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

ODESA, ONUT 2022

Ministry of Education and Science of Ukraine

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Proceedings

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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

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.

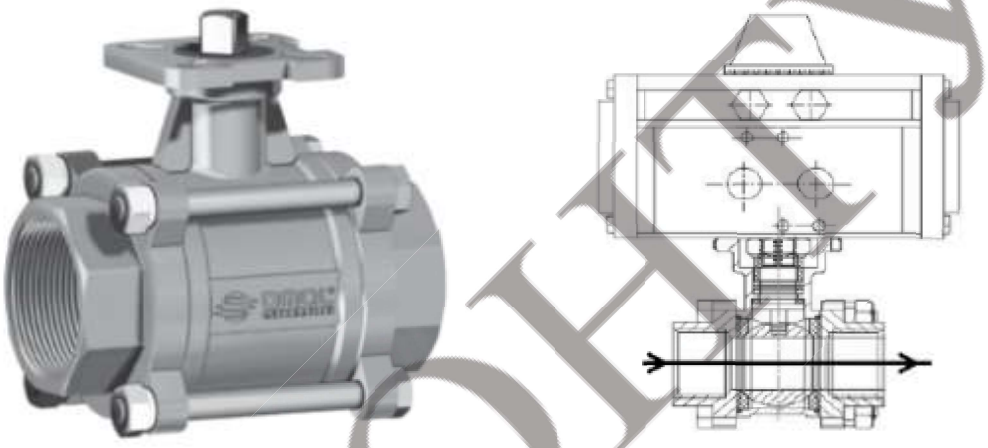


Fig. 1. Three-component ball valve: 1 – shaft; 2 – nut; 3 – disc spring; 4 – sealing ring; 5 – V-shaped shaft seal; 6 – sealing ring; 7 – antistatic ring; 8 – shaft seal; 9 – housing sealing; 10 – sealing the ball; 11 – nut; 12 – bolt; 13 – bullet; 14 – building; 15 – cover

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.

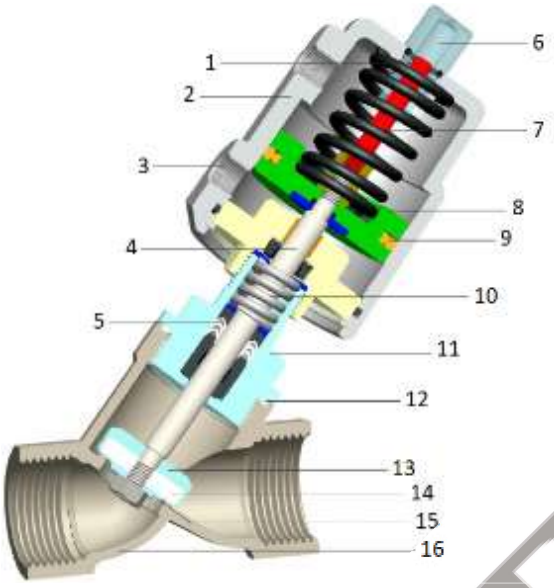


Fig. 2. Seat valve with pneumatic control: 1 – indicator; 2 – drive housing; 3 – air connection port; 4 – stock; 5 – rod seals; 6 – cap; 7 – spring; 8 – the piston; 9 – piston seal; 10 – spring; 11 – cover; 12 – sealing of the case; 13 – saddle; 14 – saddle seal; 15 – washer; 16 – housing

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

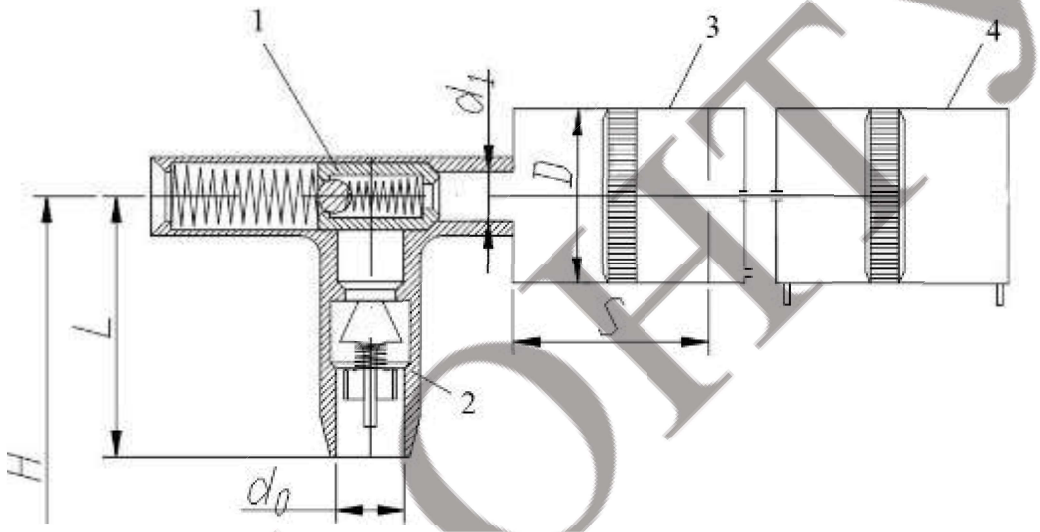


Fig. 3. The scheme of the piston batcher: 1 – locking element; 2 – outlet pipe; 3 – dosing cylinder; 4 – pneumatic cylinder

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.

