) VFA accumulation was observed, ie their number increased by 5% and 20%, respectively, indicating a slowing of reactions in anaerobic digestion. Changes in the physical and chemical parameters for the investigated substrates before and after digestion in an anaerobic reactor are given in table 2.

Table 2. Physical and chemical properties of substrates before and after anaerobic digestion

Indicators before and after anaerobic digestion	Unit	Sewage (S1)	Cattle manure (S2)	Rice husk (S3)	Weight ratio of manure : rice husk		
					3:1 (S4)	1:1 (S5)	1:3 (S6)
pH	-	7.27	6,4	6.72	6.41	6.53	6.43
		6.81	6,22	6.65	6.51	6.47	6.41
Dry organic matter	mg/l	5.8	11,65	25.2	15.1	18.6	20.4
		3.3	5,7	11.25	7.9	9.2	11.0
COD	mg/l	1270	4455	1410	2892	2620	2078
		737	1871	888	938	943	935
Total nitrogen	mg/l	102	458,2	108.3	173	228	157
		98.7	439	106	172.5	224.7	156.4
VFA	mg/l	165	427	311.8	328	334.3	372.6
		174	218,4	373	148.5	164	171.7
Degree of biodegradation	%	42	58	37	66	64	65

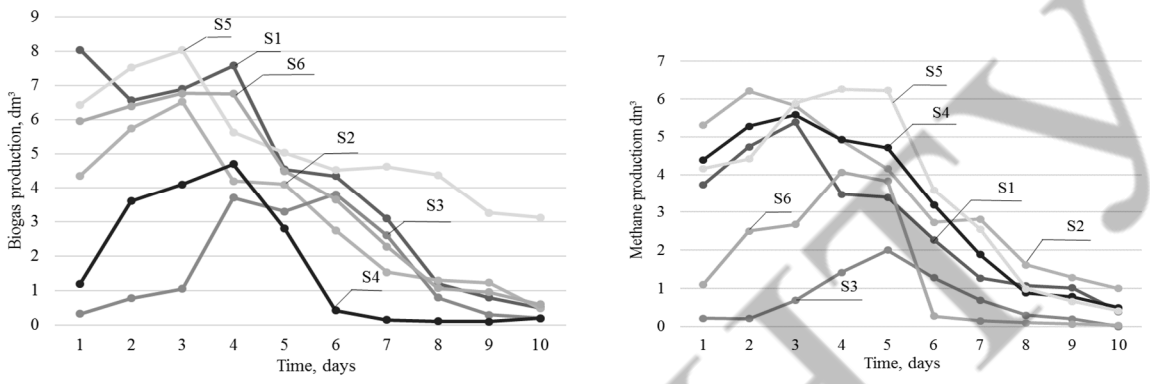
According to the dynamics of the intensity of production for biogas, the substrate samples S4 (3m : 1r.h.) and S2 (cattle manure) showed the highest level of bacterial activity on the first day, and the production of biogas was 8.04 dm^3 and 6.43 dm^3, respectively.

The low levels of activity of bacteria in fermentation were noted on the first day for S1 (sewage) – which produced1.22 dm^3 of biogas, and S3 (rice husk), which produced 0.33 dm^3 of biogas.Other substrates with a significant share of cattle manure contained methanogenic bacteria (Methanococcus, Methanobacteriales, Methanomicrobiales, Methanosarcina and Methanosaeta) [10].

The best biogas production results I during the 10 day period were S4 (3 m:1r.h.) – 8.04 dm^3 on the first day, S2 (manure) – 8.03 dm^3 on the third day, S5 (1m : 1r.h.) – 6.76 dm^3 on the third day, and S6 (1m:3r.h.) – 6.52 dm^3 on the third day of fermentation. The total amount of biogas produced over the entire period for each substrate was (in order of size): S2 (manure) – 52.53 dm^3, S4 (3m : 1r.h.) – 43.54 dm^3,

S5 (1 m:1r.h.) – 38.9 dm^3, S6 (1 m:3r.h.) – 32.2 dm^3, S1 (sewage) – 17.38 dm^3, S3 (rice husk) – 16.86 dm^3.

The results of the tests of the dynamics of biogas formation from various substrates are shown in Figure 2 a). The volume of methane in biogas for the period of study was: S2 (manure) – 35.9 dm^3, S4 (3 m:1r.h.) – 35.2 dm^3, S5 (1m:1r.h.) – 32.1 dm^3, S6 (1m:3r.h.) – 26.7 dm^3, S1 (sewage) – 14.8 dm^3, S3 (rice husk) – 7 dm^3. The dynamics of the intensity of methane as a result of methanogenic bacteria during anaerobic digestion are shown in figure 2 b).



2 a) 2 b)

Figure 2. a) dynamics of intensity of the production of biogas, b) dynamics of intensity of the production of methane in biogas, formed from substrates (S1, S2, S3, S4, S5, S6.)

V. CONCLUSIONS

The aim of the work was to investigate the impact of rice husks on the anaerobic digestion process of industrial meat processing wastewater and cattle manure for 10 days. Changes in the physical-chemical characteristics of substrates showed that the pH during substrates fermentation remained within optimal conditions for methanogenic microorganisms. Dry organic matter content after fermentation in all samples decreased by 2 times, and the amount of total nitrogen in the substrates decreased by 5-10%. A slight accumulation of intermediate components of fermentation wre also noted – volatile fatty acids in the substrates S1 (sewage) – 5% and S3 (rice husk) – 20%, which indicated a failure in the phase change of anaerobic digestion process.

Substrate fermentation was characterized by varying degrees of organic matter decomposition, which depended on the components of the substrate. The quantity of biodegradable organic matter ranged from 37% in the substrate S3 (rice husk) to 66% in substrate S4 (3m : 1r.h.). According to the results of the investigation into substrates' gas-forming properties, during the period of fermentation the largest amount of biogas production was noted for substrates S2 (manure) – 52.53 dm^3 and S4 – 43.54 dm^3. Total methane content in biogas samples was S2 – 35.9 dm^3 and S4 – 35.2 dm^3.

The results of comparative analysis of indicators before and after the fermentation of mixed substrates with different weight ratios of cattle manure and rice husks (S4 – 3:1, S5 – 1:1, S6 – 1:3) show that the effectiveness of organic matter

biodegradation in all three substrates was 65 ± 1%; the amounts of collected biogas were: S4 (3m : 1r.h.) – 43.54 dm^3, S5 (1m : 1r.h.) – 38.9 dm^3, S6 (1m : 3r.h.) – 32.2 dm^3. The amounts of methane in the collected biogas were: S4 (3m : 1r.h.) – 35.2 dm^3, S5 (1m : 1r.h.) – 32.1 dm^3, S6 (1m : 3r.h.) – 26,.7 dm^3. Thus, the joint fermentation results of rice husk and meat production wastewater in an anaerobic bioreactor demonstrate the significant efficiency of this recycling method which provides high rates of organic substance decomposition and biogas formation with high methane content.

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THE ORGANIC PART OF MUNICIPAL SOLID WASTES' COMPOSTING USING SOIL MICROORGANISMS

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Annotation: *In order to increase the efficiency of composting the organic component of solid municipal waste as a highly effective biotechnological method, and to compare the characteristics of the processes, it is suggested to use soil as an inoculum, as a microbiological additive - an extract from the soil. The original compost mixture is a multicomponent system, the decomposition and transformation of which depends on the functioning of a microorganisms complex, in particular, fungal and bacterial microflora. A similar microbial complex is observed in soils.*

The work presents the results of the study of the soil microbiocenosis qualitative and quantitative composition in order to use it as an inoculum in the process of composting the organic part of solid municipal waste. The influence of microbiological additive on the process of the organic waste composting for acceleration in mesophilic and thermophilic temperature regimes with controlled parameters was studied.

The results of the conducted studies allow us to conclude that the organic waste composting with the microbiological additive is appropriate, both in the case of thermophilic and in the case of mesophilic regimes. The period of the compost maturation with the use of a microbiological additive is 6 weeks. It was shown that the microbiological complex accelerates the process of composting the organic component of solid municipal waste by 3.3 times for the thermophilic regime and by 2.1 times for the mesophilic conditions of composting process, which testifies to the efficiency of its use in the operation of the solid municipal waste processing in order to improve the general level of environmental safety.

Keywords: *soil; microbiocenosis; composting; waste; microbiological additive; mesophilic and thermophilic composting regimes*

I. INTRODUCTION

The management of municipal solid waste (MSW) is the subject of an annual regional report on the state of the environment [1], statistical surveys [2], special studies [3], environmental programs. Description of the problem is mainly limited to data on the number and area of landfills, volumes placed in specially designated waste sites (mostly industrial). But such an array of information on waste disposal in specially designated areas does not allow fully characterizing the environmental consequences of the existing waste situation in the Odessa region and determining the resource potential of such waste.

In recent years, the countries of the European Union (EU) have gained considerable experience in utilizing MSW and, in the course of time, have improved their methods of handling, taking into account the features of the territory and ecological and economic feasibility [4,5]. In the EU, over 90 directives in the field of environmental protection have been adopted, the main principles in the field of waste management are defined in [6], which form the general EU strategy for management of MSW flows. Recycling, in particular, composting and receiving biogas as an energy source, is the main methods used by the EU government to dispose of MSW [7].

The most environmentally appropriate solutions for management of MSW reprocessing are recognized as minimization and prevention of environmental pollution. The international recycling system is aimed at minimizing waste by sorting and recycling feedstocks, the rest goes to recycling and composting, combustion and stockpiling of residues. Since up to 40% of the MSW relates to easily degradable organic wastes (food waste, market waste, urban greenhouses, municipal power supply, sewage systems, household waste [8]), the removal of this part of waste from waste land due to composting and waste conversion on the secondary material resource will significantly reduce the environmental burden on actually deployed and potentially planned landfills.

Aerobic composting is one of the best available technologies for an integrated waste management system by minimizing anthropogenic environmental impact, complying with the latest domestic and foreign developments, economic and practical acceptance of technology.

But composting is characterized by relatively low popularity in comparison with other methods of waste utilization due to a number of its disadvantages, such as a long production cycle and sometimes the obtaining of a product of unstable quality. Because of this, many studies on MSW processing are devoted to methods of accelerating the process of composting, which can be achieved in various ways, such as the development of high-efficiency composting machines and the change of biotic (vermicomposting, use of specialized cultures and communities of microorganisms) or abiotic (temperature, pH, etc.). parameters of the process.

II. ANALYTICAL REVIEW OF LITERATURE

Attention to the technologies of rationalization of methods for the preparation of manure and other organic waste was drawn in the early twentieth century. On the basis of the formed stratified composting method in piles in the 30s, a composting technique with stratified formation of semi-buried piles was proposed (Indore method) [9,10]. Some exploration work was aimed at developing various ways to speed up the composting process with a change in the abiotic parameters of the process [11,12].

Among modern researchers of the composting process as a rational method of waste management, there are innovative works of M. V. Gatsenko [13], M. K. Linnik [14], A. A. Lyashenko [15], V. V. Shatsky [16], in which a lot of attention is paid to the issues of composting technology, mechanization of the preparation of the substrate, optimization of the controlled parameters of the process, design of piles, composition of the substrate and the ratio of the main nutrients in it.

The feedstock for composting – the organic fraction of the MSW – typically has a low density of anaerobic microorganisms that spontaneously colonize waste during collection, transportation, and storage. This amount of microorganisms is not enough for the composting process. To start and speed up the fermentation process, it is necessary to inoculate the raw material with an active anaerobic microbial community from other sources. Fermented sludge from wastewater treatment plants, ground extracts, sludge from industrial wastewater treatment systems, manure, etc. are used as inoculum [17]. According to the literature, fermented sewage sludge contains all the necessary groups of microorganisms and is a versatile inoculum to start the process of fermentation of various organic wastes to produce biogas [18]. Other experiments with composting organic MSW and food waste at ambient temperature (20 ± 2 ° C) and in a moderately thermophilic mode (50 ° C) showed that the soil of the MSW landfill is the best inoculum compared to fermented sewage sludge, since provides a higher rate of methanogenesis [19]. The soil of the MSW landfills is widely available, however, for use as an inoculum, its previous activation is needed by dilution, incubation with an organic substrate at the desired temperature, as well as the separation of solid particles of sand and clay.

According to the results of studies [20], the structure of microbial complexes is an integral component of the detailed characteristics of soils. Soil as a habitat and a waste product of microorganisms is a complex system, including physiological and taxonomic species that provide biological circulation of substances, soil formation processes and their resistance to natural and anthropogenic factors. Heterotrophic organisms that inhabit the soil (in particular, organic and organogenic horizons), provide a complex transformation of detritus, participate in the processes of decomposition and re-synthesis of organic substances in it.

The microbial biomass of the soil is represented by the biomass of soil microorganisms (bacteria, fungi, protozoa) in the soil. Its content substantially depends on the type of ecosystem, as well as the complex of hydrothermal conditions and ranges from 1 to 5% of the total content of soil organic matter [21]. These data are confirmed by studies [22], according to which microbial biomass contains from 0.27 to 4.8% of the total carbon content and 0.5 to 15.3% of nitrogen.

One of the important factors on which the temperature sensitivity of organic matter to mineralization depends is the physiological activity of the soil microbiota and it determines the effectiveness of the utilization of the substrate. Therefore, it is advisable to use microbial soil complexes containing cellulolytic microorganisms and bacterial colonies as a microbiological additive for composting in natural conditions. Bacteria and micromycetes are among the most active pulp decomposing microorganisms, however, bacteria play a major role in the decomposition of cellulose wastes during the composting process [23].

In the work it is envisaged to establish the technological features of the inclusion of a microbiological additive to compost mixtures with the food component of MSW, which makes it possible to determine the operating parameters of the technological operations of waste management. It is also proposed to establish the patterns of influence of microbiological additives on the biogenic and abiogenic parameters of composting processes, which allows regulating the process of utilization of the food

component of MSW, which has not been done before and reflects the scientific novelty of the work. It is provided that the bacterial consortium isolated from the soil exhibits high cellulose activity, which allows accelerating the composting processes and improving the quality characteristics of the finished compost.

III. OBJECT, SUBJECT AND METHODS OF RESEARCH

The purpose of this study was to study the role of soil microbiocenosis in the process of composting the organic part of MSW and the possibility of accelerating the process of composting plant waste by introducing microbiological additives. It was assumed that their addition to the composition of the feedstock will lead to the activation of microbial activity in the initial stages of the composting process. Since the main component of the organic fraction is cellulose, it is expedient, along with the definition of the total number of the microflora bacterial and fungal components, to determine the number of cellulose-decomposing microorganisms. An estimation of the change in the compost mixtures' microbial population has been made, which shows that bacteria dominate over fungi in compost mixtures.

In the course of this study, it was necessary to perform the following tasks:

1) to investigate the composition of soil microbiocenosis for use as an inoculum and feedstock for the preparation of a microbiological additive;

2) to investigate the effect of microbiological additives on the processes occurring during composting of the organic part of MSW in mesophilic regimes;

3) to investigate the conditions of the processes of composting with the addition of a microbiological additive by the main abiotic and biotic indicators and by the indicators of maturity.

Soil samples were collected in the background relative to the soil of the MSW dump site (MSW-1 «Dalnitsky quarries», taking into account typical signs (typical for the region black southern earth less humus), uniformity of vegetation and meteorological conditions. So, in total, three soil samples from the fields of the Ovidiopolsky district were used, which were taken in an envelope (zig-zag) pattern from a depth of 5-10 cm. After transportation in a plastic container, the samples were subjected to laboratory analysis using standardized methods. Soil samples were freed from inclusions, sifted through a sterile sieve, and the sample of 50 g, which was subject to tenfold dilution (1:1000, 1:10,000, 1:100,000), was selected by the quartering method.

All indicators of a complete bacteriological analysis of the soil were determined by the generally accepted methods of quantitative introduction of the prepared average soil sample into the corresponding media [24], temperature control of the samples, visual inspection and quantitative count of cultures. The total number of bacteria was determined by the deep culturing method on the plain agar medium. The presence of Escherichia coli (coliform bacteria analysis) was determined by culturing in modified medium Kessler. To determine the titre of *Clostridium perfringens*, iron sulfite agar (Wilson-Blair medium) was used. Identification of proteus was carried out according to the method of Shukevich.

A mixture of food, agricultural and landscape gardening wastes was used as a raw material for composting in a weight ratio of 1:1:1. Deciduous waste was used as a

filler. The feedstock was crushed to a size of 10-15 mm, dried in air for two hours and loaded into the reactor for composting. To increase the efficiency of the composting process and compare the features of the processes, an extract from the soil was used as a microbiological additive.

The experiment was carried out in three stationary reactors with a volume of 3 dm^3 with forced aeration for 6 weeks. A mixture was introduced into each reactor, composted, in the amount of 1.2 (2/3 of the reactor volume) with a moisture content of 72%, which was mixed with 100 g of soil as an inoculum. 100 ml of distilled water was added to reactor 1 (control), and 100 ml of a microbiological additive was added to reactors 2 and 3, which is an aqueous extract of the soil obtained by incubating the soil with water from the water module 10 for 20 minutes while stirring. An extract from the soil was used as a microbiological additive to increase the efficiency of the composting process.

Reactors 1 and 2 were isolated from exposure to ambient temperature. The reactor 3 was placed in a thermostat with a set temperature of 55 ° C for the purpose of thermophilic composting. Composting was continued for 6 weeks, while the mixture was composted, stirred daily and moistened to maintain a moisture level of about 70-75%. Each week, we conducted a selection of samples weighing about 10 g for research.

The parameters of the composting process were controlled with a change in temperature, pH and the number of microorganisms in the mixture composted, as well as CO_2 emissions from the reactor [25]. The maturity of the compost, which was obtained, was determined by the germination index [26] and the ratio of the total carbon and nitrogen in the mixture, composted [27].

The temperature inside the mixture, composted, measured using an alcohol thermometer, which was fixed in the lid of the reactor, the lower end of which was in the mixture, composted. Once a week, the gas fraction was collected from the reactors using disposable plastic syringes per 50 cm^3. The amount of carbon dioxide in the sample was determined using a gas chromatograph «Hromatek Crystal 5000.2». The determination of total organic carbon was carried out by the Tyurin method, and total nitrogen by the Kjeldahl method [27]. The pH of the aqueous extract was determined using a laboratory pH meter Hanna 221X. The number of microorganisms was determined by culturing on solid nutrient medium in Petri dishes by the method of Koch. The coefficient of germination was determined by the number of seeds of radish seed that germinated, with ten and the length of seedlings in water extracts from composts compared to control (distilled water). The quality control of the finished product was determined by the C / N ratio and the total nitrogen content in the dry matter.

IV. THE WORK RESULTS

The results of the study of the soil microbiocenosis for use as an inoculum and raw material for the further preparation of a microbiological additive in the composting process showed a relatively high quality of soil samples and proved the presence of common microbiological properties of the same type of soil from different sampling sites. Thus, the microbial grouping of typical low-humus black earth is 24.5-30.8

million CFU / g of soil, which is a high indicator of the total number of microorganisms in the soil. Such soils are the most biogenic and are characterized by a high content of bacteria, which are able to assimilate the nitrogen of organo-mineral compounds (6.4-7.9 million CFU / g of soil). Using the averaged data on the total number of microorganisms in the samples studied, we can estimate the soil according to the degree of its enrichment with microorganisms [28] and assign it to group I with a "very rich" rating with average values of 27,700,000 CFU / g of soil containing the total number of microorganisms in the soil.

As for the qualitative composition of the soil samples, it is worth noting that the soil is a multicomponent system, the decomposition and transformation of which depends on the functioning of a whole complex of microorganisms capable of producing such exoenzymes as cellulase, phosphatase, chitinase, dehydrogenase, etc. The main groups of such organisms are fungal and bacterial microflora, therefore, for a more detailed understanding and explanation of the composting process, the total number of bacteria and fungi was taken into account.

Since the main component of the organic fraction is cellulose, it is advisable, along with determining the total number of bacterial and fungal components of the microflora, to determine the number of cellulose microorganisms. An assessment of the change in the microbial population of compost mixtures has been carried out, which suggests that bacteria in the studied samples dominate the fungi.

Based on various morphological and biochemical characteristics, it was determined that most microorganisms isolated in pure culture belonged to the genus Bacillus. The entire bacterial community is divided into three main groups: gram-positive cocci, gram-positive bacilli and gram-negative bacilli. The first group is represented by bacteria of the genus Micrococcus, Planococcus and Staphylococcus. All gram-positive bacteria belong to the genus Bacillus. Gram-negative bacteria, found in specimens, were representatives of the genus Enterobacter and Flavobacterium.

Among the representatives of mushroom flora, mainly euroocomycetes and Ficomyces were found. In samples of two soil extracts anaerobic cellulose-decomposing bacteria of the genus Clostridium perfringens, insignificant number of bacteria of the genus Proteus were found; in all three samples of the series of experiments, no BGKP was detected, which in general indicates a high sanitary-hygienic index of the soils examined and proves the possibility of their use as an inoculum in the composting process.

Thus, enrichment of the microbial consortium of compost mixtures in the initial stage of cellulose-decomposing organisms can help reduce the time of waste composting: mesophilic bacteria are the dominant organic waste debris at the initial stages of composting. During the thermophilic phase, they are replaced by thermotolerant bacteria. The domination of bacteria is due to their ability to grow rapidly, using proteins and other available substrates, as well as tolerance to high temperatures.

Destruction of cellulose is carried out by bacteria, fungi and actinomycetes under various aeration conditions, at different temperatures and at various pH values of the medium. The development of microorganisms on cellulose involves biosynthesis and the removal of cellulases. The regulation of the process of biosynthesis and excretion

of enzymes is controlled by the mechanisms of induction and catabolistic repression. Cellulase synthesis inducers can be cellulose, cellobiose, lactose, etc. The reagent of biosynthesis of cellulases is glucose most often. Some organisms synthesize cellulolytic enzymes when they grow on any substrate, others, for example, bacteria belonging to the genus Achromobacter, Pseudomonas, Vibrio, Cellulomonas, use cellulose only when there are no other sources of carbon.

The process of destruction of fiber begins with hydrolysis. Bacteria are able to break down cellulose under anaerobic and aerobic conditions. Most of the anaerobic cellulose bacteria identified in the soil extracts belong to the genus Clostridium.

Other anaerobic bacteria can also decompose cellulose: Acetovibriocelhdolyticus, Bacteroidessuccinogenes, Anaerocellumthermophillum, Thermotoganeapolitana, Halocellacellulolytica. All of these bacteria form the extracellular complex of cellulases, and the products of cellulose fermentation are ethanol, acetic, formic and lactic acids, molecular hydrogen and carbon dioxide, and extracellular cellulose is decomposed into celobiose. Cellulose is decomposed to actinomycetes, representatives of the genera Streptosporangium, Microbiospora, and also the species Streptomycescellulosae, Micromonosporachalcea, Thermoactynomycescellulosae, Thermomonosporacurvata.

Therefore, in the future, it was necessary to evaluate whether inoculation of compost mixtures with biological additives affects the composting process of solid waste.

In general, the completeness of the composting process is characterized by two concepts – «stability» and «maturity» of compost, which, despite their conceptual differences, are simultaneously used to determine the degree of decomposition of organic substances in the composting process. Were selected parameters that allow evaluating both the intensity of decomposition of organic substances (temperature, organic matter content, soluble organic carbon and ammonium nitrogen) and its stability (respiratory activity and cellulolytic activity, number of bacteria and micromycetes) and maturity (pH, phytotoxicity).

The results of studies of changes in the pH of the mixture, composted with a microbiological additive, are presented in Fig. 1.

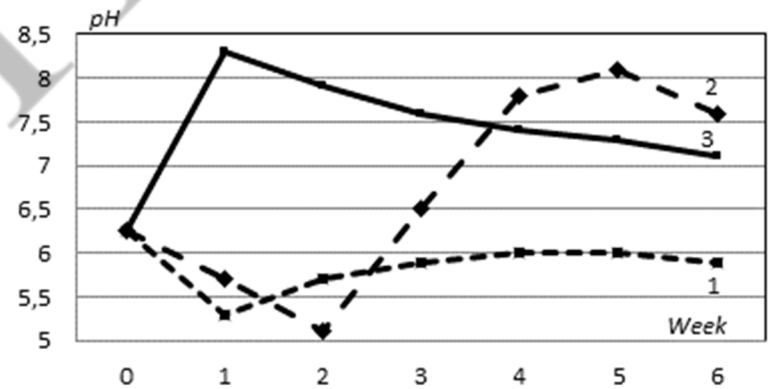

Fig. 1 - Change of the pH of the composted mixture in microbiological reactors in the mesophilic (2) and thermophilic modes (3) in comparison with the control sample (1)

Initial pH value of raw materials was subacidic, close to neutral (6.3). After the composting started, the pH value in the mesophilic regime in the reactor 2 decreased to 5.1 before the second week, at the fifth week it rose to 8.1, then decreased to 7.6. This can be explained by the formation of organic acids in the process of fermentation, and then their neutralization. Under the thermophilic conditions in the reactor 3 after the first week, the composting of the pH of the medium became alkalescent (8.3), which can be explained by the release of quaternary ammonium bases and salts, and then gradually decreased, stabilized at the value of 7.1. Thus, in reactors with a microbiological additive when mesophilic composting at the initial stage of composting, the pH was deviated to the side of the subacidic parameters, with the thermophilic - in the direction of alkalescent ones. The pH values observed in reactors 2 and 3 at the end of the composting process are optimal for growing plants and meet the requirements of mature compost. Stabilization and even a slight decrease in the pH level observed at the last week is likely to result from the formation of humus-like substances, as indicated indirectly by the stabilization of organic matter and soluble organic carbon during this period.

The rate of destruction of organic matter is directly dependent on the number of microorganisms and the composition of the microbial colonies of the mixture, which is composted. In reactor 2, accelerated growth of mesophilic microflora was observed, since the temperature in them was 23-25 ° C. In reactor 3, thermophiles reached a significantly larger number, since temperature conditions were more suitable for their growth (55 ° C). Thus, the addition of bio-additives based on soil extract increases the number of microflora in the compost samples by 2-3 times compared with the control. Since bacterial colonies correspond to composting for the decomposing of the organic part of the mixture, their increase in various modes of composting is expected to activate the formation of compost.

By the end of the composting process, there is a significant increase in the number of bacteria, in particular, cellulose-decomposing. So, if at the beginning of composting their number was $1.2\text{-}2.3*10^6$ CFU g^{-1}, then at the end of the process it was 2-4 times higher. The number of cellulose fungi, on the contrary, sharply decreased from $0.7\text{-}1.9*10^4$ CFU g^{-1} at the initial stage of composting to their complete elimination at the end. The likely reason for this dominance of bacteria is an increase in temperature, which creates unfavorable living conditions for most fungi.

The activity of microorganisms can be judged by the intensity of their respiration (oxygen consumption or release of carbon dioxide). Presented in Fig. 2 the time dependence of the change in CO_2 concentration in the reactor space is indicative of changes in the activity of the microbial community during the composting process.

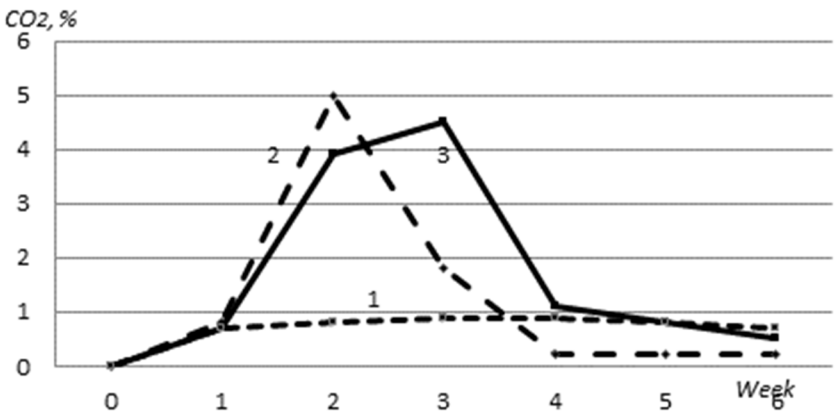

Fig. 2 - Change of CO_2 emissions from reactors during composting process of the composted mixture in reactors with microbiological additive in mesophilic (2) and thermophilic modes (3) in comparison with control sample (1),% CO_2

The activity of microorganisms is much higher in a reactor that is in thermophilic conditions (reactor 3). In reactors 2 and 3, the peak activity is for the period from the second to the third week. Peaks of respiratory activity coincide with an increase in the rate of destruction of organic matter. In the first weeks of composting microorganisms actively decompose easily accessible compounds, which leads to an increase in CO_2 production. It is during this period that high rate of mineralization of organic matter and the maximum decrease in the content of soluble organic carbon is observed. Since the peaks of activity in mesophilic and thermophilic conditions do not coincide, we can assume that in thermophilic conditions in the third week, bacterial colonies begin to more actively decompose complex organic compounds. At the final stage, the reduction and stabilization of the level of activity indicates that all available substances in the composted mixture are mineralized by microorganisms. Thus, the introduction of the microbiological additive stimulates the increase in the activity of the community of microorganisms in the initial stages of composting - within three weeks, which indicates that it is during these terms that the destruction of the organic part of the composted mixture is actively taking place.

The nature of the change in the number of total Carbon from the time of composting, shown in Fig. 3 is approximately the same for all three reactors: in the first 4 weeks mineralization of a large amount of organic matter (about 7%), then Carbon is consumed insignificantly (3-4%). Maximum rates of consumption of organic substances in all reactors were observed after the second week, and the introduction of a microbiological additive doubles the rate of Carbon expansion, which confirms the role of the soil microflora in destroying the organic part of the composted mixture in both temperature regimes.

The total losses of the total Carbon (Fig. 4) were somewhat higher in reactors 2 and 3 (21-22%) than in reactor 1 (about 12%). Thus, the overall losses and the rate of loss of the total Carbon are more pronounced when using a microbiological additive in both the thermophilic and mesophilic regimes, which suggests a greater efficiency of the composting process, which is obviously influenced by bacterial colonies of bio Additives - respectively thermophilic and mesophilic.

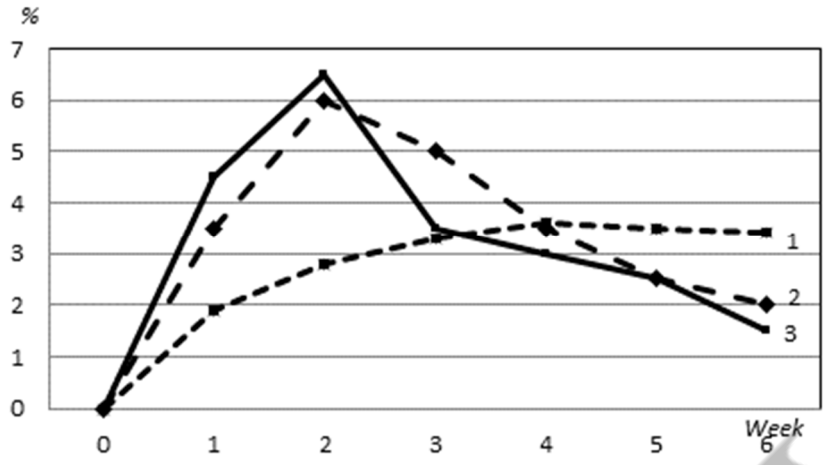

Fig. 3 - Change in the rate of loss of the total Carbon in a composted mixture in reactors with a microbiological additive in the mesophilic (2) and thermophilic modes (3) as compared to the control sample (1),% / week

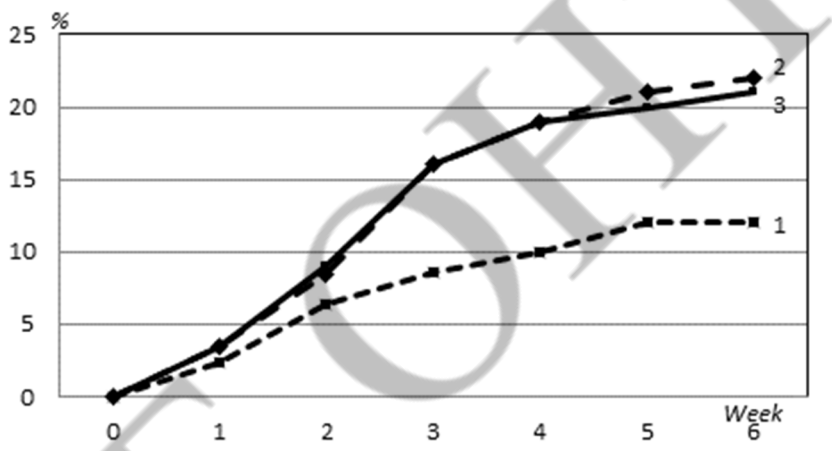

Fig. 4 - Changes in the rate of loss of the total Carbon in the composite mixture in the reactors with mineral additive in the mesophilic (2) and thermophilic modes (3) as compared to the control sample (1), % / week

The change in the content of the total nitrogene characterizes the dynamics of mineralization of nitrogen-containing substances. As can be seen from Fig. 5, the initial content of nitrogen in reactors is different: the largest amount is observed in reactors 3 and 2 (2 and 1.5 g / kg), which can be explained by the presence of bacterial colonies (possibly tuber bacteria), against 0.5 g / kg Nitrogen in a control reactor without the addition of a microbiological additive. The nature of the change in the content of the total Nitrogen in the composted mixture is virtually identical for all reactors (Fig. 5). The maximum nitrogen loss rates in all reactors were observed after the second week, and in reactors 2 and 3 they were greater (3.5 g / kg per week) than in reactor 1. Similar changes in the content of total nitrogene at the beginning of composting were associated with active the decomposition of nitrogen-containing compounds and evidence of the presence of unstable substances. Subsequently, in all experimental variants, there was a decrease in the total Nitrogen level, which by the end of the sixth week amounted to 0.2-0.5 g / kg. In general, at the end of composting, all samples

tested showed a total nitrogen content below the level that is advanced to mature compost. However, it should be noted that the level of Nitrogene in mature compost varies in a sufficiently wide range and depends on the time of composting and composition of the source components. In our variant, the composting mixture did not contain substances that are characterized by high levels of Nitrogen (manure, sewage sludge, legume crops, etc.), which explains the reduced amount of nitrogene in the finished compost.

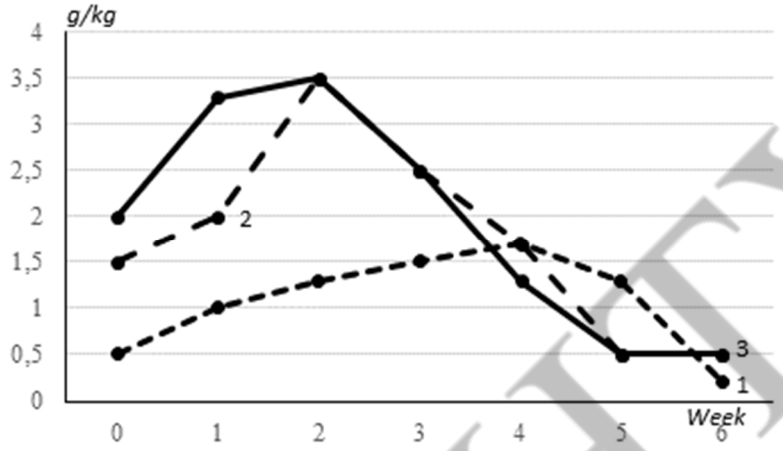

Fig. 5 - Changes in the rate of loss of the total nitrogen in a composted mixture in reactors with a microbiological additive in the mesophilic (2) and thermophilic regimes (3) as compared to the control sample (1), g / kg per week

Total losses of nitrogen in reactors 2 and 3 were the largest (about 13 g / kg of dry mass, which is compacted). In the control reactor, the losses of Nitrogen were lower (8 g / kg of dry mass, which is compacted). Thus, the losses of Nitrogen are slightly increased with thermophilic composting, however, both in the thermophilic and mesophilic modes, in the case of the introduction of a microbiological additive, the destruction of organic matter is almost 2 times greater than in the control sample.

Maturity of compost is estimated by the mass ratio in it of total Carbon and total nitrogen (C / N). According to international standards, quality compost should have C / N below 25. In Fig. 6 shows the dependence of the change of C / N on the duration of composting. The ratio of C / N reaches the minimum values after the second week of composting and then does not change significantly. The final ratio of C / N in all obtained compost is less than 25, which indicates a reduction in maturation of the compost when the microbiological additive is applied, approximately twice, taking into account the rate of its change.

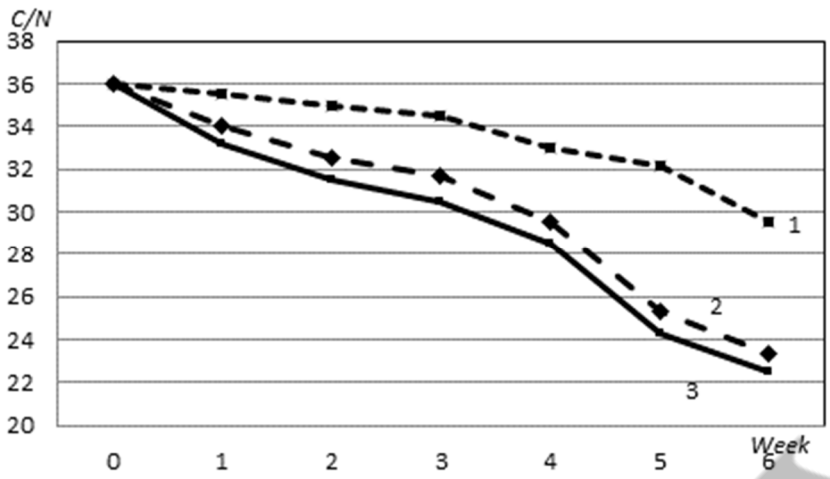

Fig. 6 - Changes in the ratio of total Carbon to total Nitrogen in a composted mixture in microbiological reactors in the mesophilic (2) and thermophilic regimes (3) as compared to the control sample, g / kg per week

An analysis of the experimental study suggests that the intensity of destruction of the organic part of the mixture of municipal waste that is composted depends on the bacterial colonies derived from the soil extract and doubles both in the mesophilic and in the thermophilic conditions. The activity of thermophilic microorganisms is somewhat higher, however, taking into account the energy costs of heating the composted mixture, it is possible to recommend composting in mesophilic mode with the addition of dietary supplements as a resource-saving means of composting organic waste.

The results of the study indicate that the index of seed germination of radish is gradually reduced with an increase in the length of composting (Fig. 7). Compost with germination index less than 80% is considered phytotoxic, more than 80% - mature.

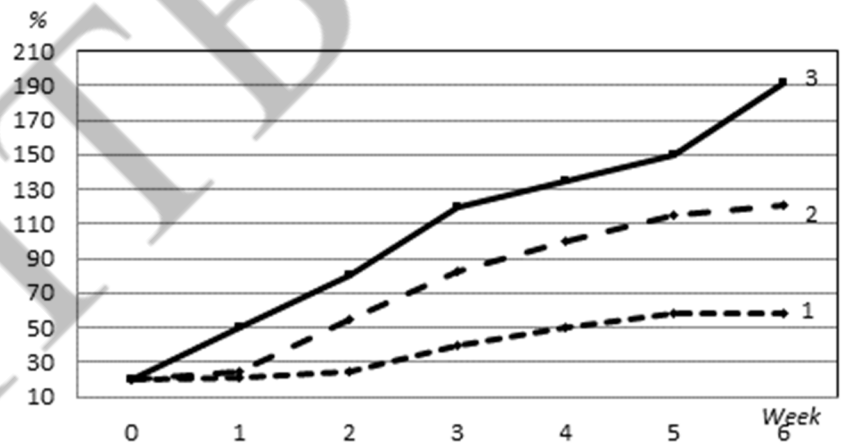

Fig. 7 - Changes in the germination index in the composting process in a composted mixture in reactors with a microbiological additive in the mesophilic (2) and thermophilic regimes (3) as compared to the control sample (1),%

After 6 weeks compost composting in reactors 2 and 3 is characterized by a germination index of more than 100%, indicating that the compost is not only free from phytotoxins, but also has a stimulating effect on germination. Experimental data of the

research allow us to conclude that maturation of the compost in thermophilic conditions is completed faster than in the mesophilic, and the duration of maturation of the compost when the microbiological additive is accelerated by 3.3 times under the thermophilic conditions and 2.1 times by the mesophilic ones. Thus, the temperature regime affects the maturity of the compost in the stage of germination and the evaluation of the phytotoxicity of the compost, but not the intensity of destruction of the organic matter, since in the mesophilic regime, the mesophilic microflora takes on the destructive role in approximately the same degree as in the thermophilic - thermophilic microflora.

V. CONCLUSIONS.

The results of the conducted research allow drawing the following conclusions.

1. Aerobic composting is a highly effective ecologically-manageable biotechnological method for treating the organic part of the MSW.

2. Microbiological characteristic of soil complexes proves the expediency of using the soil as an inoculum during composting, for launching and accelerating the process of biofermentation.

3. The microbiological additive from the soil extract can be used for composting both in the thermophilic and mesophilic modes.

4. The bacterial complex accelerates the composting process of the organic component of the MSW by 3.3 times in the thermophilic regime and 2.1 times in the mesophilic conditions of composting process, which testifies to the efficiency of its use in the processes of MSW processing in order to increase the overall level of environmental safety.

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PRODUCTIVITY OF ALFALFA OF VARIOUS SLOPES FOR SEEDS, DEPENDING ON BIO - AND BIOTIC FACTORS

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Abstract. *The scientific paper presents the results of studies of the influence of mowing on the development and formation of alfalfa seed yield when growing it on chernozems of the southern steppe of Ukraine on non-irrigated lands. Studies aimed at identifying factors that can contribute to increasing alfalfa seed productivity and improving soil fertility, reducing the pesticide load on them, are relevant. The aim of the work was to determine the influence of abiotic and biotic environmental factors (weather conditions and mowing on seeds, relationships between weeds and cultivated plants, population of agrophytocenoses with pests) on alfalfa seed productivity. It is determined that at the first mowing in the agrophytocenosis there are, on average, 12.5 specimens./ m^2 of weeds that during the growing season of alfalfa seeds of the third year of life remove 40.8 kg/ha of nitrogen, 3.5 – phosphorus, 41.3 – potassium and 9.9 kg/ha of nitrogen from the soil. calcium, and with an intermediate slope, the density of weeds is much less (9 PCs./m^2), which absorb almost 3 times less nutrients from the soil. It was found that the cultivation of alfalfa with intermediate mowing (mowing the first for green fodder at the beginning of budding) contributes to an increase in seed yield by 20.9% compared to the first, the level of profitability increases from 182.9 to 313.7%, or by 130.8 percentage points (71.5 percent. So, growing alfalfa for seeds with intermediate mowing is environmentally safer, due to a decrease in the number of pests in the agrophytocenosis, and therefore the need for insecticides, compared to the first mowing, which is proposed for introduction into production.*

Keywords: *alfalfa for seeds, weather conditions, slopes, plant growth and development, pests,.weeds, battery removal, technology efficiency.*

I. INTRODUCTION

For many decades, almost all branches of the national economy, under the guise of saving and rational use of labor, material and financial resources, ruthlessly exploited nature. They used mineral resources, land, water and plant resources, wildlife and airspace in a predatory way. For decades, it has been argued that all natural components are able to recover quickly and the possibilities of the human environment in this regard are almost limitless. Science has proven, and practice has confirmed, that in today's conditions such a statement is unacceptable, because the areas under arable land that are subject to dust and water erosion are growing, and the desert is purposefully advancing on fertile land, and an environmental catastrophe occurs. Life demands that positive changes take place in our country.One of the ways to solve this issue is to expand the area of perennial legumes, the leading place among which belongs to alfalfa.

II.THE ROLE OF ALFALFA IN THE GREENING OF AGRICULTURE (analytical literature review)

Recently, humanity has begun to perform those impossible functions that nature itself previously performed, in particular, the accumulation of food elements by biological means, strengthening the sanitary role of various organisms in the agrophytocenosis, cleaning fields, etc. The farmer, taking on all these concerns, incurs huge costs of material and technical resources with simultaneous environmental pollution. Intensification factors themselves are not unnatural, but only excessive and generally incorrect application leads to negative consequences, deterioration of soil fertility indicators [1]. The basis for reproducing soil fertility is to ensure a deficit-free balance of humus and nutrients in them, which makes it possible to maintain a certain level of their potential and effective fertility [2]. One of the ways to solve the problem of protecting and reproducing soil fertility is to introduce crop cultivation technologies with minimizing tillage and elements of agricultural biologization [3, 4]. It is already known that the main feature of perennial grasses, including alfalfa, is durability, rapid vegetative recovery after mowing, high adaptability to growing conditions and increased soil fertility [3, 5]. In the meter-long soil layer, 243.6 kg/ha of nitrogen; 38.7 kg/ha of phosphorus; 134.3 kg/ha of potassium; 102.4 kg/ha of calcium accumulate due to crop residues and alfalfa root biomass of the third year of life [5].

2.1. Origin and economic significance of alfalfa

Growing alfalfa, as a high-protein fodder crop, people began to engage in for a long time. The name of the genus *Medicago* comes from the word *medica*, or mussel grass (*Herba medica*), which Greek warriors, as a valuable forage crop, discovered in Persia in the IV century BC, during the Greco-Persian wars, in the mussel region, located in Asia Minor. Alfalfa was first introduced by the Persians to Greece, and in the IV century BC. - to the Apennine Peninsula (Italy) and only in the VIII century BC it was widely distributed in North Africa and Spain, but already with the Arabic name *alfalfa*, instead of the Roman *Melissa* [6], alfalfa began to be grown in Ukraine in the XIX century. In 1840-1860, its agrocenoses were located in the former Kiev, later (1870-1890) in the Kherson, Ekaterinoslav and Poltava provinces [7]. As of 2000, the area of alfalfa crops in Ukraine was about 500 thousand hectares [8]. Now the general state of feed production is deteriorating due to a significant decrease in technical and technological support for all branches of Agriculture [9]. Thus, the area under forage crops in 2000 (7063.1 thousand hectares) decreased by almost 20% compared to 1990, and in 2020 –by another 2.4 times, and cultivated pastures in 2000 – by 70 thousand hectares (35%), and in 2020 by another 14.3 times. The biological value of feed decreases: an average of 85 g of digested protein is produced per feed Unit [10]. In a market economy, agricultural producers neglect both the production of alfalfa seeds and their cultivation for feed. According to the State Statistics Committee of Ukraine, the area allocated for seed purposes has more than halved in five years (from 2001 to 2006) (from 123.1 to 55.2 thousand hectares). In 2020, this figure was 8.4 thousand hectares, that is, it decreased by another 6.6 times [11].

Alfalfa is grown in all countries with a developed livestock industry, since the green mass and hay of this crop contain a high amount of protein. So, 100 kg of green mass, depending on the phase of development, contains 16-22 kg of feed units, 3.5-4.8 kg of digested protein, 0.4-0.8 kg of calcium, 0.08-0.14 kg of phosphorus. Alfalfa is rich in vitamins, essential amino acids that are essential for animal life [12]. Alfalfa plays a very important role in preserving and improving soil fertility. It is able to structure it, pickle it, enrich it with organic matter (due to a well-developed root system), biological nitrogen compounds [13]. This crop meets its needs for nitrogen Nutrition up to 70% by fixing it from the atmosphere. After the alfalfa formation is developed, up to 200 kg/ha of nitrogen remains in the soil. This is Nitrogen of biological origin, it is not lost or washed out of the soil, but is fully used by subsequent crops. According to the generalized data of scientists, in the absence of manure and other organic substances, the share of alfalfa in the structure of sown areas of forage crops should increase from 35 to 50% [7]. For such an expansion of crops, farms should be provided with a sufficient amount of high-quality seed material.

2.2. Biological and morphological features of alfalfa

Alfalfa (*Medicago* L.) belongs to the legume family (*Fabaceae, Leguminosae*), the order of legumes *(Fabales*). This genus includes 21 perennials and 43 annual species. In the Culture, three types of tetraploid alfalfa are most common: seed, or blue (M. *sativa* L.), variable, or hybrid (M. *Varia* Mart) and sickle-shaped or yellow (M. *falcate* L.) [7]. Plants are quite winter - and frost – resistant-in the absence of snow cover, they can withstand frosts up to 20 – 25 °C, and with a constant snow cover-up to minus 40 °C. Alfalfa is a moisture-loving and drought-resistant crop, optimal conditions for the growth and formation of the mass crop are created at a soil humidity of 60-80% HB. The best soils for it are chernozems, chestnut, brown, it grows well on sod-carbonate and sod-podzolic [7, 13]. The growth and development of alfalfa is significantly affected by the temperature regime [14]. Alfalfa seeds begin to germinate at a temperature of 5-6 °C, and plant growth in spring – at a temperature of 7-9 °C. A close inverse correlation was established to a high degree (r = - 0.87) between the duration of the sowing–germination period (in spring) and the air temperature [15]. Alfalfa grows and develops better at a soil humidity of 70-80% HB. To create 1 kg of dry weight, it spends from 700 to 1200 kg of water. During the two months of vegetation, the alfalfa root system is buried in the soil by an average of 90-100 CM. Alfalfa is a crop that is most sensitive to light in the period from emergence to the beginning of stemming and during flowering. When forming a crop of green mass, as well as seed herbage, not only the amount of light is important, but also the depth of its penetration into different tiers of crops [7, 13].

2.3. Harmfulness of weeds and pests in alfalfa crops

A negative factor is the spread of weeds, especially parasitic plants, in agrophytocenoses. The intensification of feed production creates favorable conditions for the growth and development of not only cultivated plants, but also weeds, which consume up to 50% of the nutrients that are applied with mineral fertilizers [16]. Weeds are better adapted to unfavorable conditions, grow more intensively and often

predominate in the development of cultivated plants, especially in the juvenile period [17]. Both annual and two - and perennial weeds clog up crops.

Alfalfa damages many types of harmful insects. Damage, first of all, to generative organs is caused by the alfalfa thick-legged (*Bruchophagus roddi* Guss), alfalfa yellow seed eater, or tuchius (*Tuchius flavus* Beck), alfalfa scoop (*Chloridea viriplaca* Hfn, as well as the alfalfa root (nodule) weevil (*Sitona longulus* Gyll.), leaf alfalfa weevil, or fitonomus (*Fitonomus transsilvanicus* Petri) and others [18, 19].

III. OBJECT, SUBJECT AND METHODS OF RESEARCH

The object of research is the processes of growth, development and regularities of alfalfa seed crop formation under the influence of certain abiotic and biotic factors, in particular mowing.

The subject of the study is alfalfa for seed purposes, biological features, Southern chernozem, crop changes depending on slopes, economic and energy efficiency of technologies.

The research was conducted in the fields of the Nikolaev NAU in 2020-2021 and in the Vitovsky District (Southern Steppe). The terrain of the sections is flat. Soil - southern chernozem residual slightly saline heavy loamy. The depth of the humus horizon is 28-30 CM, its transition in some places up to 36 cm. The arable layer of 0-30 CM contains 2.8-3.0% humus. The acidity is close to neutral (pH 6.4–6.7). Ground water lies deeper than 20 meters. 100 g of soil contains an average of 1.2 mg of nitrates, 8.5 mg of mobile phosphorus and 18 mg of exchange potassium, wilting humidity-11.4%.