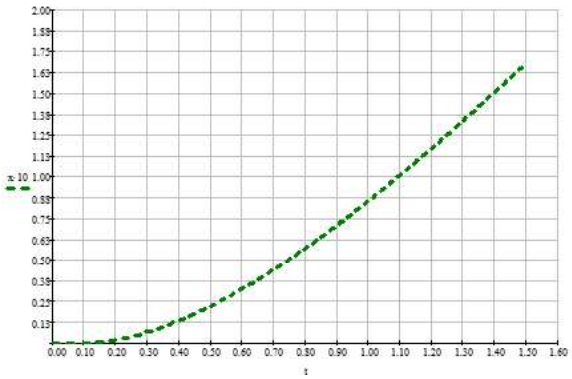


Fig. 4. Graph of the distance traveled over time for the output link of the rotary drive, m

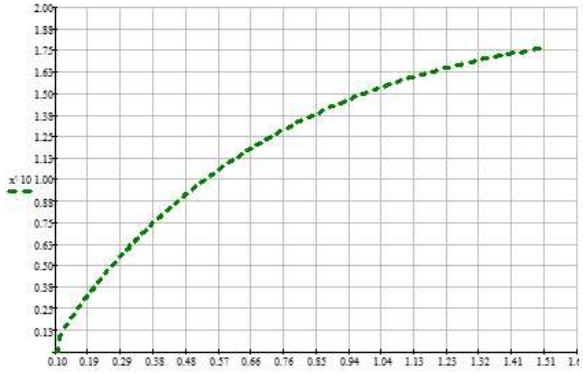


Fig. 5. Graph of the acquired speed when turning the output bench of the rotary drive, m/s

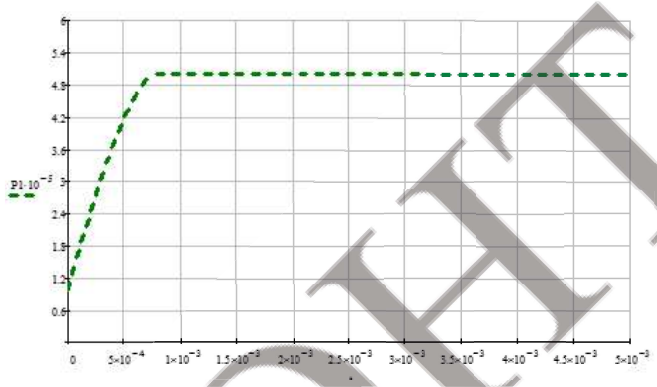


Fig. 6. Partially presented graph of the pressure at the time of pressure supply cavity S_1, bar

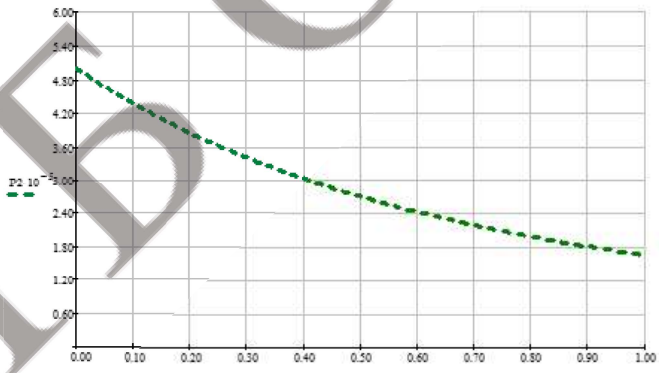


Fig. 7. Graph of pressure relief from the cavity S_2 pressure, bar

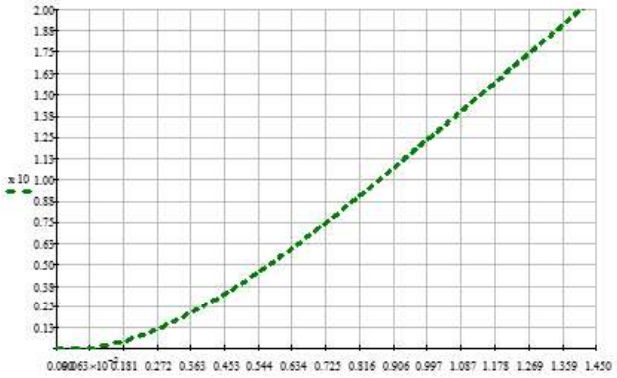


Fig. 8. Graph of the distance traveled over time for the output link of the rotary drive, m