The average monthly air temperature in March 2021 (3.9°c) was significantly lower compared to 2020 (7.7°C). At the same time, this indicator of heat supply during the alfalfa growing season was almost the same in both years (in 2021, 0.1°C less compared to 2020. March-August was more saturated in 2021: 305.5 mm of precipitation fell at a rate of 422. significantly less of it was observed during 2020 (185.3 mm). Thus, the temperature conditions, amount and nature of precipitation distribution were more or less favorable for the normal growth and development of alfalfa plants. It should also be noted that the dry periods of the year coincided with critical periods in the phenology of crop plant development, which affected their productivity and depended on the period of mowing for seeds.

The following options were included in the scheme of the experiment to study the productivity of alfalfa testicles depending on the slope: 1. First mowing for seeds – control; 2. Intermediate mowing for seeds: first mowing for green food at the beginning of budding; 3. second mowing for seeds: mowing the 1st mowing for green food during budding-the beginning of flowering. The area of the sown area is 30, the accounting area is 10 m^2. Repeat four times. The cutting height when cutting alfalfa for green fodder is 8-10 CM.

The seed yield was taken into account by the method of continuous threshing of plots. Field and laboratory studies were performed according to the methods [22, 23], phenological observations of alfalfa growth and development-according to the method of V. V. Koperzhinsky (1950). The contamination of alfalfa crops was recorded on 4 fixed sites measuring 0.5 x 0.5 m (0.25 m^2) on each variant by quantitative and weight

method during mass weed germination and during alfalfa seed harvesting according to the method [23, 24]. In accounting mowing, 100 single swings of the net were used [19, 24]. The pest population of plants was determined by collecting insects on individual plants. For analysis, 10 plants were selected in 10 places along the diagonal of the field in different districts and farms of the region. The structure of the crop was determined by the method [23]. Economic efficiency was evaluated according to generally accepted indicators. considering typical performance standards. The variance analysis was carried out using the software and Information complex PIK "Agrostat" [25].

IV. RESULTS OF RESEARCH

4.1. Weather conditions and duration of alfalfa interphase periods depending on the slopes

It is well known that our region belongs to the zone of risky crop production due to unfavorable weather conditions for agriculture. Due to the biological characteristics of alfalfa, its seeds can be obtained from various slopes, reducing the negative impact of such conditions. The duration of interphase periods in alfalfa plants of the third year of life depended on weather conditions and on average for two years of research was as follows: the period of vegetation recovery–budding lasted for alfalfa of the first mowing for seeds 70 days; intermediate – 32, second – 27 days. The duration of the growing season reached 134, 86 and 81 days, respectively, for mowing (table 4.1).

Table 4.1.Duration of interphase periods in alfalfa Veselka depending on the bite for seed purposes (average for 2020-2021)

Slope on seeds	**Slope for seeds, the number of days from the resumption of spring vegetation (regrowth)**			**Number of days per period**	
	budding	**flowering**	**seed ripeness**	**budding-flowering**	**flowering -seed ripeness**
First	70	90	134	20	44
Medium	32	50	86	18	36
Second	27	44	81	17	37

The cold, prolonged spring of 2021 did not allow for the formation of a sufficient amount of aboveground biomass for the month of May, and alfalfa was first mowed down in experiments on May 18 for green fodder (a variant of intermediate mowing for seeds). On June 3, alfalfa was mowed down for green fodder in the areas of the "second mowing for seeds" option, while in 2020 – on May 14 and June 2, respectively. The duration of these periods of plant development depended on the temperature regime during the growing season of alfalfa of various slopes for seeds.

The lowest average daily air temperatures were observed during the initial period of development to the budding phase: 11.2-21.4 (table 4.2).

Table 4.2. Average daily air temperatures during the growth and development of alfalfa seeds, depending on its mowing for seeds, °C (average for 2020-2021)

Mowing on seeds	**Restoration of spring vegetation (regrowth)**		
	budding	**flowering**	**seed ripeness**
First	11,2	13,5	16,7
Medium	18,3	20,0	21,7
Second	21,4	22,2	22,6

A slightly higher temperature regime was typical for the period of renewal of vegetation–alfalfa flowering on all slopes. The average daily air temperatures during this period of growth and development of the crop ranged from 13.5 (first) to 20.0 (intermediate) and 22.2 (second mowing for seeds). During the growing season, this indicator was 16.7; 21.7; 22.6°C, respectively.

4.2. Formation of alfalfa seed yield of various slopes

It is known that a necessary condition for the growth and development of any living organism is water supply. Different weather conditions over the years, months, and slopes affected the linear growth of alfalfa. On average, for two years of research, the height of plants of the first mowing for seeds in the budding phase was at the level of 62, intermediate – 54 and second – 45 cm (table 4.3).

Table 4.3. Dynamics of linear growth of alfalfa plants in height depending on the snake bite for seed purposes, CM (average for 2009-2010)

Mowing on seeds	Phase		
	budding	flowering	seed ripeness
First	62	72	93
Medium	54	65	76
Second	45	56	68

During the seed ripeness period, the above indicators for the first, intermediate and second slopes were 93, 76, 68 cm, that is, they decreased depending on the slope and air temperatures during the growing season and providing plants with soil moisture and precipitation.

The results of observations show that the largest aboveground biomass is formed in the first class for seeds (3.25 t/ha), and in the second mowing this indicator is almost halved (table 4.4).

Table 4.4. Yield of dry aboveground alfalfa biomass of various slopes for the period of seed ripeness, (average for 2020-2021)

Mowing on seeds	Dry biomass, c/ha
First	32,5
Medium	24,6
Second	16,6
NIR05, c/ha	1,6

The difference in the formation of aboveground biomass is caused by different precipitation and temperature conditions over the years of research.

When growing alfalfa for seeds, you can also get an additional green mass to increase the overall productivity of the agrophytocenosis, replenish the feed base of livestock with feed protein, the deficit of which in Ukraine is about 25-30%.

The highest collection of green mass during mowing, on average for two years of research, was formed: for the second mowing for seeds – 129, and for the intermediate – 106 centners/ha. After harvesting the first mowing for seeds, the Otava for the strut did not grow back. Therefore, if the first mowing is left on the seeds, then

after it there is almost no satisfactory regrowth of alfalfa in non-irrigated conditions. In addition, it is known that alfalfa can no longer be mowed down if there are three to four weeks left before the first frost. During this period, the vital activity of plants slows down, the dormant period begins and they accumulate a supply of carbohydrates for breathing during the winter. It was found that the leafiness of plants is highest during the beginning of budding for all slopes (table 4.5).

Table 4.5. Leafiness of alfalfa plants of various slopes on seeds (average for 2020-2021)

Slope	Leafiness of plants (%) in the period		
	beginning of budding	beginning of flowering	end of flowering
First	42,6	39,7	27,8
Medium	40,5	37,8	26,6
Second	38,4	33,4	26,2

With intermediate mowing, the mass of leaves in aboveground biomass during the two years of research was lower compared to the first mowing. Even lower at the beginning of budding was leafiness at the second mowing and averaged 38.4%. At the beginning of alfalfa flowering, this indicator decreased for all mowing, but the pattern between them was the same as during the beginning of budding: the highest percentage of leaves in biomass for the first mowing and its gradual decrease for the intermediate, and its smallest value – for the second mowing for seeds. Significantly less leaves are contained in the aboveground mass of agrophytocenosis at the end of flowering for all slopes. Therefore, during the period of harvesting alfalfa for green mass, it is necessary to prevent the loss of leaves, as the most valuable part of plants.

4.3. Dynamics of pest populations in alfalfa crops

One of the reasons for the decline in seed yield is the large number of pests. Of the total number of 130-140 species of alfalfa phytophagous insects registered in Ukraine, 30-50 of them reproduce en masse and are dangerous for this crop [19, 26], and the seed yield decreases by 20-30, and sometimes by 50%.

In this work, which was carried out in 2020-2021, considerable attention is paid to determining the species composition of alfalfa phytophages.

Significant damage to crops is caused by nodule weevils. At the first mowing, their density at the beginning of the growing season reached 2.4, while at the second – only 1.2 copies/100 P.s.

Alfalfa root (nodule) weevil beetles overwinter in the upper layer of soil under plant remains. Alfalfa is damaged by both beetles and larvae. The economic threshold of harmfulness (hereinafter referred to as EPH) is 5-8 individuals/m^2. The greatest number of them was observed during the budding and flowering period of alfalfa and exceeded the EPH, especially during the first mowing for seeds. The larvae feed on the roots and bulbs that are on it.

One of the main harmful and widespread phytophages in our region is the Alfalfa bug (*Adelphocoris lineolatus* Goeze), which develops in 1-3 generations.

Alfalfa bedbug egg laying ends in September. Eggs overwinter in the shoots of perennial grasses (table 4.6).

Table 4.6. Specific structure of pest populations in different periods of development alfalfa depending on its mowing for seeds (average for 2020-2021)

Pests	Of the total number (%) within the time frame for determining			
	spring (post-autumn) regrowth	mass budding	mass flowering	mowing ripeness seeds
1st slope				
Nodule weevils	50,0	41,7	32,8	6,0
Phytonomus	21,7	26,9	26,3	18,8
Alfalfa bug	28,3	31,4	37,6	61,8
Others	0,0	0,0	3,6	13,4
Total	100,0	100,0	100,0	100,0
2nd slope				
Nodule weevils	76,9	22,0	21,5	17,7
Phytonomus	0,0	10,2	14,6	7,0
Alfalfa bug	0,0	55,1	48,7	61,7
Others	23,1	12,7	15,1	13,6
Total	100,0	100,0	100,0	100,0

One of the main harmful and widespread phytophages in our region is the Alfalfa bug (Adelphocoris lineolatus Goeze), which develops in 1-3 generations. Alfalfa bedbug egg laying ends in September. Eggs overwinter in the shoots of perennial grasses. The number of alfalfa bedbugs in the spring during the Alfalfa regrowth period, on average for 2020-2021, according to the general quantitative accounting of various types of seed pests, was 28.3% at the first mowing, and at the second - in the initial period of plant growth, it was not observed.

It is also advisable to provide data on the population of alfalfa crops with entomophages (table. 4.7). On average, over three years of observations, the number of these beneficial insects was always higher in the alfalfa flowering phase with the first mowing for seeds – 14 individuals/100 P. S., while in the second mowing – in the budding phase. Given the significantly higher number of phytophages in the first class, the ratio between predators and their victims was different. Thus, during the budding period, the ratio of entomophages to pests was 1:2.3 in the first slope, 1:2.8 in the second. A large difference between the first and second mowing in the ratio between entomophages and phytophages occurred during the mass flowering phase – 1:3.0 and 1:5.1, respectively.

Table 4.7. Ratio of the number of pests and entomophages in alfalfa crops in different periods of its development, depending on the slope (average for 2020-2021)

Phases of growth	First slope			Second slope		
	pests	entomophages	entomophages : pests	pests	entomophages	entomophages : pests
Regrowth in spring	4,6	7	1:0,7	1,3	0	-
Budding	22,3	9,7	1:2,3	36,3	13	1:2,8
Mass flowering	41,8	14	1:3,0	47,8	9,3	1:5,1
Mowing ripeness seeds	33,5	9,7	1:3,5	24,3	4,3	1:5,7

During the seed ripeness period, this ratio was 1:3.5 – in the first mowing and 1:5.7 – in the second mowing. So, a significant role in the formation of seed yield is played by the harmfulness of phytophages and the population of crops with entomophages and pollinating insects. It is necessary to note a significant decrease in beneficial entomophagous insects in recent years, which is explained not only by unfavorable weather conditions for their existence in nature, but also by the deterioration of the environment. Mowing significantly reduces the growing season of alfalfa and, consequently, the period of insect harm. It was found that intermediate mowing is more environmentally friendly compared to the first: alfalfa plants of intermediate mowing were treated with insecticides only 1-2 times, while agrocenoses of the first mowing had to be sprayed against pests 4-5 times during the growing season. It should be noted that in the first mowing (control), 2.53% of seeds were damaged by pests, in the intermediate – 1.89% and the least (1.57%) – in the second mowing.

4.4. Contamination of alfalfa crops of various slopes

When growing alfalfa seeds in coverless crops, it is characteristic that agrophytocenoses are clogged with weeds to a high degree and if certain measures are not followed to regulate undesirable plants to an economically imperceptible level, alfalfa plants form a low yield of both aboveground mass and seeds.

The highest density of weeds (12.5 copies)/m^2) was formed during the growing season of alfalfa seeds of the third year of life of the first mowing. A significant decrease in crop contamination compared to the first mowing was observed with intermediate and second alfalfa mowing for seeds: 9.0 and 7.2 PCs./m^2, respectively. Between the intermediate and second mowing, the difference in the number of weeds was insignificant. It was found that the biomass of weeds, when leaving the first mowing of alfalfa for seed purposes, in the raw mass for the period of seed ripeness reached 645, and in the air-dry – 216 g/m^2. With an intermediate slope, these indicators decreased to 219 and 73 g/m^2, respectively, or almost 3 times compared to the first one (table. 4.8).

Table 4.8. Contamination of alfalfa crops during seed ripeness depending on the slope (average for 2020-2021)

Slope	Number of weeds, PCs./m^2	Weed biomass, g/m^2	
		raw	air-dry
First	12,5	645	216
Medium	9,0	219	73
Second	7,2	151	68

Even less weed component is formed in the agrophytocenosis during the second mowing of seeds – 151 g/m^2 of raw, or 68 g/m^2 of dry matter, which is 4-6 times less than in the first mowing. As you know, the harmfulness of weeds is manifested in the fact that they absorb a significant amount of moisture and nutrients.

It was found that at the first mowing, weeds remove 40.8 kg/ha of nitrogen DW, 3.5 – phosphorus, 41.3 – potassium and 9.9 kg/ha of calcium DW from the soil (table. 4.9).

Table 4.9. Absorption of nutrients by weeds depending on alfalfa mowing for seeds (average for 2020-2021)

Slope	Plant weight, g/m^2	Content in 1 kg of dry matter of weeds, G *				Absorption of elements nutrition, kg/ha			
		N	P_2O_5	K_2O	Ca	N	P_2O_5	K_2O	Ca
The first - control	216	18,9	1,6	19,1	4,6	40,8	3,5	41,3	9,9
Medium	73	18,9	1,6	19,1	4,6	13,8	1,2	13,9	3,4
Second	68	18,9	1,6	19,1	4,6	12,9	1,1	13,0	3,1

Note. * according to the data [27].

During intermediate mowing, weeds removed 3 times less nutrients from the soil. Even less harm is caused by these undesirable neighbors by the agrophytocenosis of the second mowing of alfalfa for seed purposes.

4.5. Influence of slopes on alfalfa seed yield and yield structure

The main indicator that characterizes the feasibility of an agricultural measure is crop yield. According to the law of minimum (J. Liebig), biotic potential, ie viability, productivity of the organism, is limited by those of environmental factors that are at a minimum, although other conditions are favorable.

Under very arid conditions in 2020, the highest seed yield was formed by alfalfa of intermediate slope - 2.45 c/ha, the lowest - 1.86, for the first. A similar pattern was observed in alfalfa crops in 2021, but the productivity of seed crops was much higher. Yields for the technology, which included intermediate mowing for seeds, reached 2.94 at a control value of 2.48 c/ha (Table 4.0).

Table 4.10. Alfalfa seed yield depending on bite, c/ha

Slope	2020	2021	Average	Increase to control
First mowing for seeds - control	1,86	2,68	2,27	0
Intermediate mowing for seeds: mowing alfalfa on the railway station on the beginning of budding	2,45	3,29	2,87	0,60
Second mowing for seeds: mowing the first slope on the railway station in budding period – the beginning of flowering	1,99	2,78	2,36	0,07
NIR_{05}, c/ha	0,11	0,32	0,18	-

The low productivity of alfalfa in 2020 was due to less precipitation during the growing season and high temperatures during the summer months of vegetation. On average, over the years of research, the largest amount of alfalfa seed material of intermediate mowing was also obtained – 2.87 centners/ha. At the first mowing for seeds, the yield was 2.27, and at the second – 2.36 c/ha with the smallest significant difference of 0.18 c/ha. It is determined that the seed productivity of the crop in our zone strongly depends on the amount of precipitation in the period from flowering to

maturation of alfalfa seeds: for the first mowing, the correlation coefficient r = 0.77, for the intermediate one – 0.75, and for the second – 0.84.

The results of the analysis of sheaf samples indicate a positive effect of intermediate mowing on the formation of individual elements of the crop structure. It was found that when mowing the first slope on the green mass at the beginning of budding and obtaining seeds from the intermediate slope, 111 generative stems/m^2 were formed with this alfalfa cultivation option (table 4.11).

At the control sowing, without preliminary mowing of plants for green fodder, there were 98 seeds for the period of seed collection. generative stems/m^2. So, with an intermediate slope, they were formed into 13 PCs./ m^2, or 13.3% more than at the first mowing of alfalfa for seeds. According to the analysis of sheaf samples of seed herbage, it was determined that alfalfa of intermediate mowing formed 4.6% more brushes on 1 stalk and 20.2% more full-fledged seeds in one brush compared to the control.

Table 4.11. Indicators of alfalfa crop structure depending on the seed bite (average for 2020-2021)

Slope	**Quantity, pcs.**						
	productive stems per 1 m^2	**brushes on 1 stalk**	**in one brush**				**full-fledged seeds per 100 beans**
			beans	**seeds**			
				total	**including a full-fledged one**		
					pcs.	**%**	
First - control	98	19,7	6,6	15,0	9,4	62,7	142
Medium	111	20,6	6,4	17,8	11,3	63,5	177
Second	104	19,1	6,8	14,6	9,5	65,1	140

In total, 63.5% of full – fledged seeds were counted for intermediate mowing, while only 62.7% were counted for the first mowing.

An important indicator of the productivity of seed crops is the number of full-fledged seeds per 100 beans; 177 units were formed along the intermediate slope, while for the first-142 pcs.; full-weight seeds per 100 beans, or 24.6% less.

There was no significant difference between the first and intermediate mowing by weight of 1000 seeds (2.11 and 2.13 g, respectively).

4.6. Economic assessment of alfalfa seed cultivation technologies depending on the slope

The analysis of economic efficiency indicators allows us to state that under non-irrigated conditions of crop cultivation, intermediate mowing for seeds has an advantage, compared to the first and second.

Although the total cost of this mowing increases from 9063 to 9845 UAH/ha (by 8.6%) compared to the first, at the same time the cost of 1 centner of seeds decreases by 14.1%, which is explained by a decrease in the cost of protecting crops from pests. Net profit under the intermediate slope increases by 85.6% compared to the control,

which received only UAH 13,637/ha, and the level of profitability increases from 150.5 to 257.0% (by 70.8%) or by 106.5 percentage points (table 4.12).

The performance indicators of the second slope are slightly worse than those of the intermediate one, but they are significantly higher than those of the first slope.

Table 4.12. Economic assessment of alfalfa seed cultivation technologies depending on the slope (average for 2020-2021)

Indicators	Slope			± to slope control, %	
	the first - control	medium	second	medium	second
Seed yield [1], c/ha	2,27	2,87	2,36	26,4	4,0
Green mass Yield [2], c/ha	0	129,0	136,0	-	-
Cost of seed harvest, UAH/ha	22700	28700	23600	26,4	4,0
Cost of harvesting green mass UAH/ha	0	6450	6800	-	-
Cost of the entire crop, UAH/ha	22700	35150	30400	54,8	33,9
Total expenses per 1 ha, UAH	9063	9845	9826	8,6	8,4
Cost of 1 Centner of seeds, UAH	3993	3430	4164	-14,1	10,6
Net profit, UAH/ha	13637	25305	20574	85,6	50,9
Profitability level, %	150,5	257,0	209,4	70,8	39,1

Notes: 1.the cost of 1 Centner of seeds is 10000 UAH.
2.the cost of 1 Centner of green mass is 50 UAH.

Thus, the profitability of growing alfalfa for the second mowing is 209.4%, which is 39.1% higher compared to the first, but it is slightly less compared to the intermediate mowing for seeds (257.0%).

CONCLUSIONS

Based on studies conducted during 2020-2021 on the impact of various slopes and weather conditions on alfalfa seed productivity, the following conclusions can be drawn:

1. Productivity of alfalfa crops significantly depends on abiotic factors, especially weather conditions. Thus, under unfavorable very arid conditions in 2020, the yield of alfalfa seeds in the third year of life in the control (the first mowing of seeds) was 1.86, and for intermediate mowing - 2.45 c/ha. In the more favorable 2021 (arid conditions) the yield was much higher: 2.68 and 3.29 c/ha of conditioned seeds, respectively.

2. Seed productivity increases by 0.60 c/ha (on average for two years of research) or by 26.4% compared to the control (2.27 c/ha) for the technology that includes intermediate mowing. At the same time it is possible to receive in addition at mowing at the beginning of a budding phase of 129,0 c/ha of green weight for providing animals with high-quality forage.

3. During the first mowing in the agrophytocenosis there are, on average, 12.5 specimens/m^2 of weeds, which during the vegetation period of seed alfalfa of the third year of life remove from the soil 40.8 kg/ha of nitrogen, 3.5 - phosphorus, 41.3 -

potassium and 9.9 kg/ha d.r. calcium, and at the intermediate slope the density of weeds is much lower (9 pcs./m^2), which absorb from the soil almost 3 times less nutrients.

4. Net profit on the intermediate slope increases by 85.6% compared to the control, which received only 13637.0 UAH/ha, and the level of profitability increases from 150.5 to 257.0%, or 70.8 percent. The cost of 1 quintal of seed for this slope is 14.1% less than the first mowing for seeds.

5. Growing alfalfa seeds on an intermediate slope is more environmentally friendly, due to the reduction in the number of pests in the agrophytocenosis, and hence the need for insecticides, compared to the first mowing, which is proposed for implementation in production.

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GEOINFORMATION MODELING OF RADIOACTIVE CONTAMINATION OF TERRITORIES ON THE EXAMPLE OF THE MINES OF THE EASTERN MINING AND PROCESSING PLANT

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***Annotation**: using geoinformation technologies, modeling of the distribution of natural radionuclides for soils and plants based on the actual results of measurements of the volume activity of isotopes ^{234}U, ^{238}U, ^{210}Po, ^{210}Pb, ^{226}Ra. With usage of the methods of mathematical statistics was found correlation between soil / vegetation and soil / root vegetable. The identified dependencies and constructed maps will be useful for assessing the safety of the population within the source of radioactive contamination and the consumption of agricultural products by the local population.*

***Key words:** radionuclides of natural origin, volumetric activity, soil, vegetation, root vegetable, interpolation, modeling, correlation.*

I. PREAMBLE

The problem of radioactive pollution both separate regions in Ukraine and the territory of the whole country generally stays on the front burner during last few decades, which is connected not only to a major accident of Chernobyl Atomic Power Station, but also to utilization of nuclear weapon and to utilization of atomic-industry waste. Uranium ore deposits have been developed and enriched in some regions of Ukraine since the middle of the twentieth century, accompanied by the accumulation of significant amounts of radioactive waste that dangerously affect the ecosystem of the surrounding areas, including the health of the population.

One of such radiation-contaminated regions of Ukraine is the Kirovohrad region, and in particular the outskirts of Kropyvnytskyi, where since 1951. carries out economic activity of the State Enterprise "Eastern Mining and Processing Plant", which develops uranium ore deposits and performs the full range of works on mining and radiometric enrichment of uranium ores [1].

II. ANALYTICAL REVIEW OF SCIENTIFIC LITERATURE

2.1. Natural radionuclides and their threat to people

The main part of the radiation the entire population of the Earth receives from natural sources of radiation: natural radionuclides contained in the earth's crust, building materials, air, food, and water formed in the atmosphere under the action of cosmic rays. On average, they determine more than 80% of the annual effective dose received by the population, mainly due to internal radiation [2-4].

The main radioactive isotopes found in the Earth's rocks are potassium and rubidium and members of two radioactive families, originating from uranium and thorium, respectively, long-lived isotopes that are part of the Earth's rocks.

Much of the effective dose of radiation that a person receives from natural sources of radiation is formed by radionuclides of a number of uranium contained in the soil. Additional impact have natural radionuclides with which people deal because of anthropogenic activity. Process of increasing an amount of natural radionuclides and regular pollutions of environment occur already at the stages of extraction and enrichment of mineral resources. At mining and concentrating plants of neuraunian industries, the sources of constant inflow of aerosols of natural radionuclides into the atmosphere and natural radionuclides into surface and groundwater are dumps of overburden and industrial waste, as well as tailings of concentrators [2]. As a rule, the ratio of uranium radionuclides in the emissions of these enterprises is close to equal.

Natural radionuclides are leached from rocks and pass into surface and groundwater, which with surface runoff accumulate them on the surface of agricultural soils. Mining speeds up this process, so in the extraction and processing of ore with a high content of natural radionuclides, workers in mining companies and the public may be exposed to radiation.

Natural radionuclides are toxic because they are not destroyed in soil and water but migrate in the trophic chain: "soil → plant (feed) → animal → products → humans." But because the bulk of radionuclides are in the root layer of the soil, and their movement into deeper horizons is very slow, this leads to the entry of radionuclides into crop products, and then to animals and humans. As a result, there are hidden negative changes in the overall metabolism in humans [5].

Consumption of radionuclide-contaminated products leads to additional internal exposure of the human body above natural levels. However, their content in food and drinking water should not exceed the accepted annual effective dose of internal radiation up to 1 mSv/year [6]. In areas with contamination levels where agricultural activities are possible, the radiation dose does not exceed the established limit, but a significant proportion of the population is exposed to low regular doses, which increases the likelihood of long-term radiobiological effects (tumors, mutations, decreased immunity) [5].

2.2. Statistical and geostatistical methods of modeling

Statistical modeling methods include correlation analysis, which is performed automatically by using an feature of computer program Microsoft Excel. Correlation analysis is a method of studying the interdependence of features in the general population, which are random variables with a normal nature of the distribution [7]. The main requirements for the application of correlation analysis are a sufficient number of observations, a set of factor and performance indicators, as well as their quantitative measurement and reflection in information sources.

The main tasks of correlation analysis are to determine the form of connection, measure the density (strength) of connection and identify the influence of factors on the performance trait.

The formation of a correlation model involves determining whether it will be a simple (pair) correlation (resultant feature with one factor) or multiple (performance feature and several factors). Conversely, the nature of the relationship correlation models can be linear (rectilinear, with inverse linear dependence) or nonlinear (curvilinear) [7].

Geostatistical modeling methods are used to study spatial data and construct surfaces using advanced statistical methods. Geostatistical Analyst is an ArcGIS software module that has a powerful set of tools that can be used to create a continuous surface or map based on measurements stored in a point vector or raster layer that facilitate visualization, analysis and understanding of spatial phenomena [8].

The Geostatistical Analyst module provides access to several interpolation methods, which are divided into two main types: determination and geostatistical. Deterministic interpolation methods create surfaces from measured points based on either the degree of similarity (inverse weighted distances) or smoothing levels (radial basis functions). Geostatistical methods of interpolation use the statistical properties of the measured points. Geostatistical methods measure the spatial autocorrelation at the measured points and calculate the spatial configuration of the reference points around the interpolated location [8].

III. OBJECT, SUBJECT AND METHODS OF RESEARCH

The aim of our research was to model the territorial distribution and statistical assessment of migration by the trophic chain of natural radionuclides released into the environment as a result of uranium ore mining.

There were the following tasks of the research *to achieve the mentioned goal*:

- to perform an analysis of the environmental components' state of pollution within the object of the study;
- to develop models of territorial distribution of natural radionuclides in those soils and plants which were the object of study, using tools of geoinformation modeling;
- to carry out the mathematical modeling of migration of natural radionuclides between the components of environment;
- to substantiate the need to increase the level of radioecological safety of the population, which lives within the existing uranium mines.

The object of research – processes of migration and territorial distribution of natural radionuclides in the environment.

The subject of research – the level of radiation pollution of the environment and methods of modeling the migration of natural radionuclides between components of the environment.

Statistical, geoinformation and experimental *methods of research* were used in the work. Interpolation of the results of volumetric activity of natural radionuclides in the components of the environment and the development of spatial models of their territorial distribution were carried out using the software product ArcGIS; statistical processing of modeling results, development of mathematical models of migration of natural radionuclides between components of the environment were carried out using applications of computer programs Microsoft Excel, ArcGIS Geostatistical Analyst.

The scientific novelty of the achieved results is the following:

- for the first time ever the choice of the method of geostatistical modeling of territorial distribution of volumetric activity of natural radionuclides in soils and plants was substantiated, which allows to model the values of probabilistic indicators of radioecological pollution in the absence of a sufficient array of initial actual research results;

- the methodology of mathematical modeling of migration of natural radionuclides between soil and parts of plants have been further developed, which will take into account the specifics of migration of natural radionuclides in the trophic chain and determine the level of radioecological danger for the environment, the final link of which is the population living within the industrial facilities.

Practical significance of the obtained results:

1. For the first time ever, the radioecological situation around the industrial sites of the "Pivdenna" and "Pivnichna" mines of the Eastern Mining and Processing Plant State Enterprise and the territory of the nearest settlements falling within the area of influence of these mines and dumps of uranium enrichment was simulated. The developed territorial models allow to obtain stochastic data for their further analytical processing and to visually display areas of radioecological danger.
2. The need to increase the level of radioecological safety of the population living within the existing sources of radiation pollution, which means the safety of homestead agriculture of local residents, was substantiated.
3. The results of scientific work were introduced into the educational process of Dnipro State Technical University during lectures and practical classes in the discipline "Radioecology", "Fundamentals of GIS", "GIS in Ecology" for students who obtain higher education, whose specialty 101 - Ecology.

IV. RESULTS OF WORK

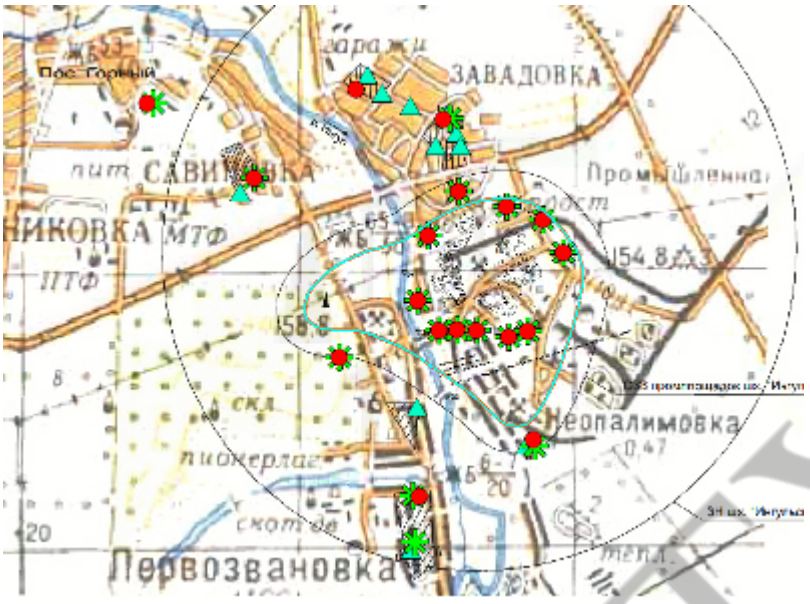
4.1. Characteristics of the object of study and the radioecological situation within it

The industrial sites of the mines "Pivdenna" and "Pivnichna" of the State Enterprise "Eastern Mining and Processing Plant" (Kropyvnytskyi) and the settlements of Pervozvanivka, Zavadivka, Neopalimivka, Sonyachnyi, Hirskyi (Kirovograd region) were selected as the object of this study, which are in the area of influence of these mines and dumps of waste rocks after enrichment of uranium ores.

Samples of soil, aerial parts of plants (perennial grasses) and roots of agricultural plants (potatoes, beets, carrots) were analyzed to assess the volume activity of natural radionuclides (^{234}U, ^{238}U, ^{210}Po, ^{210}Pb, ^{226}Ra). 18 samples of soil and plants were analyzed (10 of which were taken from the territory of the sanitary protection zone of the enterprise), as well as 10 samples of root crops grown in the homesteads of local residents. Sampling sites are shown on the map in Figure 1.

To compare the obtained results, similar samples were analyzed at two background points located within a distance of 30 kilometers from the industrial sites of the mines (the villages of Velyka Vyska and Subotka).

The results of the measurements indicate fluctuations in the volume activity of natural radionuclides in the soils around the dumps and the industrial site of the mines. Also, the soils within the ore-concentrating plant on the industrial site of the Pivnichna mine differ by two orders of magnitude, exceeding the figures around the dumps located within the sanitary protection zone of the mines. Within the dumps, the radioecological situation is characterized by twice the background indicators of the volumetric activity of a number of natural radionuclides.



The boundaries of the industrial site of mines
Coordinates of soil sampling
Sampling points of the aboveground part of plants
Sampling points for root crops of agricultural plants

Fig. 1. Map of the research object and sampling sites

Within of the object of research at the place of residence of critical groups of the population living in the nearest settlements, for all observation points a significant excess of background values was recorded for:

- isotopes of uranium, lead and polonium within the settlements of Neopalimivka, Pervozvanivka, located to the south almost within the sanitary protection zone of the industrial site of the mines "Pivdenna" and "Pivnichna";
- radium isotopes within the settlements of Zavadivka north of the sanitary protection zone of the industrial site of the Pivdenna and Pivnichna mines.

Fluctuations in the measurement of the volumetric activity of natural radionuclides in the treated soil samples are shown in figure the Annex 1.

The highest volume activity in comparison with the background values is possessed by samples of plants, which were taken within the dumps for all studied natural radionuclides except lead. As can be seen from the figure in Annex 2, for all natural radionuclides, the background values were exceeded.

The results of measurements of the volumetric activity of natural radionuclides in samples of root crops grown in the habitats of the population are shown in the figure in Annex 3. The figure shows that potato samples have the highest volume activity compared to beet samples, and twice the excess is observed for isotopes of uranium, polonium and lead, in particular for the village of Pervozvanivka. There is a reverse trend for the same radionuclides for the village Zavadivka.

4.2. Modeling of territorial distribution of natural radionuclides in environmental components using GIS

As shown on the map (Fig. 1), observation points for the studied components of the environment are not always territorially superimposed, which makes it impossible

to establish a correlation between them and predict the territorial distribution of the studied natural radionuclides. The task of forecasting is also complicated by the small amount of initial data with a significant difference in the obtained results of the volumetric activity of natural radionuclides (dumps - sanitary protection zone - observation zone – background radiation).

Given the high population density in the observation area, as shown in the map in Figure 1, with insufficient territorial and quantitative sampling coverage, it is proposed to use the basic set of ArcGIS software interpolation tools (Natural neighbor interpolation, Inverse distance weighted (IDW)). Kriging, Spline) to model the surfaces of the territorial distribution of natural radionuclides within the study area.

The selection of simulation methods with different settings was carried out experimentally, however, the most optimal way of interpolation of the specified data in the conditions of initial parameters is the method Natural neighbor interpolation. The surface obtained in this way makes it possible to smooth the peak values of the indicators and determines a wide gradient that is more similar to the natural distribution, while the background values of the indicators also have a significant impact on surface modeling.

Figure 2 shows the result of surface modeling that interpolates the value of ^{234}U volume activity in soil, plants, and roots.

The constructed surfaces allowed to model the values of volumetric activity of natural radionuclides in soils and parts of plants for any point of the study area and to visualize the territorial distribution of radioactive contamination.

According to the made modelling maps, which interpolate the volume activity of natural radionuclides in the soil, the epicenter of pollution is observed within the waste dumps, located within the southwestern border of the sanitary protection zone of the mine site and more than 10 times higher than the background value for uranium and radium, up to 20 times for isotopes of lead and polonium within the village Pervozvanivka.

Simulated indicators of volumetric activity of natural radionuclides in the aboveground part of plants indicate a tenfold excess of background values within the sanitary protection zone of the industrial site of mines; twice the background values of uranium and lead isotopes were found within the settlements of Gorskiy, Neopalimivka and village Pervozvanivka, respectively.

It was determined that the epicenter of radioactive contamination of rootstocks of agricultural plants is observed within the settlements of Neopalimivka and Pervozvanivka with exceeding background values by 2-2.5 times, and zones of lead isotope contamination with twice exceeding background values extend to Golsky and Sonachnii settlements.

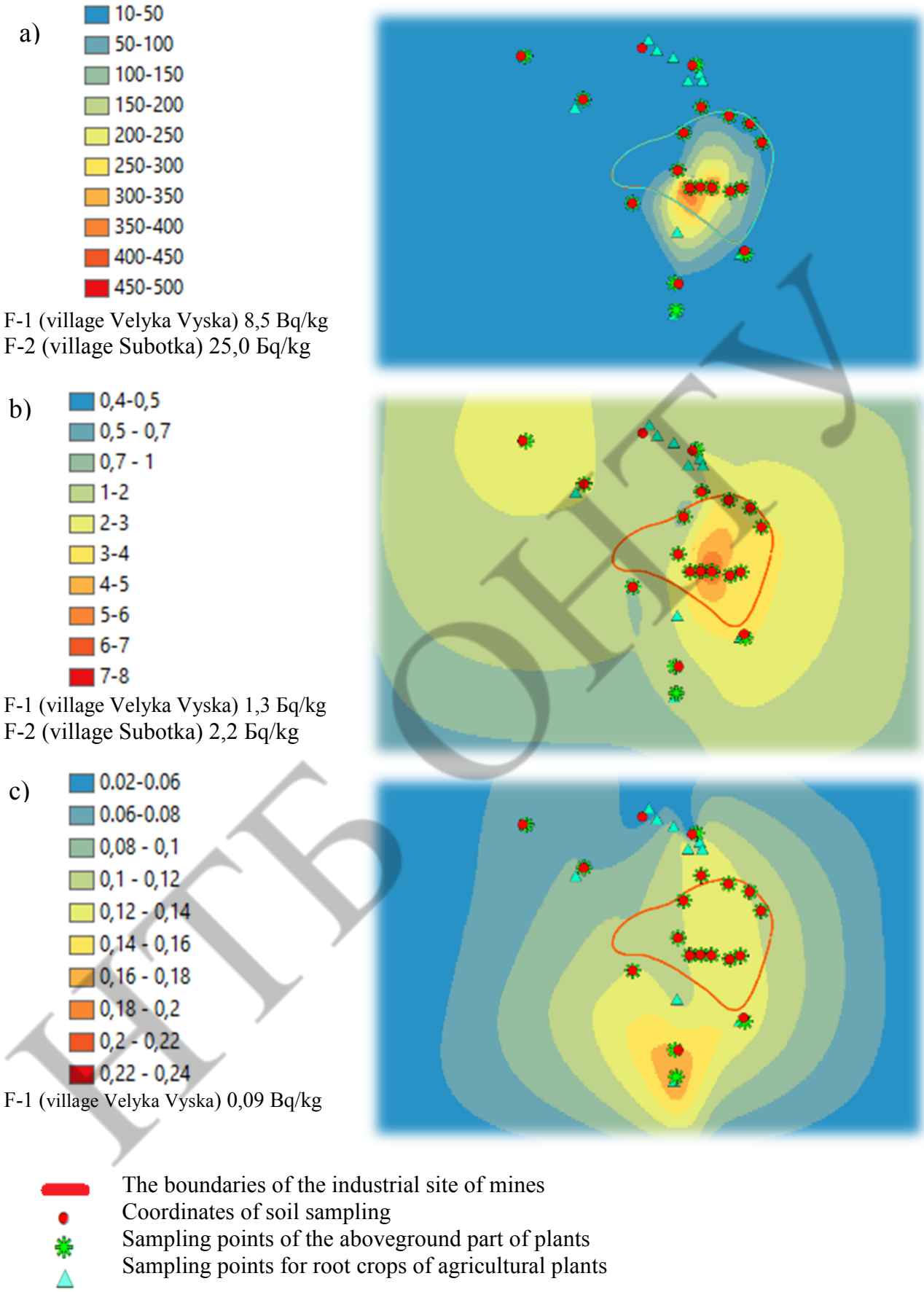
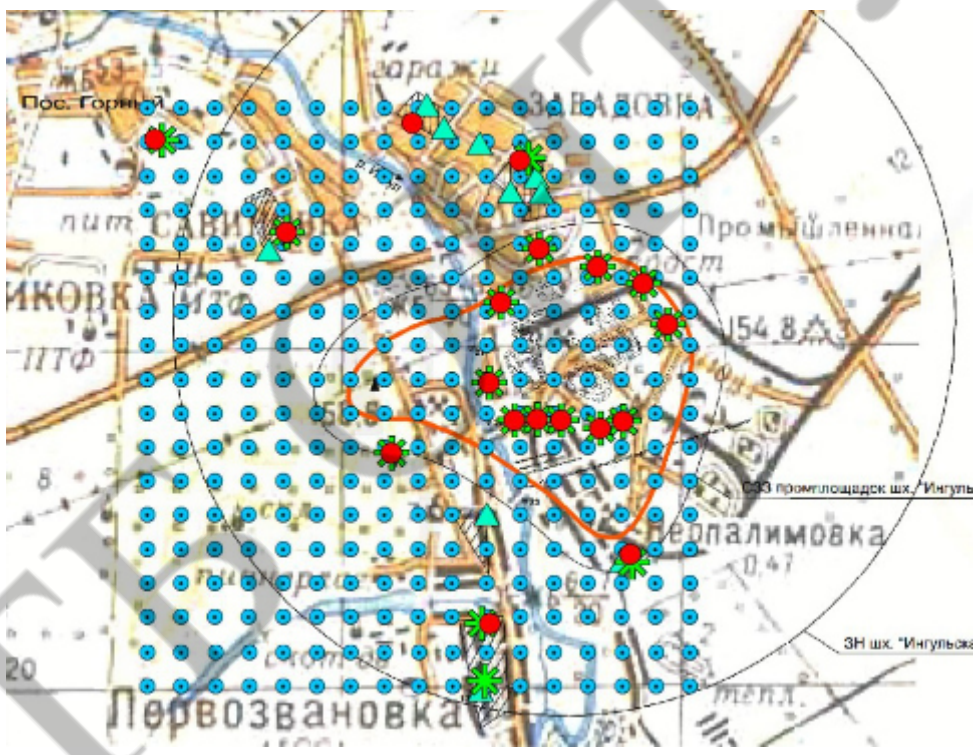


Fig. 2. Map of surface modeling by the method of Natural neighbor interpolation, which interpolates the results of bulk activity on the example of ^{234}U, Bq / kg: a) – in soil; b) – in plants; c) – in root plants

Developed electronic maps of radionuclide distribution will allow a comprehensive approach to assessing the risk of living within the source of radioactive contamination and modeling the spread of radioactive contamination in agricultural plants based on their use by local populations, develop recommendations for agricultural activities within the territory.

4.3. Mathematical modeling of migration of natural radionuclides between environmental components

Constructed surfaces shown in Fig. 2, allowed to simulate the volume activity of natural radionuclides for soils, plants, and roots at any point in the study area. By creating a uniform distribution of virtual points of study, the result of which is shown in Fig. 3, obtained the values of the volumetric activity of natural radionuclides for soils, plants, and roots at each of the 300 set points.



The boundaries of the industrial site of mines
Coordinates of soil sampling
Sampling points of the aboveground part of plants
Sampling points for root crops of agricultural plants
Virtual points

Fig. 3. Map of creating a uniform distribution of virtual research points

It should be noted that the territorial coordinates of the simulated points for all components of the environment coincide and are therefore available to determine the pairwise correlation.

Based on the methods of mathematical statistics using computer programs Microsoft Excel and Geostatistical Analyst, correlations were established between the values of the volumetric activity of natural radionuclides, simulated for virtual points

in the soil and plant elements. The results of mathematical modeling on example ^{234}U using Microsoft Excel tools are shown in Figure 4 and using the Geostatistical Analyst toolkit - in Figure 5.

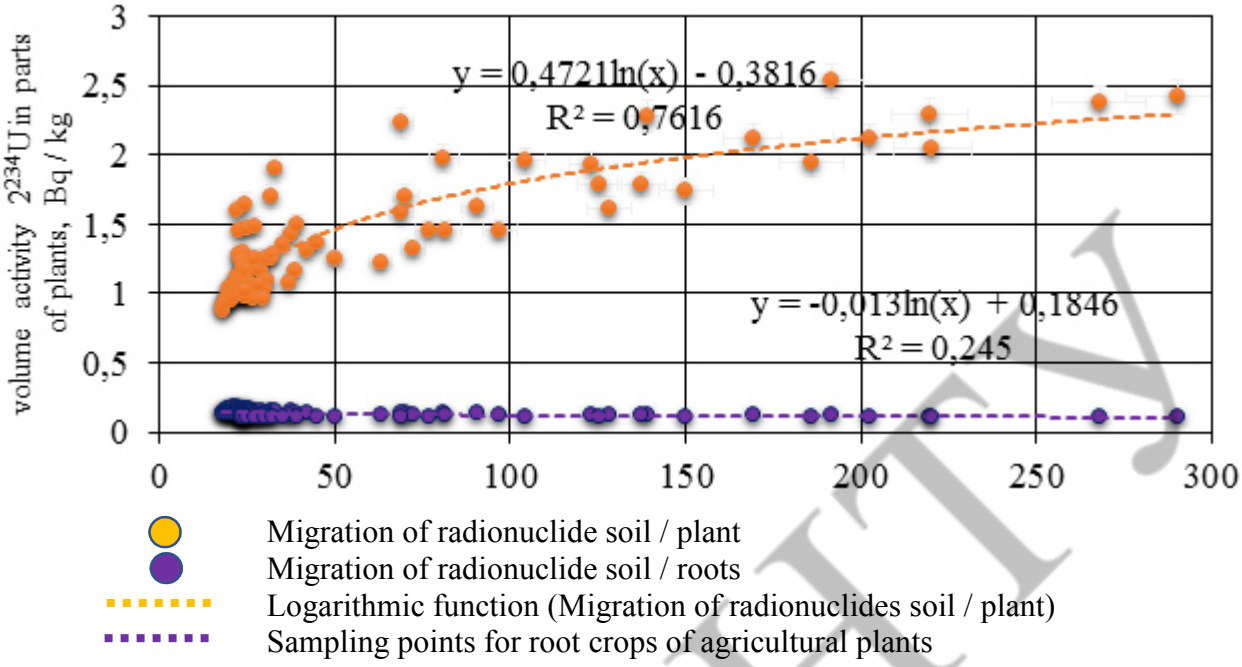


Fig. 4. Mathematical model that characterizes the probability of migration of natural radionuclides between environmental components on the example of ^{234}U, Bq / kg

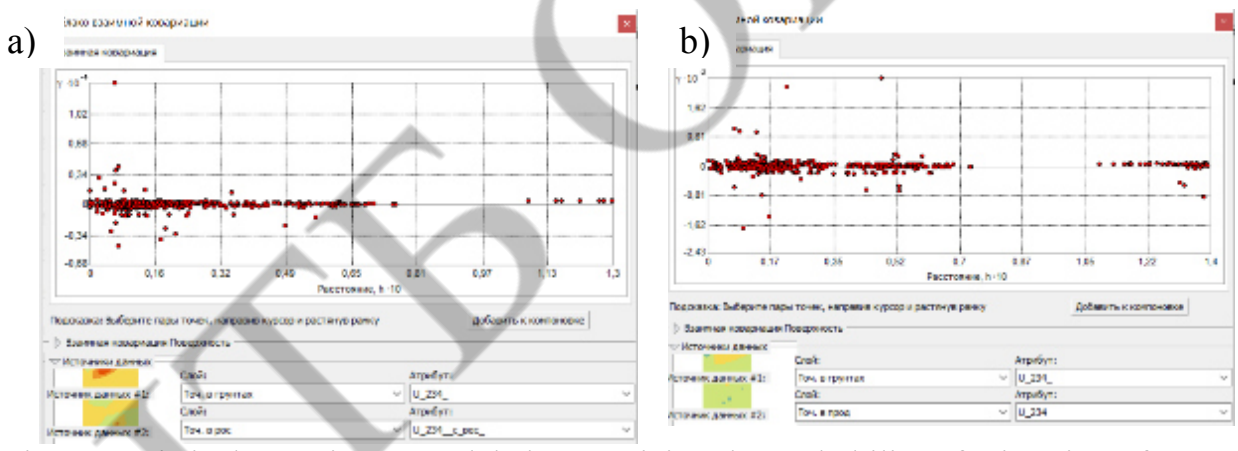


Fig. 5. Statistical covariance model characterizing the probability of migration of natural radionuclides between environmental components on the example of ^{234}U, Bq / kg: a) pair model Soil / Plants; b) pair model Soil / Root crops

These models show that the closest relationship is observed between the values of volumetric activity ^{234}U in soils and aboveground parts of plants, as indicated by the high correlation coefficient (R = 0.87) and high density of mutual covariance of the pair model Soil / Plants.

Models for all studied natural radionuclides were constructed in a similar way. The simulation results are shown in Table 1. The obtained pairwise correlation models indicate a high correlation (R = 0.78 ÷ 0.87) primarily of the logarithmic nature of such parameters as the value of the volume activity of natural radionuclides in soils and aboveground parts of plants in particular for uranium isotopes, as well as ^{210}Po and

^{226}Ra. For ^{210}Po, this dependence is obtained with a low coefficient of determination, which indicates the presence of other factors that become more important.

Table 1. Results of mathematical modeling of migration of natural radionuclides between soil and plants

Natural radionuclides	Soil / Plant	Soil / Roots
^{234}U	$y_1 = 0{,}4721\ln(x) - 0{,}3816$ $R^2 = 0{,}7616$	$y_2 = -0{,}013\ln(x) + 0{,}1846$ $R^2 = 0{,}245$
^{238}U	$y_1 = 0{,}4146\ln(x) - 0{,}3178$ $R^2 = 0{,}7298$	$y_2 = 0{,}0005x^2 - 0{,}0286x + 0{,}4324$ $R^2 = 0{,}3666$
^{210}Pb	$y_1 = -0{,}3312x^2 + 19{,}007x - 261{,}22$ $R^2 = 0{,}2658$	$y_2 = -0{,}0018x^2 + 0{,}1082x - 1{,}4305$ $R^2 = 0{,}295$
^{210}Po	$y_1 = 68{,}985e^{-0{,}144x}$ $R^2 = 0{,}6352$	$y_2 = 0{,}0067x^2 - 0{,}3033x + 3{,}4542$ $R^2 = 0{,}23$
^{226}Ra	$y_1 = 0{,}458\ln(x) - 0{,}2344$ $R^2 = 0{,}6055$	$y_2 = -0{,}0006x^2 + 0{,}0292x - 0{,}2709$ $R^2 = 0{,}5019$

Note: x is the value of the volume activity of natural radionuclides in soils
y_1 is the value of the volume activity of natural radionuclides in vegetation
y_2 is the value of the volume activity of natural radionuclides in root crops

Regarding the dependence of the volume activity of natural radionuclides in root crops on the indicators modeled for soil samples, a much lower correlation than in the previous case (R = 0.48 ÷ 0.71) was found to be mainly polynomial.

4.4. Justification of the obtained results

The obtained simulation results confirm the validity of the chosen method of modeling the migration of natural radionuclides by trophic chain, but certain parameters of mathematical models indicate a more likely accumulation in the surface layer of soil accessible to the root system of perennial grasses. soil horizons from the movement of pollutants, accumulating in their green mass a significant amount of natural radionuclides.

Based on the results obtained for the pair of parameters "Soil / Root crops", the movement of natural radionuclides into deeper soil horizons for these natural conditions is significantly slowed down, which leads to radionuclides entering crop products (roots) less actively than in aboveground green mass of plants.

The developed mathematical models of migration of natural radionuclides between soil and plants, given their high reliability, can be used to predict the levels of radioecological contamination of agricultural products grown by locals in their backyards.

Further calculations of the consumption of agricultural products contaminated with radionuclides grown in the study area will determine the risks of additional internal exposure of the human body. And taking into account possible trophic chains:

«Soil → roots → human»

«Soil → perennial grasses → animal → livestock products → human»

will provide recommendations on the norms of consumption of these agricultural products or the possibility of conducting agricultural activities within the territory in general, as regular exposure, although not significant doses, increases the likelihood of radiobiological effects in the local population.

V. CONCLUSIONS

1. The analysis of the state of pollution of environmental components within the industrial site of the mines "Pivdenna" and "Pivnichna" of the State Enterprise "Eastern Mining and Processing Plant" and the surrounding villages and recorded a significant excess of volumetric activity of natural radionuclides relative to background values. Plant elements for isotopes of uranium, lead and polonium within the settlements located south of the sanitary protection zone of the mine site, and radium isotopes - north of them.

2. Models of territorial distribution of natural radionuclides in soils and plants of the object of research have been developed, using the basic set of interpolation tools of ArcGIS software. It is established that the most optimal method of geospatial modeling is the method Natural neighbor interpolation, which provides the ability to smooth the peak values of indicators and determines a wide gradient taking into account the significant influence of background values of indicators. The constructed surfaces allowed to model the values of the volume activity of natural radionuclides in soils and parts of plants for any point of the study area. Visualized territorial distribution of indicators indicates the epicenter of radioactive contamination within waste heaps, territorially located within the sanitary protection zone of the mine site, 10-20 times higher than the background values of the studied natural radionuclides in soils within soils within 2-10 parts adjacent settlements.

3. Modeling of migration of natural radionuclides between environmental components by mathematical statistics using computer programs Microsoft Excel and Geostatistical Analyst and a close correlation between the values of volumetric activity of natural radionuclides in soil and aboveground plants, which confirms the reliability of the selected method of modeling the migration of natural radionuclides by the trophic chain. The obtained simulation results indicate a more probable accumulation of natural radionuclides in the surface layer of the soil, which slows down with deepening to the soil horizons available for root crops.

4. The necessity of increasing the level of radioecological safety of the population living within the existing uranium mines is substantiated. The danger is due to the migration of natural radionuclides through food chains, the final link of which is the population consuming home-grown agricultural products, which is a source of regular exposure to small doses, but increases the likelihood of radiobiological effects in the local population.

Approbation of research results.

The main scientific and practical results of the research were reported and received a positive assessment: International Scientific Symposium "Ecologist's Week" (Ukraine, Kamyanske, 2021); VI International Scientific and Practical Conference «Scientific community: interdisciplinary research» (Hamburg, German, 2022); 7th International

Youth Congress "Sustainable Development: Environmental Protection. Energy saving. Balanced nature management "(Ukraine, Lviv, 2022).

Publications. According to the research results, 3 printed works were published, including 1 article in a foreign edition, including:

- Kornienko O, Huba O Neposhivaylenko N, Soroka Y; "Assessment of the volumetric activity of natural radionuclides in natural waters within the activities of uranium mines" // Collection of abstracts of the international scientific symposium "Ecologist's Week - 2021", October 18-20, 2021 - Kamyanske: DDTU. - 2021.– P. 100-103.
- Natalia Neposhyvailenko, Oleksandr Korniienko, Oleksandr Huba; "Geoinformation modeling of radioactive pollution on the example of mines of Eastern mountain-concentrating plant" // VI International Scientific and Practical Conference «Scientific community: interdisciplinary research». January 26-28, 2022. - Hamburg, Germany: Busse Verlag GmbH, 2022. – C. 786-792.
- Kornienko O, Guba O Neposhivaylenko N; "Geoinformation modeling of radioactive contamination of territories on the example of the mines of the Eastern Mining and Processing Plant" // Collection of abstracts of the 7th International Youth Congress "Sustainable Development: Environmental Protection. Energy saving. Balanced Nature Management", February 10-11, 2022 - Lviv: Lviv Polytechnic National University. – 2022.

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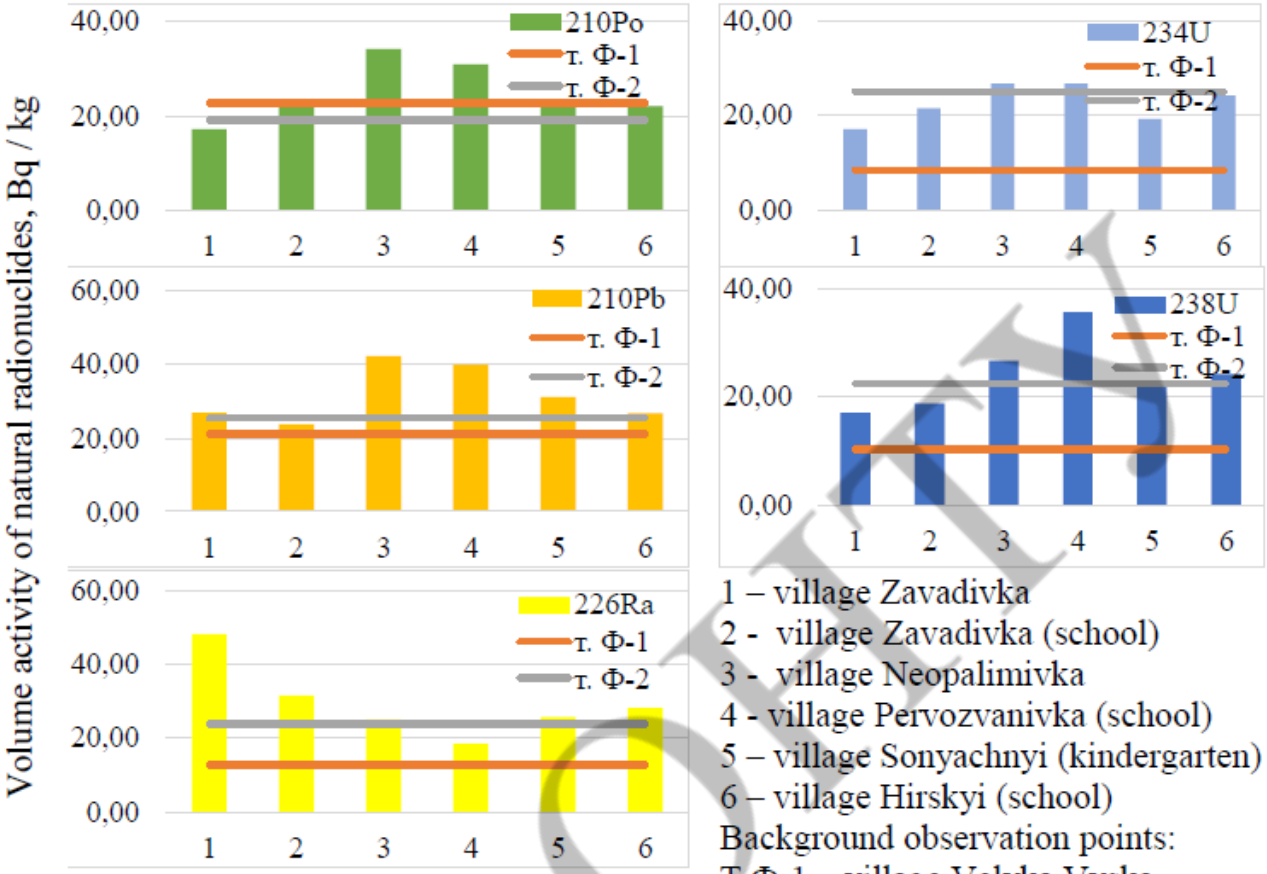
APPENDIX 1

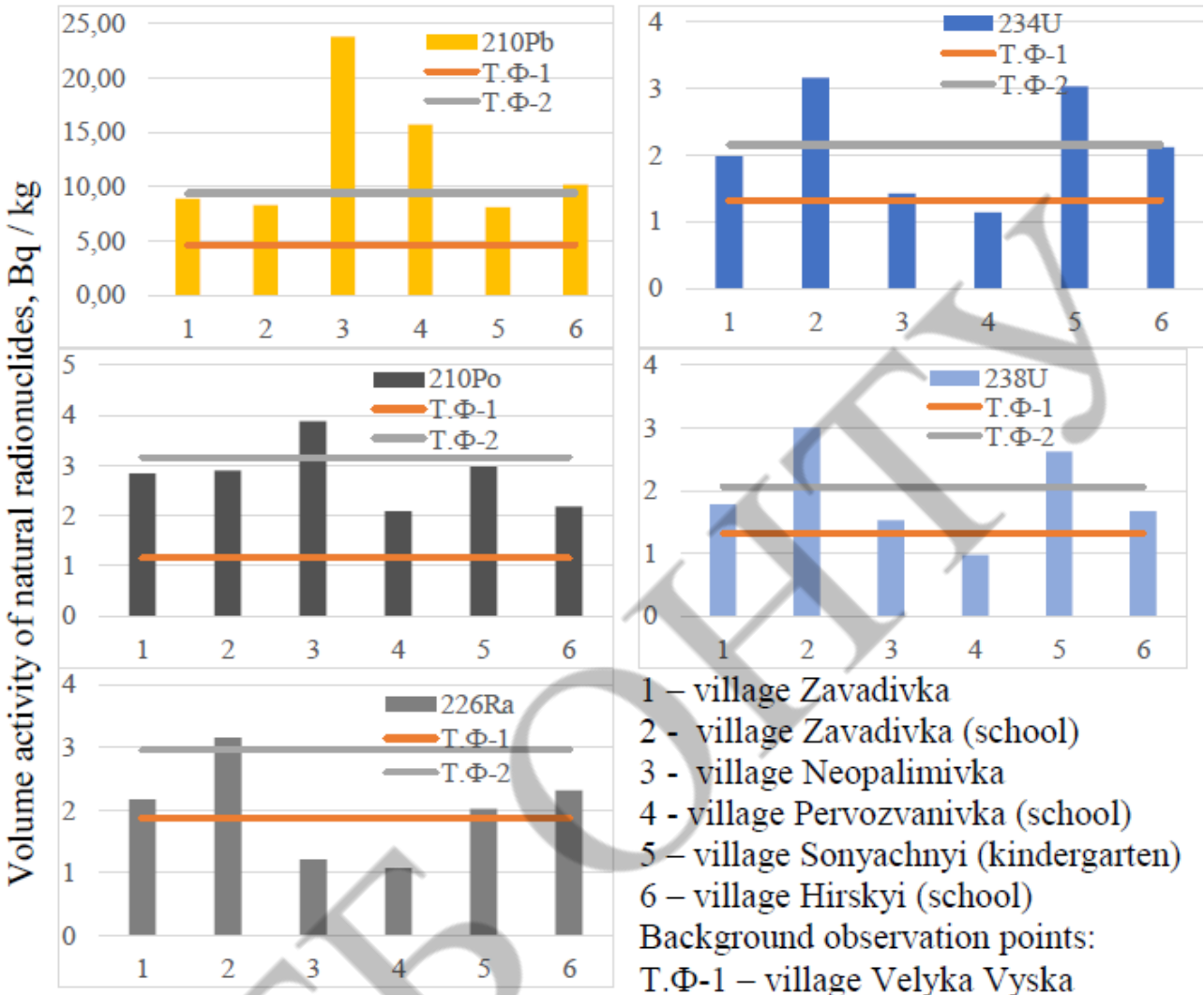
Fluctuations in the measurement of volumetric activity of natural radionuclides in soil samples of the object of study at the place of residence of critical groups



1 – village Zavadivka
2 - village Zavadivka (school)
3 - village Neopalimivka
4 - village Pervozvanivka (school)
5 – village Sonyachnyi (kindergarten)
6 – village Hirskyi (school)
Background observation points:
Т.Ф-1 – village Velyka Vyska
Т.Ф-2 – village Sybotka

APPENDIX 2

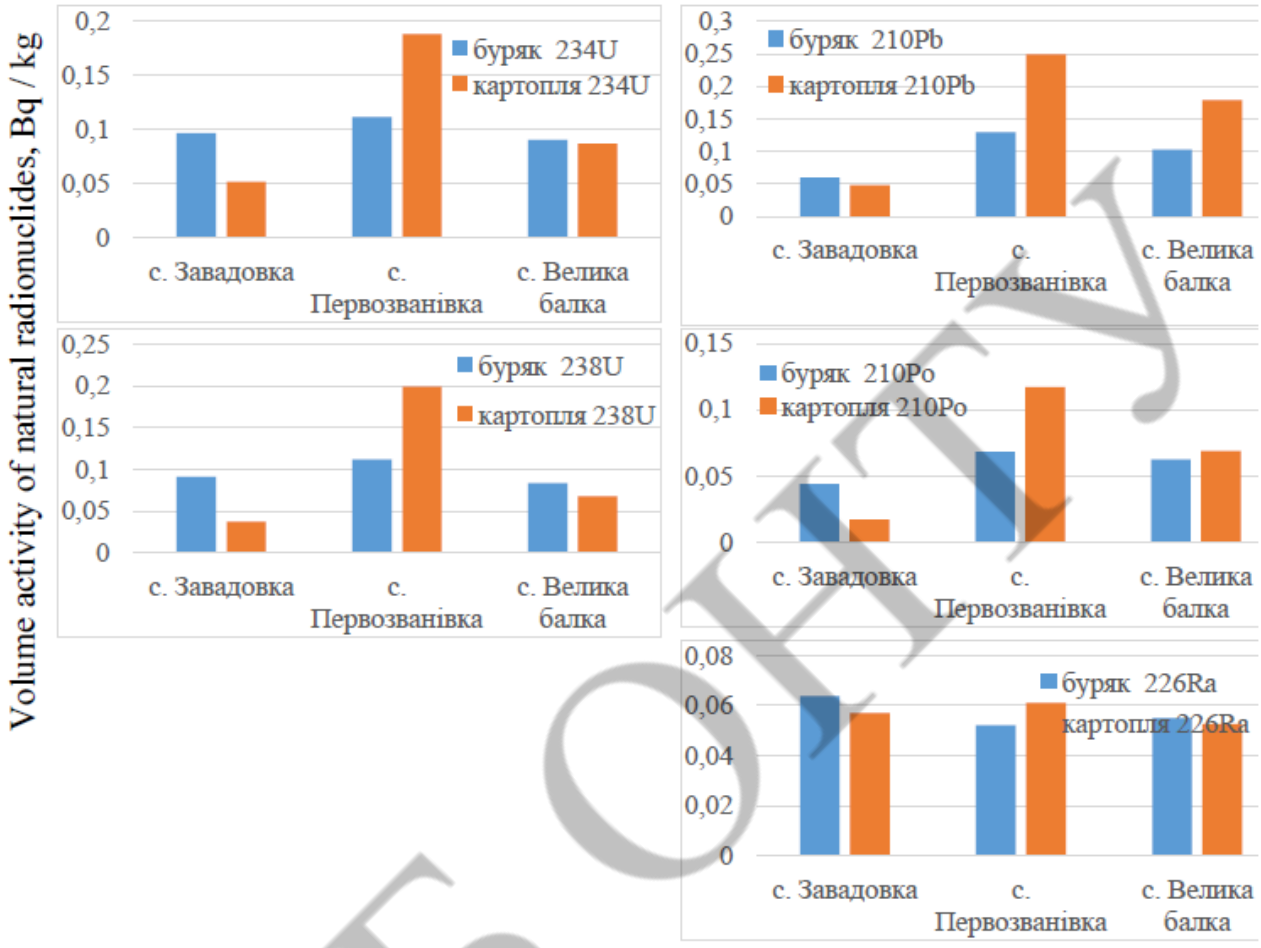
Fluctuations in the measurement of the volumetric activity of natural radionuclides in plant samples of the object of study at the place of residence of critical groups



1 – village Zavadivka
2 - village Zavadivka (school)
3 - village Neopalimivka
4 - village Pervozvanivka (school)
5 – village Sonyachnyi (kindergarten)
6 – village Hirskyi (school)
Background observation points:
Т.Ф-1 – village Velyka Vyska
Т.Ф-2 – village Sybotka

APPENDIX 3

Fluctuations in the measurement of the volumetric activity of natural radionuclides in the samples of root crops of the object of study at the place of residence of critical groups



BIOLOGICAL TREATMENT OF LEACHATE LANDFILL FILTRATES

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Abstract: Actuality of the work. *Existing landfills of Ukraine today turned into powerful sources of environmental danger. The problem is specifically hectic for Ukraine since there are many landfills from Municipal solid wastes (MSW) in Ukraine that have been in a need for closing for a long time already. Same problem exists in other countries. For solution of this problem it is suggested a two-stage purification for infiltrates on landfills in Ukraine and reduction of environmental danger from their accumulation (that is observed on the example of Hrybovytske landfill).*

Aim and tasks of the work. *Aim of the work is to increase a level of environmental safety of hydrosphere with the help of two-stage purification of infiltrates from landfills in aerobic lagoons and municipal sewerage pollution control facilities (PCF).*

For achievement of the set aim the following tasks should be solved:

-to conduct analysis of environmental danger sources of hydrosphere on the territory of Hrybovytske landfill;

-to study process of biological purification of infiltrates in aerobic lagoon in static regime;

-to set optimum conditions for biological purification of infiltrates in aerobic lagoon in dynamic regime;

-to set technological peculiarities of implementing a stage of pretreatment of infiltrates on landfills in aerobic lagoon;

-to set stability of parameters for tertiary treatment of infiltrates on municipal PCF;

Scientific part of the work lays in*: 1. Setting impact of parameters in implementation process (time of delay of infiltrates in aerobic lagoon, temperature, periodicity of it) on effectiveness of infiltrates` purification in aerobic lagoon that would give opportunity to optimize purification process.*

2. Studied peculiarities of biocenosis development of aerobic lagoon that enabled to prognosticate a development of biological process of infiltrates` purification.

Result of the work is: *setting optimum conditions for implementation of two-stage technology of landfills infiltrates purification.*

INTRODUCTION

Existing landfills in Ukraine, processes of creation and functioning of which is highly resembling for all the objects, today turned into powerful sources of environmental danger. Problems of infiltrates purification of SMW exist during all projection period, exploitation period, and closing of the objects. It is worth mentioning that most of storage places for MSW in Ukraine are basically landfills, not polygons. Unlike SMW landfills, polygons are engineering buildings that are equipped with protection anti-filtration display, collection systems and utilization of filtrates and biogas, system of technical and biological recultivation of cards filled with wastes,

harvesting system and drainage of conditionally clean atmospheric waters. In most cases all these systems (or the majority of them) on the MSW collection places in Ukraine don't exist. The problem is choosing the system of infiltrates purification at the stage of MSW landfill closing, for majority of which uncontrolled flow of infiltrates caused accumulation of their volumes in pounds-accumulators.

For purification of infiltrates before the beginning of landfill recultivation perspective is two-stage purification of landfill infiltrates in aerobic lagoons and municipal PCF, though enough reasonable scientific and practical recommendations for two-stage purification application under different conditions of different composition of infiltrates purification are absent. This has led to a need to conduct scientific research aiming setting optimum conditions for two-stage purification for landfills infiltrates in Ukraine and environmental danger elimination from their accumulation.

1. Environmental danger of hydrosphere pollution caused by filtrates of MSW landfills and its assessment

Polygons of MSW – sources of chemical and biological pollution of the environment. Specifically dangerous is impact from MSW landfills on the surface and underground water that lays within the impact of these objects. MSW polygons are inseparably connected with environmental objects and influence on its compounds condition: soils, underground and surface water sources, atmosphere air, biotes. Continued accumulation of municipal wastes on landfills causes unpredictable physical and chemical and biochemical processes in liquid, solid and gas state.

MSW dumps are powerful sources of environmental pollution – atmosphere, hydrosphere, soils. Because of variety of wastes that are directed to landfills and polygons, to assess chemical composition of wastes is highly difficult. On bumps with a depth of 1,5–2 m and more there always appears grey-black coloured with BOD_5 ranging between 500 – 5000. mg/dm^3 . It is so called infiltrate, very toxic substance that continuously leaks from wastes thickness. Toxicity of infiltrate doesn't reduce even after its dissolution for 100 times. As a rule, these dumps aren't equipped with anti-filtration screens, collection systems of infiltrate that creates in dump body resulting from atmospheric falls and processes of organic compounds decomposition. Soil and surface waters that leak through land covering, capture dissolved and suspended solid substances and products of biological decomposition, that's exactly why MSW leaching solutions contain different chemical elements and compounds. Volume of filtrate that creates during a year depending on climate conditions from 1 ha of waste body, reaches generally from 2000 to 4000 m^3.

1.1.Infiltrate purification technology

The most popular technologies in Ukraine are the following:

- Reverse osmosis technology;
- Technology of chemical and biological oxidation;
- Infiltrate knotting technology;
- Technology of biological purification in anaerobic and aerobic medium.

Aerobic methods of biological purification of filtrates have row of undeniable advantages over anaerobic: they are flexible in using, fast include in stationary regime of work, fast accommodate to changeable composition and expanses of filtrates. Aerobic reactors are far more simpler in construction and far more cheaper than anaerobic, they are also much easier automatized and easier in exploitation.

From analysis of existing natural studies it is possible to make conclusion, that purification of infiltrates in aerobic lagoon (or simultaneously connected lagoons) is simply, low-budget and enough efficient method of pretreatment of infiltrates.

2.Characteristic of Hrybovytske (Lviv) landfill

The dump has started to exist since year 1969, according to different information sources its space reaches from 33,3 ha to 45,3 ha, accumulated wastes reach maximum height of 45 m.

The body of MSW Hrybovytske landfill reaches around 12 – 15 mln. tons of wastes. Specifically hazardous effect on the environment around MSW Hrybovytske landfill territory have four pound-accumulators of acid flux tars (one of them is filled with wastes). General space of flux tars reaches around 5 ha. Level of infiltrate danger - «extremely hazardous», and danger class of infiltrate on MSW Lviv landfill reaches 1.

3.Methodology of laboratory experiments of infiltrates` aeration and methodology for research of infiltrate tertiary treatment stage on municipal PCF

3.1.Study of the aerobic purification was conducted at plant (Ill. 2.1).

The plant contained from 5-litter bulb, that with volume of 4 l was filled with infiltrate. Infiltrate for studies was chosen from pound-accumulator of Lviv MSW For aeration the air was supplied to bulb with the help of laboratory compressor. With the help of regulation compressor, set on air flow tube, it was regulated air expanses on aeration and supported constant significance of this expanse throughout the whole experimental time.

Ill. 3.1. Scheme of experimental plant for infiltrate aerobic purification.

In bulb there was set an aquarium aerator, via which division of air took place in bulb volume. After some periods of time from bulb was taken probes, that were analysed on ammonium nitrogen content, COD, it was set also a content of dissolved oxygen and hydrogen indicator pH.

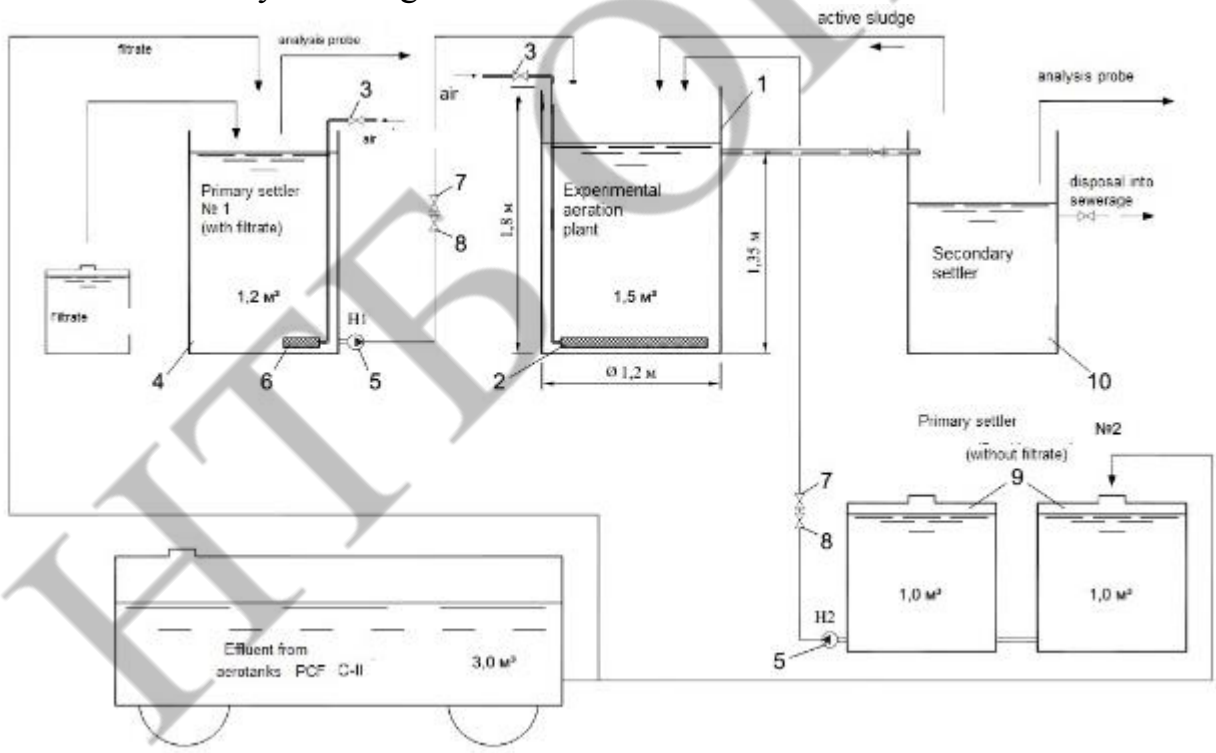
Experimental work was conducted in two stages.

At first stage (static) was set alteration of COD, concentrations of ammonium nitrogen, pH and concentration of dissolved oxygen under conditions of continuous aeration without allotment of pretreated infiltrate and accordingly without addition into volume `fresh`, untreated infiltrate.

At second stage (dynamic) that was conducted after obtaining maximum possible level of purification under static regime, it was modeled continuous regime of purification, that is planned to be implemented at industrial pollution control facility. Once in 24 hours from bulk it was taken certain amount of infiltrate and was poured same amount of `fresh` unpurified infiltrate. For certain proportion significance of the sample the researches were conducted for obtaining constant concentrations of ammonium nitrogen and COD. After that, the daily volume of purified and `fresh` infiltrate was substituted, that accordingly was collected and poured into aeration plant, and it was studied a process of aerobic purification in dynamic regime for another time significance of infiltrate delay in aeration zone. Once in a day an infiltrate sample from bulk for analysis and sample for addition of infiltrate were taken.

3.2.Methodology of tertiary infiltrate treatment research at PCF

Studies on infiltrates` impact on process of biological purification at sewerage pollution control facilities of Lviv city were conducted at experimental plant, displayed at Illustration 2.2, that imitated sewerage pollution control facilities. The studies were held in static and dynamic regimes.



Ill. 3.2.

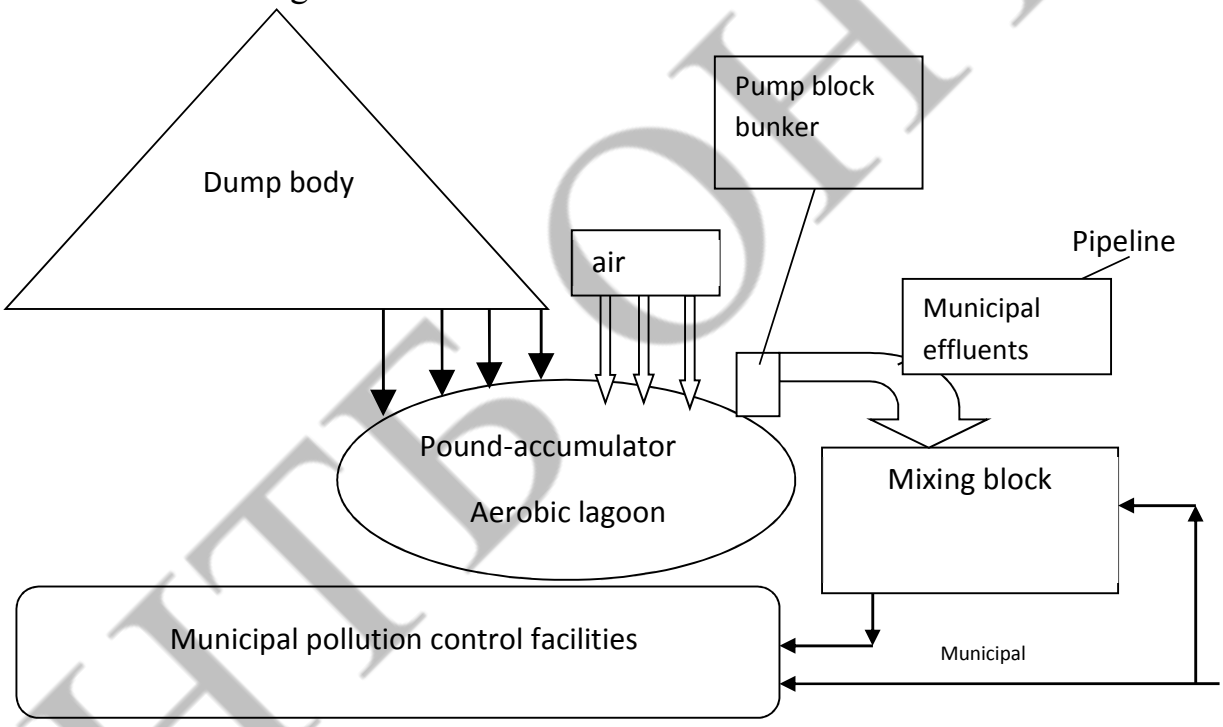
For experiments in static regime for research place a mixture of effluents with active sludge was taken. Infiltrate in quantity of 1 m^3 was selected from pound-accumulator №5 in MSW Hrybovytske landfill. In experimental aeration plant was poured mixture of effluents and active sludge and was added calculated quantity for obtaining mixtures, that met the following dissolving criteria: 10; 500; 1000; 1250; 1500. In reactor it was added mixture of effluents with active sludge till obtaining

general volume in 1,64 m^3. After that samples were taken for chemical experiments and the plant was launched. Every study cycle in static regime lasted 6 hours. After finishing of air supply a sample was taken for conducting chemical experiments.

Experiments in dynamic regime were conducted at the same plant (Ill.2.2.) The plant contained primary settlers: primary model settler for mixture of effluents with infiltrate and primary model settler for effluents without infiltrate. During 8 daily experiments the mixture from effluents and infiltrate as equally carried to aeration plant 1. Regulations of expanses were carried with the help of circulation pump and valve. Homogeneity of the mixture was obtained with the help of aerator. After 8 hours of mixture supply from effluents with infiltrate it was modeled working process of aerotank during 16 hours without adding infiltrate.

4.General strategy for two-stage cultivation of landfill infiltrates

Analyzing research data it is recommended principal scheme for implementation of landfill infiltrates pretreatment technology that is illustrated in Ill..5.2. According to this scheme, infiltrates are accumulated in pound-accumulator that simultaneously serves as aerobic lagoon.



Ill.3.3. Principal scheme of two-stage landfill infiltrate purification in aerobic lagoons and at municipal pollution control facilities.

For this it is equipped with aeration system. Pound-accumulator is being screened with protective display by using well known technologies. In aerobic lagoon biological aerobic oxidation is taking place of organic contaminants and of ammonium nitrogen. Constant inflow is being realized and harvesting of infiltrates under conditions of supplement with necessary period of infiltrate residence in reactor. Infiltrate collection is being done with the help of pump station throughout set pipeline «landfill – municipal PCF» infiltrate is transferred into mixing block PCF where at given proportion it is mixed with municipal effluents and in mixture is directed to tertiary treatment at municipal PCF. For every particular case for technology implementation

it is necessary to make balance calculation. In ratio of Lviv PCF it is set the following input of infiltrates: 1) infiltrate disposal into system of city sewerage of Lviv is necessary to conduct from 09 am to 5 pm with gradual productivity increase from 10 m^3/hour to 25 m^3/hour; 2) it is necessary to cease disposal of infiltrate under nonfavourable climate conditions, particularly: under exceed of temperature of effluents in aerotanks КОС-II over 20 ^oC and its reduction under 10 ^oC.

Concerning two-stage scheme for infiltrate purification application at other objects, then in every particular case it is necessary to make additional calculations and based on their results to set optimum regimes for infiltration pumping.

CONCLUSION

An identification of environmental danger sources was conducted on the impact territory of Hrabovytske landfill. It was set, that in the hazardous impact zone of Hrabovytske landfill it is possible to distinguish three potential sources of environmental danger: stored MSW, lakes from crude oil recycling and industrial activity of the population. It is impossible to concretize an impact from every form of the source, yet it is possible to judge which type of contamination is causing each from the sources.

Ukrainian landfills create consistent environmental danger in their impact zone because of absence of protection anti-filtration screen, collection system and utilization of filtrates and dump gas, plants system of physical and biological recultivation of cards filled with wastes, harvesting systems and drainage of conditionally clean atmospheric waters. Analysis of possible technologies for purification of accumulated infiltrates has shown perspective to apply technologies for biological purification of infiltrates in aerobic lagoons.

Suggested two-stage purification scheme of landfill infiltrates enables to purify infiltrates effectively with primary purification under conditions of aerobic lagoon on the territory of landfill, transporting of infiltrate with the help of pipeline «landfill – municipal PCF», dissolving it with municipal sewerage effluents and pretreatment on municipal PCF. To apply the two-stage infiltrate purification scheme on proper objects, in every concrete case it is necessary to make additional equations and calculations and on their result bases to set optimum regimes of pumping over the infiltrate.

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THE IMPACT OF THE COMBAT ON THE ENVIRONMENT: THE EXPERIENCE OF THE WORLD AND UKRAINE

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Abstract. *Despite all the achievements of progress, war remains an important means of resolving the contradictions of mankind. Moreover, the growth of the world's population and the large-scale level of industrialization have led to the fact that since the last century, wars have begun to cause significant damage to the environment. Despite the efforts of environmental scientists, the issue of environmental protection is still not given enough attention, while the issue of environmental security in the armed conflict is becoming increasingly important. The purpose of this work is to comprehensively assess the impact of wars and armed conflicts on the environment, both globally and in the context of the war caused by Russia's armed aggression against Ukraine. This work assessed the environmental impact of all modern wars and armed conflicts since the beginning of the XXI century, as well as a detailed analysis of the environmental aspects of the war that has been going on in the East of Ukraine since 2014 caused by Russia's armed aggression against our state. The study also provides a predictive assessment of the further nature of changes in the impact of wars on the environment and provides recommendations on ways to minimize them, both in Ukraine and internationally.*

Keywords: *war, Russian aggression, East of Ukraine, African continent, Middle East, Afghanistan, Georgia, climate change, environmental impact, environmental security.*

I. WARS OF THE XXI CENTURY: ASSESSING THE IMPACT ON THE ENVIRONMENT

Wars and armed conflicts have been an integral part of human existence throughout its history, from ancient times to the present day. Despite the destructive nature of the war and the awareness of all its negative consequences, the international community has failed to secure a peaceful settlement of the dispute. Moreover, any state that has succumbed to the illusions of pacifism and lost its military potential will sooner or later fall victim to armed aggression, which became especially familiar to Ukraine after Russia started the war in 2014.

At present, there are no signs that wars and armed conflicts will end in the foreseeable future. Moreover, the growth of the Earth's population, the gradual depletion of resources, the limitation of living space and the deterioration of the environment will be the causes of new wars. This is an objectively realistic scenario that cannot be prevented. At the same time, the awareness of the inevitability of such a forecast necessitates a comprehensive readiness for it, including in the field of ecology.

Scientists Rafael Reuveny, Andreea S. Mihalache-O'Keef, Quan Li in their

article «The effect of warfare on the environment» reviews theoretical studies of the possible effects of war on the environment and evaluates statistical models of these effects on air emissions per capita population, the rate of change in forest area and a composite indicator of environmental stress reduction [1].

It is generally assumed that war always harms the environment, but it is logical to say that this is not the only possible outcome. War can also disrupt and reduce harmful human activities. Another possibility is that war may not have a significant impact on the environment. Since all these possibilities are logically plausible, the net impact of the war on the environment is an empirical question (Table 1).

Table 1. Theoretical impact of warfare on the environment [1]

Effect	Direct/ Indirect	Mechanism	Examples
Harmful	Direct	Destruction as a winning strategy	Destruction of arable land, agricultural land, forests and lakes; flooding; burning of oil fields; destruction of mines; extermination of livestock
Harmful	Indirect	Side effects of war-related activities	Movement of armed forces; waste and pollution from military production; neglect of environmental standards; damage to the environment by refugees
Favorable	Direct	Destruction of normal economic activities that harm the environment	Destruction of environmentally harmful industries; destruction of vehicles and transport network that reduces emissions; destruction of fishing fleets
Favorable	Indirect	Side effects of war-related activities	Reduction of fishing in dangerous areas, reduction of activity in restricted areas, reduction of fuel used at home, as more is sent to the front, mobilization of workers from environmentally harmful sectors of the economy
No clear effect	Direct	Minor impacts	Point air/missile strikes, border skirmishes, low-tech armed conflicts
No clear effect	Indirect	Harmful and beneficial effects are offset	The growth of military production is balanced by the destruction of normal economic activities that harm the environment

The publication finds that the war has a significant impact on the environment, but the signs and magnitude of these consequences depend on the studied environmental indicator, the place of hostilities on its own territory or abroad, as well as the level of technological development of the studied state.

Scientists Michael J. Lawrence, Holly L.J. Stemberger, Aaron J. Zolderdo, Daniel P. Struthers, Steven J. Cooke with their study «The effects of modern war and military activities on biodiversity and the environment» conduct a detailed analysis of the impact of hostilities and armed forces on the environment. The article objectively

reveals the nature and features of different types of impact on the environment in the following areas (Fig. 1):

- by the nature of the weapons used (conventional or nuclear);
- by components of the armed forces involved (land, air, sea);
- by stages of war (preparatory period, active warfare, postwar period);
- by the nature of the armed forces (activity of military facilities, exercises, etc.) [2].

Fig. 1. Review of the potential adverse effects of war on the environment, including land, air and naval theaters of war [2]

The results of the study confirm that the impact of warfare on the environment is mostly negative. The authors of the publication claim that since war is an integral part of human activities, it is advisable to further deepen the level of study of the impact of war on the environmental situation in order to develop potential strategies to minimize the harmful effects.

Unlike their Western counterparts, Ukrainian scientists pay full attention to the environmental problems of Russia's armed aggression against Ukraine. Seven year of the war in eastern Ukraine has serious consequences for the biosphere of the entire planet, not just a particular region. Therefore, under the auspices of international organizations, namely the OSCE and UNEP, with the participation of numerous volunteer organizations and donors from European countries, domestic researchers are developing material to address the environmental crisis in the Donbass.

The International Charitable Organization «Environment People Law» (hereinafter EPL) is a pioneer among researchers of the impact of the war on the environment of Donetsk and Luhansk regions. They were the first to assess the damage caused by shellings, such as the battles for Savur-Mohyla mound (summer 2014), which is located within the Donetsk Kryaz Regional Landscape Park, which is a natural monument and has significant recreational potential. The use of artillery caused significant losses to the park's forest due to large-scale fires, as well as damage to large areas of soil cover (Fig. 2-3) [3].

Fig. 2. The area of 225 km^2 with shells explosion craters

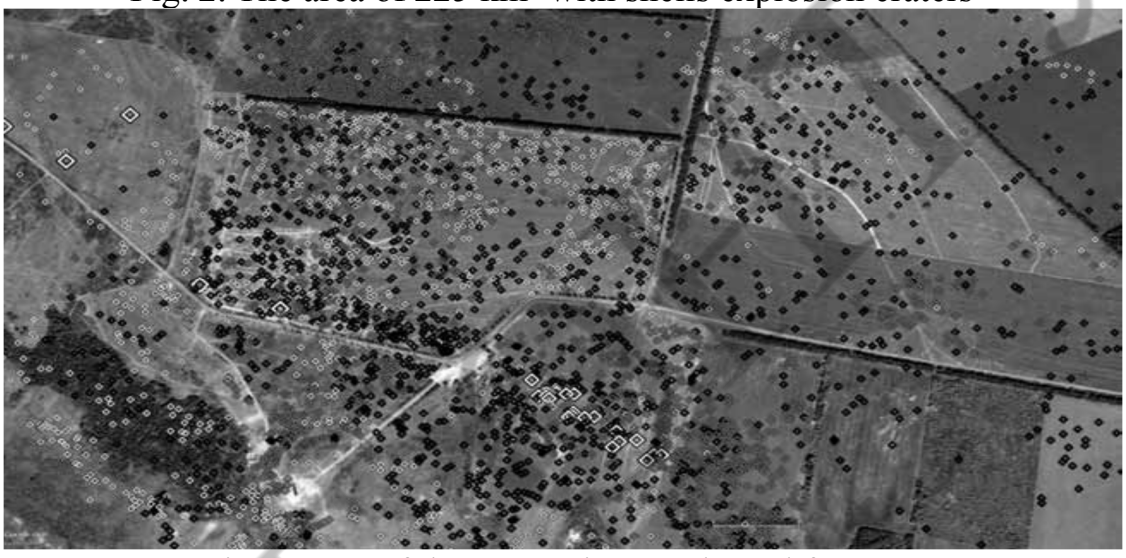
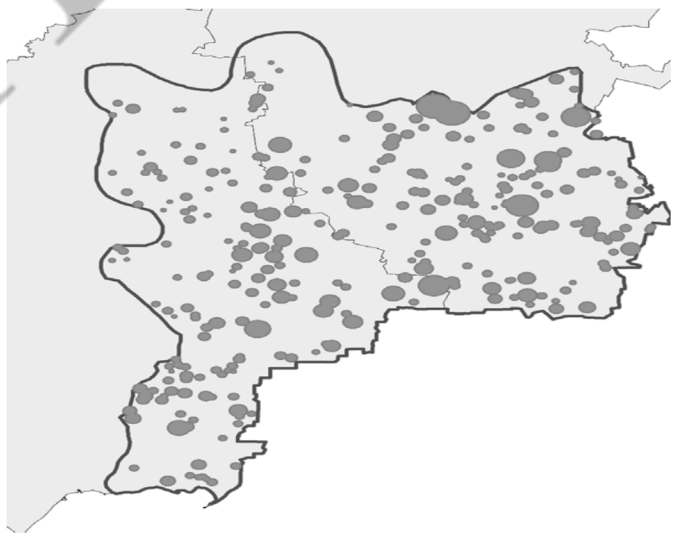


Fig. 3. Part of the craters in an enlarged format

Large-scale fires in the study area are one of the most significant factors in the impact of hostilities on the environment, which led to the choice of EPL for the next object of study. At the same time, information on this topic is relatively accessible, including in the temporarily occupied territories, which further contributes to research (Fig. 4) [3].



B. Babin, A. Chvalyuk, A. Plotnikov in their work reflect the main risks to the sea ecology of Ukraine, in particular uncontrolled fishing, ingress of wastewater from industrial facilities and coastal settlements, which in particular leads to the destruction of bottom ecosystems in Karkinitska and Kalamitsky Bays, environmental threats arising from the actions of the Russian occupants in the Crimea (Russian Black Sea Fleet, illegal usage of captured drilling rigs, construction of desalination systems, etc.), as well as Russia's use of sea reserves adjacent to the occupied Crimea to create artificial pretexts to expand their territorial claims [4].

The object of the study is the factors influencing environmental security caused by warfare during armed conflicts, their consequences in the post-conflict period, as well as the impact on the environment of military activities in peacetime.

The subject of the study is the peculiarities of the environmental situation in the war zone, taking into account regional features.

Due to the fact that the subject and object of research are directly related to war, the use of empirical methods, including field research and experiments, was objectively impossible. Therefore, in the framework of the project theoretical and complex research methods were used, in particular: analysis, synthesis, induction, deduction, comparison, abstraction, modeling.

1.1. Africa as the hottest spot on the planet

Climate change is often referred to as a «vulnerability enhancer» that can increase security risks and conflicts in fragile regions and hotspots where poverty, violence, injustice and social insecurity prevail. This is very important for the African continent due to the presence of both climate change and a large number of conflicts. Along with other factors, climate change can undermine human security and the livelihoods of vulnerable communities in Africa through a variety of components. These include:

- variability in temperature and precipitation;
- extreme weather and natural disasters such as floods and droughts;
- resource problems due to water scarcity, land degradation and food shortages;
- forced migration and farmer-herder conflict;
- infrastructure for transport, water and energy supply.

Because of these components, climate change can contribute to humanitarian crises and conflicts, depending on local conditions in different parts of Africa. While a number of statistical studies do not show a significant link between rainfall reduction and violent conflict in Africa, most studies do, mostly in conjunction with other issues. The impact of climate change on conflicts with resources is often indirect, complex, and linked to the political, economic, and social factors of conflict, including inequality, low economic development, and inefficient institutions.

An intergovernmental panel on climate change has identified Africa's vulnerability as «vulnerable to climate change». Frequency and intensity of extreme weather events, as well as variability and long-term climate change (eg, temperature and precipitation, clouds and wind) [5-6]. They act as stressors for natural systems and human society, directly or indirectly affecting natural resources and related infrastructure (eg soil and water, ecosystems, agriculture and land use, forests and biodiversity, energy and economic systems and networks) that are important for the

existence, well-being and survival of people in Africa. The African environment is highly volatile and complex. Surface temperatures, together with irregular precipitation, increase land degradation, reduce water availability and food production, and increase the frequency and intensity of droughts, heat, floods, and other natural disasters.

Climate catastrophes can destabilize a society with weak economies, mixed political regimes, as well as contribute to conflicts arising from competition for limited resources, changes in power relations, and unequal distribution of resources.

1.2. Afghanistan is a country of continuous war

Afghanistan has been in a long-running conflict for more than forty years, facing a serious environmental crisis. Major environmental problems include depletion of aquifers, air and water pollution, soil degradation, deforestation, overgrazing, desertification, biodiversity loss, climate change and urban sprawl in environmentally fragile areas. In addition, the country often suffers from earthquakes, floods, droughts, landslides and avalanches. Approximately 400,000 people suffer from natural disasters each year (about half of Afghanistan's 400 districts are at risk), and 36% of the population lives below the poverty line.

Two-thirds of Afghanistan's landscape is occupied by mountainous terrain with little or no vegetation, which is typical of an arid country. For this reason, vegetation in these places plays a vital role in the ecosystem. For example, let`s consider the role of pistachios among hundreds of other plants. This plant not only provides climate and environmental stabilization in growing areas, but facilitates the lives of thousands of families, providing them with a natural source of income.

Half of the rest of the country's landscape is desert, which is a hostile environment, and the other half is agricultural land and pastures. Currently, only six percent of Afghanistan's fifteen percent of agricultural land is cultivated. Over the past twenty-five years, agricultural land has declined sharply. Afghanistan is estimated to have lost 30 percent of its agricultural land and pastures, either through migrant farmers or degradation. Agricultural land in Kabul province has been lost due to degradation caused by the expansion of urban institutions. This has led to a drastic change in the previously dominant climatic and environmental factors in the region.

Compared to the twentieth century, agricultural production has declined by fifty percent. To compensate for this loss, villagers began to use the free natural resources of their environment. The end result of this process was a catastrophe for several natural forests that were cut down and smuggled out.

Deforestation, floods and avalanches caused greater destruction. Once forest productivity was reduced or monopolized by some military leaders, poor farmers sought another cheap and affordable alternative – opium cultivation. Afghan warlords and the growing international drug market have encouraged this. Thus, this has led to further degradation of Afghanistan's environment.

Many wooded areas and agricultural lands have been burned and degraded due to the use of heavy military technology and chemicals, ten thousand villages and a large number of landscapes have been destroyed. This continuous process is still doing damage to the environment. According to the World Bank for a Health Economics, the country must have at least 25% of the forest area, while in Afghanistan the forest area

is below 2%.

In Afghanistan, landmines are another worst environmental horror created by the ongoing war. The country's presence of more than ten million landmines makes it the deadliest minefield in the world. The daily death toll from these devices is between 20 and 30 people, mostly children and civilians.

The ecological structure of Afghanistan is very fragile and sensitive, with more than 60% of the area made up of highlands and mountains, while the climate is dry and the country is more prone to erosion and degradation. Therefore, due attention is needed, and due to the long war, this is not possible. That is why the environment in Afghanistan is in deep turmoil.

1.3. Syria as an example of a «dirty» war

Poor environmental conditions in Syria before the war were identified as the main contributors to the armed conflict, namely unprofessional management of natural resources and waste, inadequate government response to mining pollution and the severity of the drought from 2006 to 2010. This drought has damaged agriculture (25% of GDP), followed by rising unemployment, food insecurity and mass migration to urban centers. Combined with high population growth, water scarcity has created a greater risk of political instability.

Using satellite analysis of land in Deir ez-Zaur, the Dutch NGO PAX [8] has demonstrated the growth of improvised refineries. Tens of thousands of these refineries are currently in use in at least 37 locations in northeastern Syria, employing tens of thousands of civilians, including thousands of children, exposing their health to toxic fumes and hazardous substances on a daily basis. This practice has also affected local agricultural lands and water sources.

Syria suffered from high levels of air pollution before the conflict. In 2010, 69% of the population was contaminated with high levels of particulate matters (PM 2.5) [9].

This high level of air pollution was caused by industrial and vehicle emissions, waste incineration and seasonal pollution - hazardous particles contributed to chronic diseases, respiratory problems and hospitalization. Initially, the outbreak of the conflict reduced the percentage of the population affected by particulate matter (by 7% in 2011), as people fled cities en masse and industrial activity and energy consumption declined. However, since 2012, this trend has changed and reached a maximum of 72% in 2015.

1.4. Analysis of the impact of the Russian-Georgian war on the environment

The first large-scale Russian aggression in the 21st century against the post-Soviet countries that chose the Western path was the 2008 Russia-Georgia war. Except for the attack and destruction of military and civilian infrastructure (Georgia lost control of 189 villages, 125 of which remain under Russian occupation, nearly 150,000 people fled their homes after the war) the Russian military aggression caused an ecological disaster in Georgia - hundreds of hectares of unique forest in various regions of Georgia have been purposefully destroyed by the Russian military forces during the second half of August [10].

Smoke, high temperatures, fires and noise generated by firefighting have shaken the local fauna habitats and activities. They were under stress and may have migrated,

which may affect the spatial distribution of animals, leading to incredible habitat depletion and reduced reproduction. The forest fires in the Borjomi gorge have destroyed the forests, undergrowth, and topsoil. The fertile humus layer has been completely burned. Micro-biological processes required for maintaining soil functions have been stopped, and soil fertility has been destroyed.

The area directly affected by the fire is identified as a zone of high conservation value because it is characterized by the following characteristics:

- Biodiversity of global, regional, or national importance (endemism, endangered species).
- Conservation of important drinking water and control of soil erosion.
- Main resource to support the life of the local population.
- Substantial economic asset of the local population (tourism).

The environmental damage caused by forest fires includes the emission of greenhouse gases into the atmosphere. The burned forest was able to absorb 70,000 tons of carbon dioxide on average for 30 years. If considering it only from the climate change convention point of view, the damage is amount to at least EUR 7.2 million [11].

On August 13-14, 2008, the Russian occupation forces blew up and sunk 12 ships of Georgia. As a result, up to 50-70 tons of fuel oil, as well as engine and hydraulic oils were spilled into the sea. The bombs and ammunition stored on these ships also exploded, releasing an unknown mixture of chemicals into the sea. Such a large amount of oil spill in the coastal zone of Georgia is unprecedented. Spilled oil and oil products have severely polluted the Black Sea coastal zone and endangered the marine part of Kolkheti National Park and its biodiversity [10].

Consequently, because of the August 2008 war, Russian military strikes have caused significant damage to natural ecosystems in the Caucasus and Black Sea regions.

1.5. Analysis of the impact of hostilities in eastern Ukraine on the environment

Historically, Donetsk and Luhansk regions are one of the most industrialized areas of Ukraine, which has led to a critical situation in the field of environmental protection. Prior to the 2014 war, there were a total of about 4,500 industrial sites in these two regions that posed a potential environmental hazard. Russia's armed aggression against Ukraine has led to new risks and threats to environmental security, which could have catastrophic effect for both the region and Ukraine, and in the worst case scenario, in Eastern Europe.

War in eastern Ukraine could lead to disruptions in the security of enterprises, damage of infrastructure, or their destruction. In particular, among the most dangerous industries being damaged as a result of Russian aggression, it is worth noting the following:

- Alchevsk Metallurgical Plant;
- Gorlovka plant «Stirol»;
- Donetsk State Plant of Chemical Products;
- Yenakiyevo, Makeyevka and Donetsk metallurgical plants;
- Lysychansk Refinery;

- Severodonetsk plant «Azot»;
- Slovyansk, Luhansk, Uglehirsk and Myronivska thermal power plants;
- Toretsky Ferroalloy Plant;
- Yasynivsky, Avdiivsky and Yenakiyivo coke plants and many others.

In addition, a separate threat is damage of mining enterprises and their disconnection from the energy sources, which has repeatedly caused the shutdown of mine drainage systems and in some cases led to their complete flooding by mine waters. At present, there is a damage of drainage systems in almost the entire territory from Horlivka to Yenakiieve, in the Pervomaisk region, and partially in Donetsk, Makiyivka, Shakhtarsk and Toretsk. As a result, about 40 mines in the region are flooded or completely flooded and unfit for further use, some of them were illegally dismantled (Table 2).

Table 2. The state of mines in eastern Ukraine

Coal mines	Controlled territories	Temporarily occupied territories	Total
Mines in operation	29	75	104
In drainage mode	1	16	17
In the process of flooding	1	35	36
At the stage of liquidation	6	64	70
Total	37	190	227

Flooding of mines leads to pollution of groundwater and surface water with iron, chlorides, sulfates, other mineral salts and heavy metals. There is also a significant threat of flooding of mines used for waste disposal, in particular Oleksandr-Zakhid and Vuhlehirska. In addition, a special danger is the possible flooding of the mine «Young Communard», where in 1979 an underground nuclear explosion was carried out as part of the «Klivazh» project [12].

Since the beginning of warfare, there has been a systematic disruption of water supply and sewerage systems [13]. Cases of damage to municipal sewerage and water supply networks were recorded in most settlements along the line of contact.

Since 2014 to 2019, as a result of warfare in the region, 366 cases of violations of regular activities were recorded at 63 water supply and sewerage facilities.

Among the main threats are high vulnerability of water supply to settlements during hostilities (including Mariupol, Krasnoarmiysk, Volnovakha, etc.) and increased risk of emergencies (eg, flooding of Kramatorsk) in case of emergency shutdown of pumping stations near the line of contact.

As a result of the Russian armed aggression in eastern Ukraine, a significant part of forest and forest protection plantations was lost: according to ForestWatch, in 2014 alone, 479 hectares of forest in the war zone were completely destroyed. The greatest threats to forest plantations in eastern Ukraine are forest fires [13] caused by explosions of ammunition or arsons related to Russian tactics of sabotage. As a result of fires caused by hostilities, plantations along the line of contact suffered the most.

In addition, the war has led to land pollution and disturbance of the nature reserve fund. Construction of fortifications, deforestation, spread of forest and steppe fires

damaged 78 reserves, nature reserves, landscape parks and other environmental facilities in Donetsk and Luhansk regions [13].

Violations of the nature reserve fund also occur due to lack of staff, cessation of funding and protection of territories in the Luhansk Nature Reserve, «Khomutovsky steppe», «Kalmiusky reserve», «Trokhizbensky steppe», «Pridintsivska floodplain» reserves, etc.

In general, there is currently a significant negative impact on the environment of hostilities caused by Russian armed aggression in eastern Ukraine. Analysis of research shows that during the war and the occupation by Russia, the ability to obtain objective information about the state of the environment is sharply reduced. Therefore, in order to improve the capability to monitor and analyze the situation, respond quickly to challenges and threats, prevent deterioration and create the conditions for future environmental recovery after the war, it is necessary, above all, to organize cooperation between agencies and international organizations.

II. DEVELOPMENT OF MILITARY TECHNOLOGIES AND THEIR IMPACT ON ENVIRONMENTAL ASPECTS IN THE FUTURE WARS

In fact, the whole history of mankind is a history of continuous wars. It is now clear that a world without war is an unrealistic utopia, and armed conflict will continue despite calls from pacifists. As the challenges and threats are constantly changing, the forms and methods of war, as well as military technology, are constantly being improved. So far, scientific and technological progress has reached an unprecedented level of development, which provides opportunities for the development of fundamentally new weapons systems and military equipment.

From the point of view of ecology, it is determined that the impact of hostilities on the environment is negative. If in the pre-industrial era armed conflicts were of low-tech nature and could not significantly affect the environment, then during the twentieth century the situation has changed radically. Significant damage to the environment began to cause not only by the actual fighting, but also combat training activities, daily activities of troops, as well as the work of numerous enterprises of the military-industrial complex.

A wide range of environmental scientists are paying attention to finding ways to reduce the military burden on the environment. At the same time, the proposals of some researchers are limited to calls for an end to wars or a significant reduction in armed forces and a reduction in military spending, which can be considered nothing more than a manifestation of pacifist idealism. In the case of Ukraine, the long-term reduction of the army and the reduction of defense spending have led to the armed aggression by Russia, so it is clear that none of the governments will risk the existence of their own state to solve environmental problems. At the same time, a significant number of experts recommend to develop and approve at the international level standards and rules for environmental protection during wars and armed conflicts, ie, in fact, an environmental analogue of the Geneva Convention. Also, it is proposed to develop and improve a set of technological standards in the framework of environmental safety of military production.

Given that the cessation of wars is an unrealistic scenario, and the harmonization of environmental standards for warfare at the international level is a difficult task due to significant contradictions between states, the most optimal is the environmental regulation of military and military-technical spheres at the national level. In addition, it is advisable to use modern technological advances to reduce the burden of the defense component on the environment.

2.1. High-precision weapons

The first high-precision weapons (HPW) were designed by Nazi Germany during World War II, but have not been widely used for a long time. Since the US Armed Forces operation in Iraq, Desert Storm (1991), where unmanned bombs were the norm, there has been a significant acceleration in the use of high-precision weapons. Subsequently, NATO members increased the use of precision ammunition in Bosnia and Herzegovina, Kosovo, and later in Afghanistan. More recently, HPW employment has risen sharply during the last operation in Libya, where almost all combat sorties were carried out using «smart» bombs, providing the Alliance with positive and significant results in terms of accuracy and minimization of collateral damage. Developments in areas such as aerodynamics, laser technology and electronics have brought us closer to the possibility of surgical accuracy, which is considered important for modern warfare [14]. In 2012, a study commissioned by the European Defense Agency stressed that the demand for accuracy had increased both to increase the effect against the opponent and to avoid casualties among friendly forces and non-warring third parties.

Future high-tech high-precision weapons systems are likely to have versatile characteristics and be used in several variants and platforms. The next generation of the HPW is likely to be delivered and operated by both conventional manned aircraft and autonomous unmanned aerial vehicles (UAVs). These weapons must have both lethal and non-lethal capabilities and be able to operate in a physical environment, guided in the virtual. The HPW of the future can be released in cooperation with other platforms and weapons systems, while maintaining the possibility of use in certain modes, will also increase their range, maneuverability and accuracy.

Examples of this concept can be seen in the new air-to-air missiles, including the AIM-120D air-to-air missile [15] (15) (Fig. 5), which has a much longer range than the already expanded version of the AIM-120C, and multinational European METEOR missile with a range of more than 300 km. It is noteworthy that METEOR can also receive mid-course manual updates from other aircraft and control-command units (C2) participating in the mission, providing an increased degree of maneuverability and accuracy.

Defense companies in cooperation with the countries have already started projects to develop a new generation of HPW. Recent examples include the Raytheon Industry version of Excalibur S [16] and the Israel Aerospace Industries HARPY NG [17]. This new generation of weapons is becoming more accurate, but at the same time universal.

Subsequent high-precision weapons, such as hypersonic weapons and powerful laser systems, are already becoming a reality.

Fig. 5. Air-to-air missile AIM-120D

In terms of environmental impact, the development of precision weapons has several important aspects. In particular, the accuracy of weapons can significantly reduce the use of ammunition and significantly reduce the mass of explosives required to hit the target. Thus, several dozens of tons of «ordinary» bombs or shells are replaced by a surgical strike of one high-precision ammunition, which creates much less burden on the environment.

2.2. Railgun

Railgun is a promising weapon, a gun that uses electricity instead of chemical fuels (ie gunpowder charges) to fire. Magnetic fields created by high-voltage electric currents accelerate the sliding of a metal conductor or armature between two rails to launch steel shells weighing about 10.4 kg. at speeds from 7250 to 9000 km/h. The US Navy has developed several prototypes for further installation on ships for the use of rails instead of artillery and / or air defense (Fig. 6) [18].

Fig. 6. Prototype of the railgun, US Navy, 2014

The environmental aspect of this type of weapon is primarily the absence of emissions of harmful substances during firing, as the projectile itself is all-metal and is driven by an electromagnetic pulse without the use of explosives.

2.3. Combat laser systems

Laser Weapon System (LaWS) - a promising system of directed weapons, based on a solid-state laser. The development was created by the Naval Surface Warfare Center Dahlgren Division of the US Navy Naval Systems Command. Development of the system began in 2007. The weapon was installed on the US Navy ship USS Ponce in 2014, for field tests (Fig. 7) [19].

Fig. 7. Combat laser system on board the USS Ponce

The system is designed to destroy unmanned aerial vehicles, manned aircraft and small ships, suppressing electronic air target systems. In terms of accuracy, speed and cost, it is much ahead of similar missile weapons. Among the advantages of this device against projectile weapons is the low cost per shot, as each firing from the weapon requires only a minimum cost of generating energy momentum; on the contrary, munitions for shells must be designed, manufactured, processed, transported and maintained, and occupy storage space.

Thus, the combat laser is a relatively environmentally friendly example of advanced weapons, which doesn't need to use shells and explosives. In addition, a significant number of other weapons and military equipment are being developed, the main common features of which are increasing the technological level of components, the use of artificial intelligence, minimizing human participation in functioning, and the application of new physical principles.

Reducing the level of damage to the environment during warfare as well as daily activities of the armed forces is one of the main tasks of mankind. Therefore, further forecasts of changes in the impact of military confrontation on the environment based on the analysis of promising trends in the development of the art of war and defense technologies will be significant. According to the results of the study, there is a relative

reduction in the impact of war on the environment due to the refusal of conducting warfare by mass conscripts armies, reduction of collateral destruction due to the development of high-precision weapons, and the emergence of relatively environmentally friendly weapons based on new physical principles.

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WASTEWATER TREATMENT BY BIOLOGICAL METHODS

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Abstract. *Purpose of the work is to analyze existing wetland systems, biotechnologies on using hydrobionts and aerated lagoons in wastewater treatment systems. Task of the work is to elaborate experimental wastewater plant unites based on its function characteristics for suggesting improved models. Relevancy of the work is the increasing environmental pollution caused by wastewaters and urgent need for improved implemented wastewater treatment systems. Study methods used in the work included general scientific methods as system analysis, induction, deduction. Obtained results of experimental studied concluded the following: the efficiency of different pollutants removal is higher in hybrid constructed wetlands than in one-stage systems; hybrid constructed wetlands not only resolve ecological problems about wastewater management but can also provide landscape and educational profits because of their interesting shapes and innovative methods used; long term research on the operation of constructed wetland systems in Poland indicate that these systems can be used with great success on rural areas, especially in protected areas and valuable landscapes in Ukraine; cyanobacteria biomass, released from cultural medium, can be used for production of small tonnage valuable products with unique properties, large tonnage biomass of natural origin can be used for fuel production (biomethane, bioethanol, biodiesel); suggested two-stage purification scheme of landfill infiltrates enables to purify infiltrates effectively with primary purification under conditions of aerobic lagoon on the territory of landfill, transporting of infiltrate with the help of pipeline «landfill – municipal PCF», dissolving it with municipal sewerage effluents and pretreatment on municipal PCF.*

Keywords: *wetlands, aerated lagoons, wastewater treatment, biofuel production, cyanobacteria, hydrobionts, biomass.*

I. PERSPECTIVE OF USING WETLAND SYSTEM IN POLAND

Recent solutions for wastewater treatment in Poland are household wastewater treatment plants that in Poland can be defined as objects that support up to 50 people and their maximum capacity is 5 $m^3 \cdot d^{-1}$ [Water Law 2017, Poland]. There can be enumerated many different types of them and the most important ones are the facilities with drainage pipes, with active sludge, with biofilter, hybrid systems (active sludge+biofiter) and constructed wetlands [Jóźwiakowski et al. 2012]. The first one-stage constructed wetland in Poland was built during 1994-1996 and the scheme of such a facility can be seen on the Appendix 1. Constructed wetland wastewater treatment method involves the use of sorption processes of pollutants, chemical redox reactions and biological activity of selected plants that inhabit the marsh ecosystems. Wastewater treatment using wetlands can take place in natural or artificial conditions, then called "wetland" and "constructed wetland" respectively. Such wastewater treatment is widely applied in many countries (Austria, Czech Republic, Denmark,

Germany, Italy, Poland, Portugal, Korea, Japan, Australia etc.) Pollution removal in constructed weltand systems occurs due to the functioning of a biofilm which is formed during the flow of wastewater through the bed. Plants play an auxiliary role in the sewage treatment process. In the rhizosphere (around plant roots) oxygen is produced, while other parts of the bed are anaerobic zone and they are poorly oxygenated. Plants in the constructed wetland systems can be assessed as elements which enable constant oxygen supply from the atmosphere to the bed. Due to the aerenchyma diffusion of oxygen from the atmosphere through the leaves and reed stems allows oxygen to flow into the root zone and then into the ground bed ecosystem, where oxygen can be additionally transferred through molecular diffusion resulting from the chaotic movement of gas particles [Brix 1993]. Plants in constructed wetland systems can have the following functions: stabilizating the surface of beds and protecting them from erosive wind, excellent habitat for fauna (especially birds), excellent thermal insulation, protecting the filter material from freezing in winter, excellent conditions for the development of heterotrophic microorganisms responsible for the organic matter rotting.

In recent years there has been observed a tendency to build hybrid CWs consisting of two or three beds with vertical and horizontal wastewater flow [Gajewska and Obarska-Pempkowiak, 2009; Dębska et al., 2015; Jóźwiakowski et al., 2016]. According to many authors, hybrid CWs provide better conditions for biological wastewater treatment [Gajewska et al., 2004; Gajewska and Obarska- Pempkowiak, 2009; Vymazal, 2005; Masi and Martinuzzi, 2007]. There can be different types of hybrid CWs, we can combine not only different plant species but also different types of sewage flow can be implemented – with vertical and horizontal flow (Appendix 2).

So far there has been built a lot of constructed wetlands in Poland. Many researchers test different equipment and combinations of plant species in order to obtain the best efficiency of domestic wastewater treatment. One of such scientific groups which concentrate on CW systems is the Department of Environmental Engineering and Geodesy from the University of Life Sciences in Lublin. The scientists design and make studies especially on the objects located in south-eastern part of Poland, in Lublin voivodeship. The most common ones are recently the hybrid CWs located in the Roztocze National Park and in the Polesie National Park. A very interesting aspect that should be mentioned is the unique shape of these CWs. For instance in Kosobudy (Appendix 3) the ground and plant beds are designed in the shape of a christmas tree, while in Stare Załucze (Appendix 4) we can observe a turtle shape wastewater treatment plant. The application of constructed wetlands in the areas of nature protection proves that this is a great solution of wastewater treatment which enables not only reliable operation and environmental care of endangered places but can also provide landscape and educational profits because of their interesting shapes and innovative methods used. A multicriterial analysis which takes the above-mentioned criteria into account shows that the use of CWs is consistent with the idea of sustainable development [Jóźwiakowski et al. 2015]. These systems fulfil all of the sustainability criteria, in particular the ecological criterion, as they ensure high efficiency of wastewater treatment with relatively small energy demand [Jóźwiakowski et al. 2019].

It has been observed by many researchers that constructed wetland enable not only high efficiency of wastewater treatment but also a reliable operation for many years. According to many authors CW systems can be a great solution for domestic wastewater treatment as they enable the elimination of many different pollutants such as: TSS, BOD_5, COD, total nitrogen, total phosphorus, heavy metals and pathogens.

The basic element of every constructed wetland system should be an initial septic tank which ensures the elimination of the biggest pollutants during sedimentation, flotation and fermentation. Then sewage after initial purification can be easily treated while biological purification processes occurring in the ground and plant beds. About 25 years of research on the CWs in south-eastern Poland has shown that the discussed systems provide especially high efficiency (over 80%) of biological pollutants removal, which has been expressed by the decrease of BOD_5, COD and TSS values [Jóźwiakowski et al. 2019]. The changes in the state of wastewater treated in the CW system are easily visible which is presented in the Appendix 6. Long term observations have shown that the efficiency of different pollutants removal in the hybrid constructed wetlands is bigger than in the case of one stage CW systems which can be seen in the Appendix 7. For this reason the discussed systems are suggested to be implemented not only on rural areas with dispersed housing, but especially on the protected areas, where the demands of pollutants removal are extremely tight.

On the basis of the polish experiences it can be stated that the efficiency of different pollutants removal is higher in hybrid constructed wetlands than in one-stage systems. Hybrid constructed wetlands not only resolve ecological problems about wastewater management but can also provide landscape and educational profits because of their interesting shapes and innovative methods used. Long term research on the operation of constructed wetland systems in Poland indicate that these systems can be used with great success on rural areas, especially in protected areas and valuable landscapes in Ukraine.

II. PERSPECTIVES FROM USING HYDROBIONTS AND AERATED LAGOONS

Very promising and perspective biotechnology resource for wastewater treatment are such hydrobionts as cyanobacteria. Cyanobacteria play significant role for balanced development of hydro-ecosystems, since they are the main, and sometimes the only, producers of primary organic substance in them. It is estimated today, that from 20 to 30 % of oxygen, obtained from photosynthesis in our planet, is owed to cyanobacteria. This is exactly why they played central role in alteration of air content and atmosphere structure. Cyanobacteria fix oxygen not only in soils, but in coral reefs as well as in other marine ecotopes, making nitrogen available to other organisms under conditions of different ecosystems. Cyanobacteria don't need vitamins for existence and development. They can use nitrates or ammonia as source of nitrogen and also phosphorus compounds and microadditives of such elements as ferrum, sulphur, zinc, copper, manganum, cobaltum, molybdenum etc. Most of their species are phototrophs, but some filamentous types can grow in darkness, using some carbohydrates (glucose or saccharose) as source of energy. Optimum conditions for cyanobacteria growth lay in complex of interconnected, mostly abiotic factors. The method of thickening of the

aqueous suspensions of *Microcystis aeruginosa* using the coagulation-flocculation pretreatment was studied using the industrial coagulants and flocculants produced by P.P.H.U. WĘGLO-STAL (Poland). In the investigated suspension of *Microcystis aeruginosa* (without cavitational treatment, or after cavitational treatment), an appropriate reagent composition was added. Content of additives in different samples of suspension are given in Appendix 14. In order to improve the techno-economic indicators of the method researches were done using the very diluted suspensions Appendix 14. The mass contents of PAX-18 and PAX-XL19H coagulants in different suspensions were equal 10 ppm or 1 ppm, and the mass content of flocculant A100 was 10 ppm or 1 ppm, if it used separately, and only 1 ppm if it used in combination with coagulants.

The results of microalgae suspensions thickening by sedimentation with preliminary coagulation and flocculation treatment with the PAX-18 and PAX-XL19H polymer coagulants, as well as the A100 flocculant are shown in Appendix 15. The numbers of the measuring cylinders correspond to the type and concentrations of the additives indicated above in the Appendix 14. Cyanobacteria biomass contains many target products that are valuable for different fields of modern bioeconomics: food, pharmaceutical and perfumery industry. Under natural conditions these bacteria massively grow for centuries as primary source of organic compounds. In our time much effort has been put in field of genetic engineering for modification of phototrophic microorganisms, especially cyanobacteria, − producers of new useful compounds (target products) that aren't synthesized in natural way. Actual direction of modern studies is also environmental biotechnology and bioenergetics that anticipate direct application of cyanobacteria large-tonnage biomass and other massive forms of hydrobionts as raw material for biofuel production (biomethane, bioethanol and biodiesel) and mineralorganic fertilizer. Production of another fuel type − biogas (biomethane) using method of anaerobic digestion of cyanobacteria (biomethanogenesis), that uncontrollably grew during summer period in reservoir water area of Dnieper waterfall. Experiments have shown, that although no universal method for harvesting and concentration of microalgae exists (it is still productive field for studies), for every particular algae species, optimal economic ways and methods can be made. After concentration, in majority of cases it was used a biomass dehydration, resulting increase its maximum term of residence. For microalgae, such ways of dehydration are used as drum, pulverizer, sublimation or solar desiccation. Extraction of lipids and pendent fatty acids from biomass is conducted directly from lyophilization biomass. For extraction can be used such dissolvents as hexane, ethanol or mixture of both hexane and ethanol, which allows to extract up to 98 % purified lipids and fatty acids. Studies have shown, that in case of damage of cellular wall of algae with help of ultrasound procession, extraction of target product increases from 4,8 % to 25,9 %. From obtained feedstock, biodiesel can be produced using traditional technology– repeated esterification of plant oils. Lipid feedstock consists from 90–98 % (weight) triglyceride and small amount of mono- and diglyceride, contains free fatty acids (1–5 %) and small amounts of phospholipids, phosphatides, carotenes, tocopherols, sulphur compounds and remnants of water.

The most popular wastewater technologies in Ukraine are the following: reverse osmosis technology; technology of chemical and biological oxidation; infiltrate knotting technology; technology of biological purification in anaerobic and aerobic medium.

Aerobic methods of biological purification of filtrates have row of undeniable advantages over anaerobic: they are flexible in using, fast include in stationary regime of work, fast accommodate to changeable composition and expanses of filtrates. Aerobic reactors are far more simpler in construction and far more cheaper than anaerobic, they are also much easier automatized and easier in exploitation.

From analysis of existing natural studies it is possible to make conclusion, that purification of infiltrates in aerobic lagoon (or simultaneously connected lagoons) is simply, low-budget and enough efficient method of pretreatment of infiltrates.

Study of the aerobic purification was conducted at plant (Appendix 16).

The plant contained from 5-litter bulb, that with volume of 4 l was filled with infiltrate. Infiltrate for studies was chosen from pound-accumulator of Lviv MSW For aeration the air was supplied to bulb with the help of laboratory compressor. With the help of regulation compressor, set on air flow tube, it was regulated air expanses on aeration and supported constant significance of this expanse throughout the whole experimental time. Experimental work was conducted in two stages.

At first stage (static) was set alteration of COD, concentrations of ammonium nitrogen, pH and concentration of dissolved oxygen under conditions of continuous aeration without allotment of pretreated infiltrate and accordingly without addition into volume `fresh`, untreated infiltrate.

At second stage (dynamic) that was conducted after obtaining maximum possible level of purification under static regime, it was modeled continuous regime of purification, that is planned to be implemented at industrial pollution control facility. Once in 24 hours from bulk it was taken certain amount of infiltrate and was poured same amount of `fresh` unpurified infiltrate. For certain proportion significance of the sample the researches were conducted for obtaining constant concentrations of ammonium nitrogen and COD. After that, the daily volume of purified and `fresh` infiltrate was substituted, that accordingly was collected and poured into aeration plant, and it was studied a process of aerobic purification in dynamic regime for another time significance of infiltrate delay in aeration zone. Once in a day an infiltrate sample from bulk for analysis and sample for addition of infiltrate were taken.

Methodology of tertiary infiltrate treatment research at PCF.

For experiments in static regime for research place a mixture of effluents with active sludge was taken. Infiltrate in quantity of 1 m^3 was selected from pound-accumulator №5 in MSW Hrybovytske landfill. In experimental aeration plant was poured mixture of effluents and active sludge and was added calculated quantity for obtaining mixtures, that met the following dissolving criteria: 10; 500; 1000; 1250; 1500. In reactor it was added mixture of effluents with active sludge till obtaining general volume in 1,64 m^3. After that samples were taken for chemical experiments and the plant was launched. Every study cycle in static regime lasted 6 hours. After finishing of air supply a sample was taken for conducting chemical experiments.

Experiments in dynamic regime were conducted at the same plant (Appendix 17) The plant contained primary settlers: primary model settler for mixture of effluents with infiltrate and primary model settler for effluents without infiltrate. During 8 daily experiments the mixture from effluents and infiltrate as equally carried to aeration plant 1. Regulations of expanses were carried with the help of circulation pump and valve. Homogeneity of the mixture was obtained with the help of aerator. After 8 hours of mixture supply from effluents with infiltrate it was modeled working process of aerotank during 16 hours without adding infiltrate.

General strategy for two-stage cultivation of landfill infiltrates

Analyzing research data it is recommended principal scheme for implementation of landfill infiltrates pretreatment technology that is illustrated in Appendix 18. According to this scheme, infiltrates are accumulated in pound-accumulator that simultaneously serves as aerobic lagoon.

For this it is equipped with aeration system. Pound-accumulator is being screened with protective display by using well known technologies. In aerobic lagoon biological aerobic oxidation is taking place of organic contaminants and of ammonium nitrogen. Constant inflow is being realized and harvesting of infiltrates under conditions of supplement with necessary period of infiltrate residence in reactor. Infiltrate collection is being done with the help of pump station throughout set pipeline «landfill – municipal PCF» infiltrate is transferred into mixing block PCF where at given proportion it is mixed with municipal effluents and in mixture is directed to tertiary treatment at municipal PCF. For every particular case for technology implementation it is necessary to make balance calculation.

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AIR-LIQUID MICROTUBE CARBON DIOXIDE CAPTURE SYSTEM

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Abstract. *Our approach lies in using an already effective and performant mechanism of the human respiratory system repurposed to filter and transform carbon dioxide instead of oxygen.*

This concept effectively divides posed problem into three separate tasks: capturing of CO2 (taking analogy from alveoli to increase contact area), transportation of CO2 through-out the system (optimized substance analogous to blood to provide minimum losses of gas), and utilization system (inspired by cells functionality we combine CO2 with industrial waste to produce carbonates).

What is unique in our approach is the choice of materials and substances that enable us to create efficient and performant system.

Keywords: *sequestration, carbon dioxide, sorbent, superamphiphobic, capture.*

I. INTRODUCTION

Our approach lies in using an already effective and performant mechanism of the human respiratory system repurposed to filter and transform carbon dioxide instead of oxygen. This concept effectively divides posed problem into three separate tasks performed by biological constructs: capturing of CO2 performed by alveoli, transportation of CO2 through-out the system – blood, and utilization subsystem that transforms CO2 into useful product - cells.

We deconstructed underlying mechanism of each of these parts to optimize it as much as possible: refining geometry of the filtering component to maximize contact area for capturing CO2 and efficiency of diffusion, using regenerative sorbent as a transport to improve lifetime of the system and increase amount of gas processed, applying electro-chemical method to combine CO2 from previous phases and industrial waste of thermal power stations to produce carbonates making system even more ecological – all these methods and ideas combined to deliver effective and relatively cheap system for removal of carbon dioxide.

The scientific or engineering phenomena that your concept relies on:

1) gas diffusion under the action of a concentration gradient. In our case, CO2 will diffuse from the air into the sorbent where its concentration in the ideal case is 0;

2)increasing diffusion surface area due to the use of superamphiphobic porous monoliths material and special geometry ;

3)Using of special chemical properties of the KOH that make it a good sorbent for CO2 ;

4)electrochemical method of sorbent regeneration based on K2CO3 electrolysis with the formation of H2;

5)The mineral carbonation technologies which based on the spontaneous

reaction between CO2 and metal oxide bearing minerals to form insoluble carbonates.Mineral carbonates such as CaCO3 or MgCO3 are the thermodynamically most stable form of carbon, long-term storage of CO2 can be achieved once it is transformed to carbonates;

6) possibility of transformation products, such as CaCO3, to value-added materials that can be utilized in various applications such as adhesives, sealants, food and pharmaceuticals, paints, coatings, paper, cements, and construction materials.

The simple illustration of working of the system that we proposed is shown on the Fig. 1.

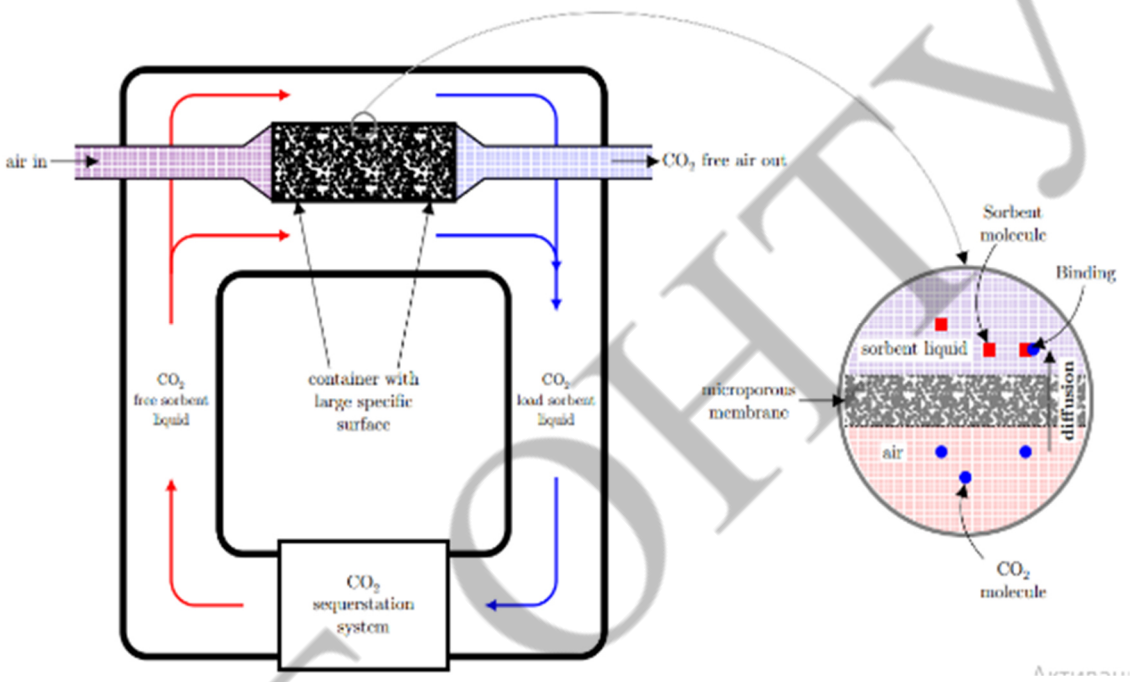

Fig. 1. Basic sheme

II. LITERATURE ANALYSIS

Our work is based on a big massive of information from science literature. The information was taken from articles from the lead science journals like “Nature”, “ScienceDirect”, “Springer” etc.

Because in our work there were used principles from different areas of physics we broke our literature analysis on subsections which contain information about such area.

2.1. Human respiratory system

Book [1] describes the structure of human respiratory system using a mathematical apparatus, and gives many interesting examples of the application of different sciences to the study of the respiratory system

2.2. Modern methods of carbon dioxide capture

[2] this book describes well the modern industrial methods of CO2 capture.

Article [3] describes the main technologies for CO2 direct air capture. Articles [4], [5] provide a qualitative description of various electrochemical methods for the regeneration of liquid sorbents.

In the article [6] is shown a method for the synthesis of superamphiphobic porous monoliths and also shows an experimental analysis of their properties. Article [7] demonstrates the practical implementation of a CO2 capture system using electrochemical sorbent regeneration. The experimental data are also compared with the simulation results.

In article [8] is demonstrated the practical implementation of a CO2 capture system using a KOH as a sorbent and also demonstrates its electrochemical regeneration using electrolysis with hydrogen evolution.

Article [9] reviews and justifies the use of the ex situ mineral carbonation route as a way to efficiently utilize CO2.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The proposed device is a combination of common design and novel materials. In the multiple studies [10–13] for adsorption of gas to the liquid, used, so called, hollow fiber membrane pipes made from polymeric materials with high specific surface. Recent publication [14] claims about manufacturing a highly permeable porous (70%) superamphiphobic material based on Low-temperature expandable graphite and polyvinylidenefluoride with good operation stability (fig.1), which is planning to use in our device.

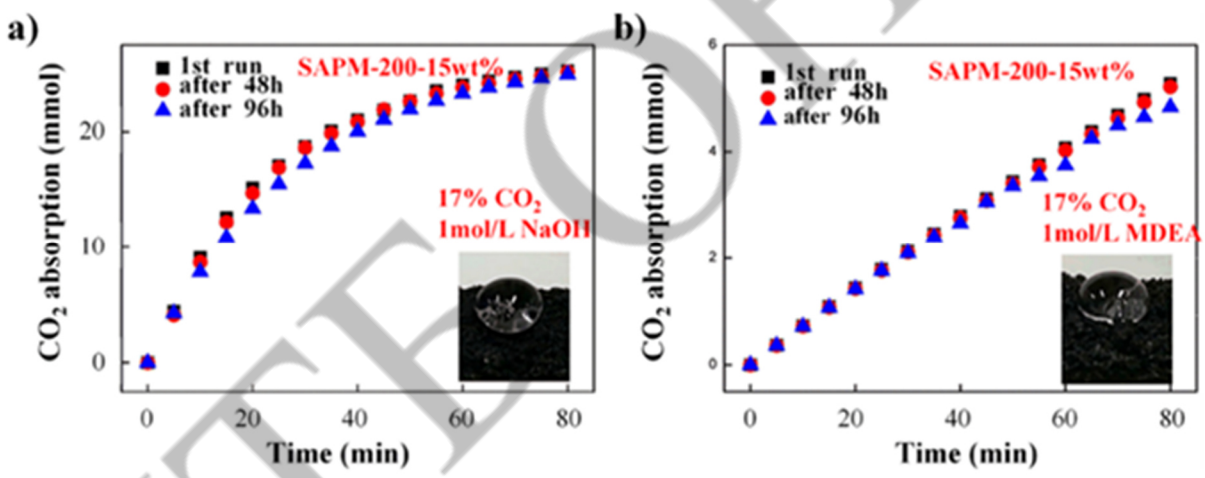

Figure 1: Operation stability of considered membrane

The device is represented as cylinder tube with diameter around 0.5-1 m and length up to 1m filled with hollow fiber tubes with diameter 10-20mm. Inner cut of device's model with some number of pipes in the center depicted on the Figure 2.

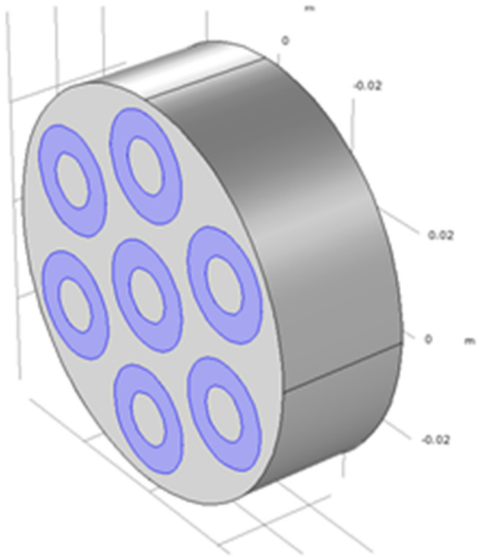

Figure 2: Inner cut of device

Gas flows in the pipes and liquid with diluted adsorption solution washed the outer shell around the pipe. Researchers conduct various studies to obtain removing rate of CO2 from concentrated mixtures of gases depending on velocity of gas and liquid flows and further adsorption with NaOH [10; 11]. From this results seems that convection transfer can significantly affect the diffusion of CO2 through membrane.

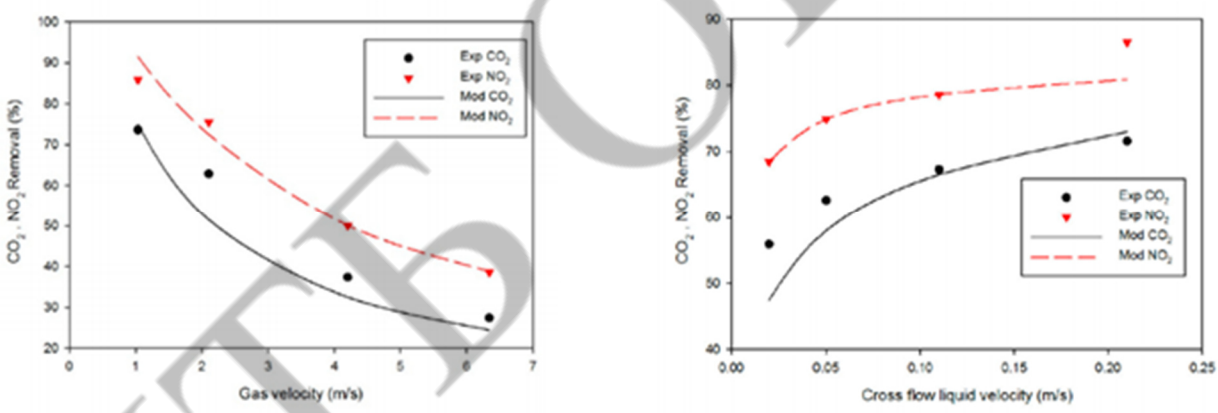

Figure 3: Percent removal of CO2 and NO2 as dependency of gas and liquid velocity [13]

We instead, tried to conduct a small research on the dependency of diffusion flow through the pipes and volume of adsorbed gas based on configuration inside the device and distance between fibers assuming constant shapes of device. Total amount of gas adsorbed through membrane will be proportional to the total outer surface area of fibers so to the numbers of fibers in the device. Changing the distance between fibers inside we can achieve better concentration gradient (so diffusion flux) but in the same time decreasing number of fibers which can be located inside device. The idea was to check whether there is an optimal distance between membranes which corresponds to maximum amount of diffused gas. For this reason in COMSOL Multiphysics was simulated (fig.4) pure diffusion (without convective flow) of CO2 concentration of 300-400ppm (average concentration in air) for model depicted on figure 2 and distance between membranes in range from 5 to 15mm.

IV. RESULTS

This section can be split into several subsections (if necessary). Tables and figures must be referenced in the text and formatted as follows:

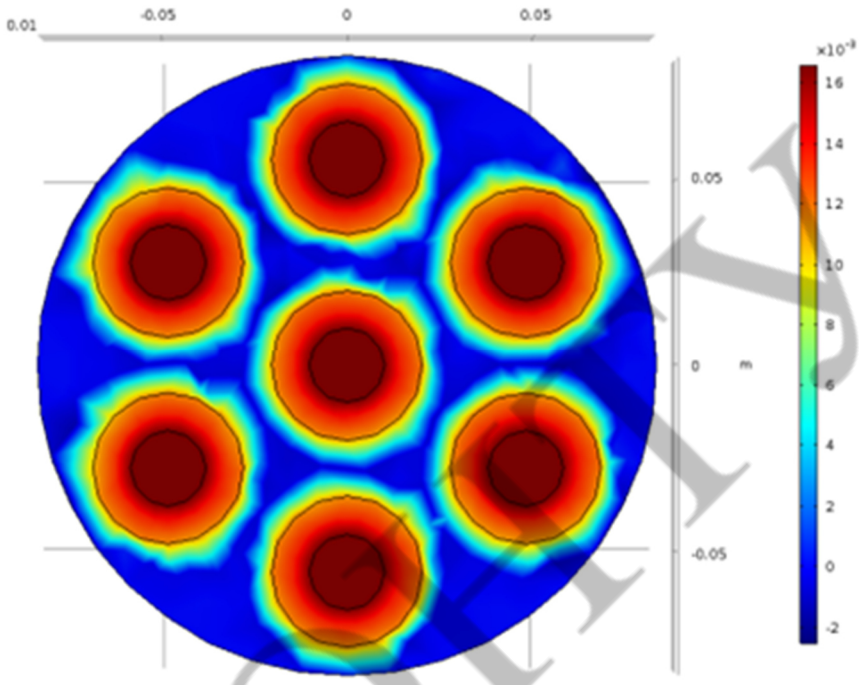

Figure 4: Simulated concentration distribution of CO2 diffused from air to water.

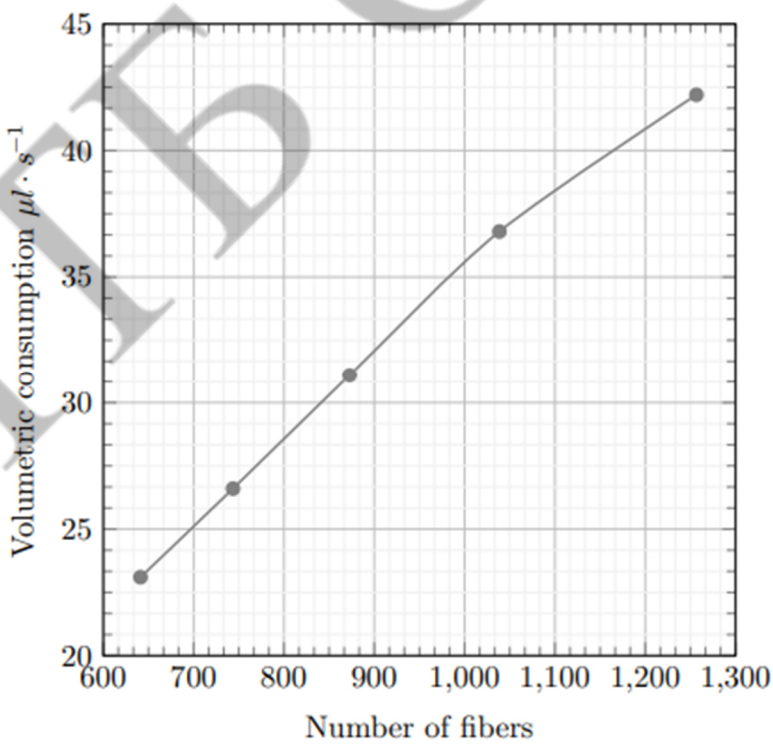

Figure 5: Dependency of volume of CO2 , that can be adsorbed for 1 second, from number of fibers required for device

Also initial results of feed pressure, pressure which is required to push gas

through pipe and allow diffusion through membrane, was obtained. To pump gas with a velocity of 1 m/s through pipe with diameter of 10mm for 2 cm require 0.5 atm of pressure. From the estimation for all device will be necessary to get pressure of 20 atm. But exact requirements can be obtained only after further simulation of coupled fluid flow/diffusion/reacting task.

The effect of increasing diffusion flux due to increasing space between membranes appeared not to make significant difference to the total volume of diffused gas, so it is almost linearly proportional to the numbers of fibers. The graph on the figure 5 can be helpful when building device with the known capacity of gas that can diffused per time unit. Using this data it's clear that for current design and maximum number of fibers (≈ 1250) device will collect almost 3 liters of pure CO2 per day.

V. CONCLUSIONS

This article proposes a method of pumping carbon dioxide using a system of microtubes. Theoretical estimates of the scheme are carried out. And also the part of microtubes is modeled. With the help of this, was calculated the number of fibers required for the construction of the device and efficient pumping of CO2.

The detailed scheme of the proposed microtube system is shown on Fig.6

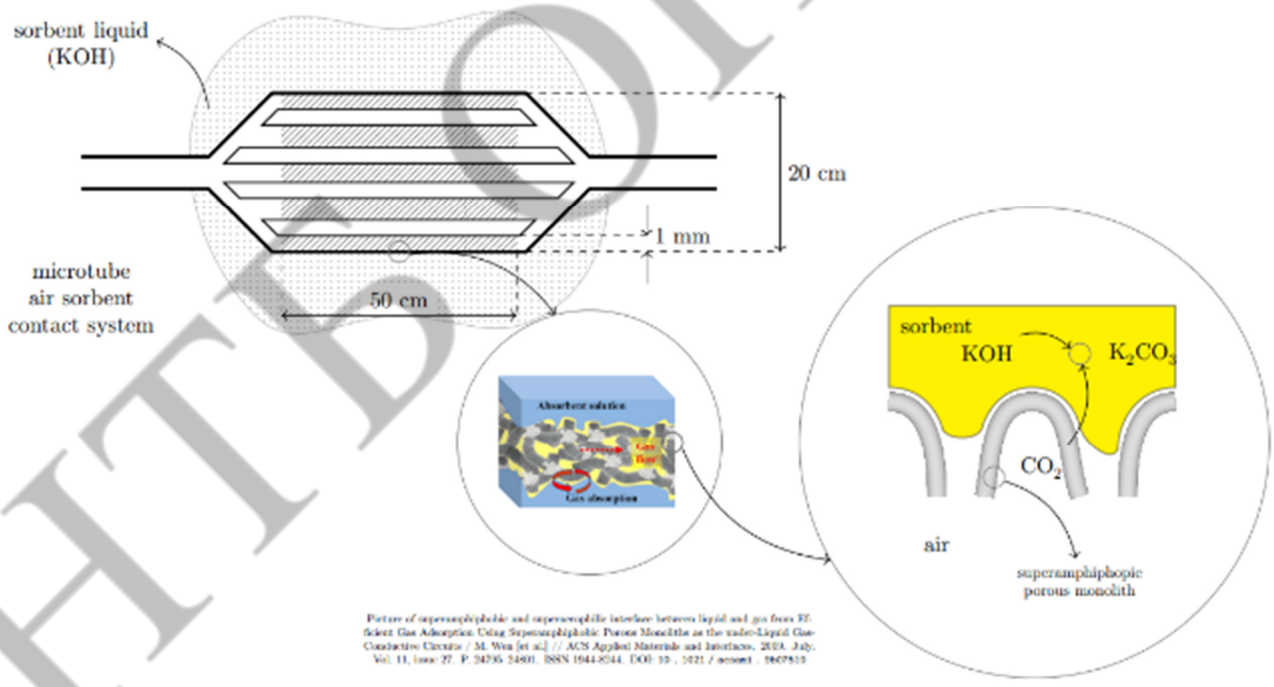

Fig.6 Detailed scheme of microtube system

The process-flow diagram of the whole carbon dioxide capture system with approximate values of energy density is shown on Fig. 7.

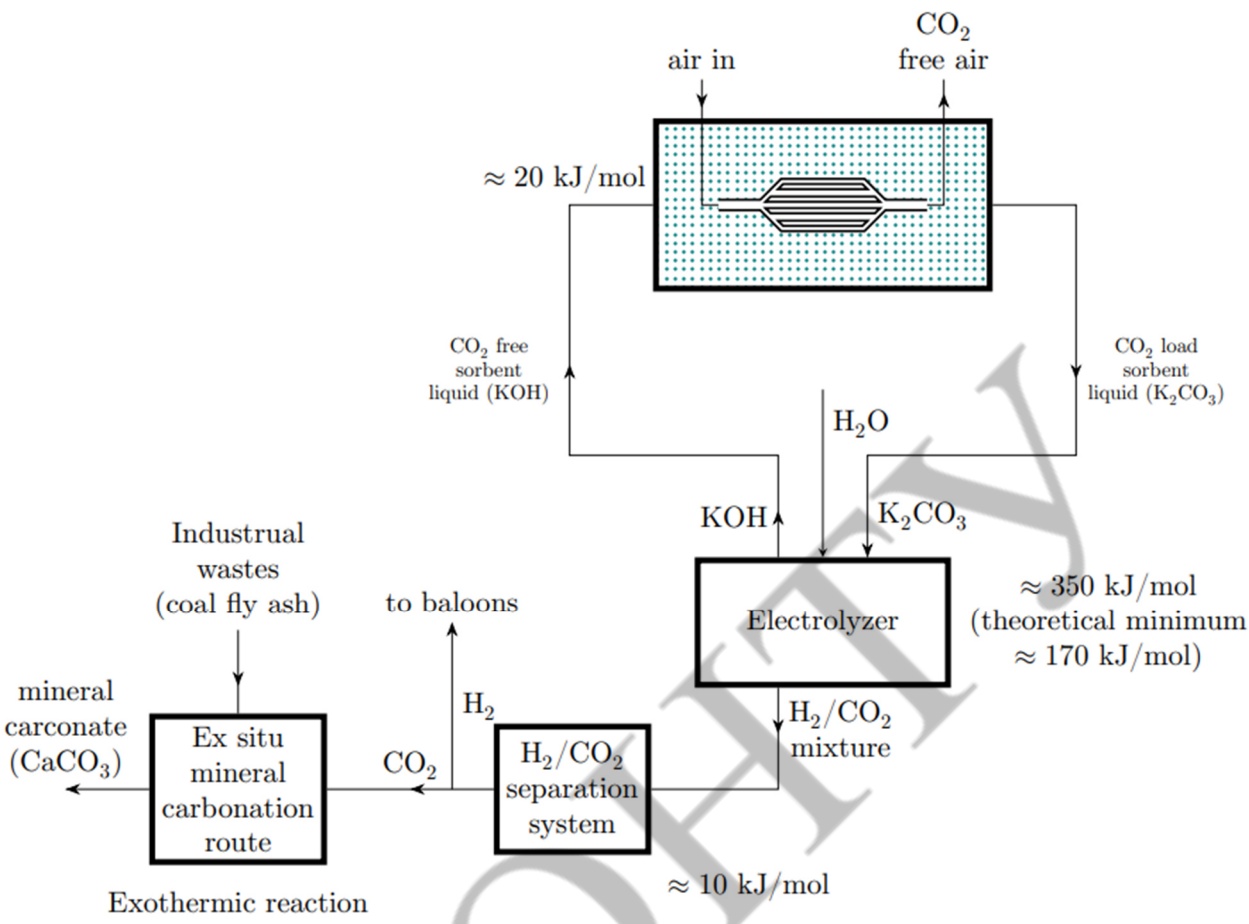

Fig. 7 Process-Flow Diagram

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