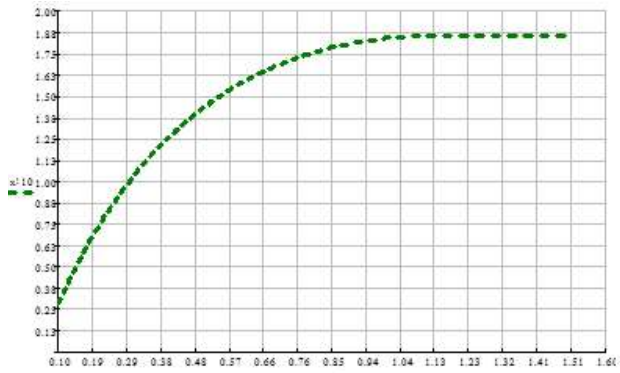


Fig. 9. Graph of the acquired speed when turning the output link of the rotary drive, m/s

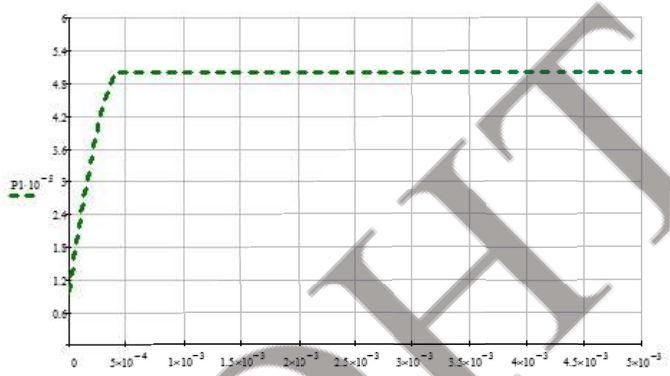


Fig. 10. Partially presented graph of the pressure at the time of pressure supply cavity S_1, bar

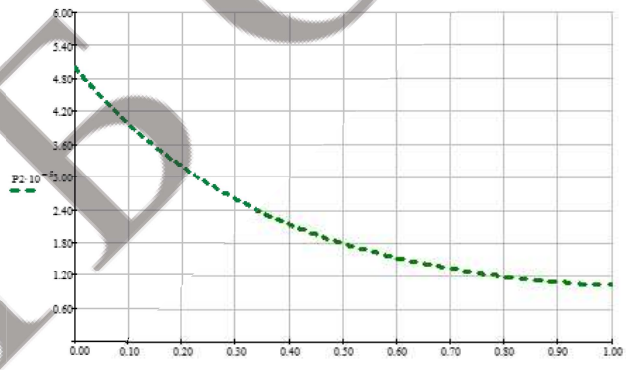


Fig. 11. Graph of pressure relief from the cavity S_2 pressure, bar

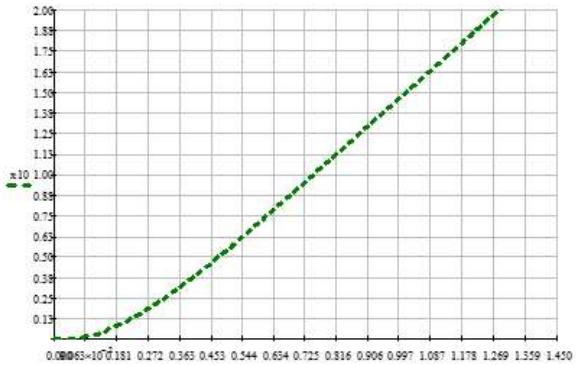


Fig. 12. Graph of the acquired speed when turning the output link of the rotary drive, m

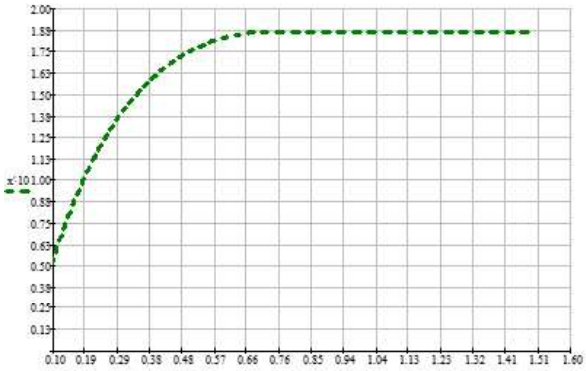


Fig. 13. Graph of the acquired speed when turning the output link of the rotary drive, m / s

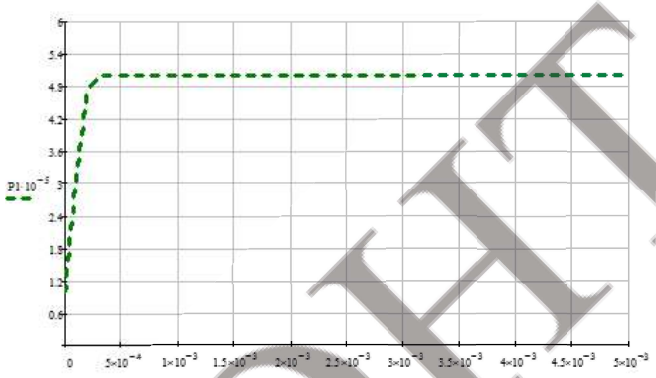


Fig. 14. Partially presented graph of the pressure at the time of pressure supply cavity S_1, bar

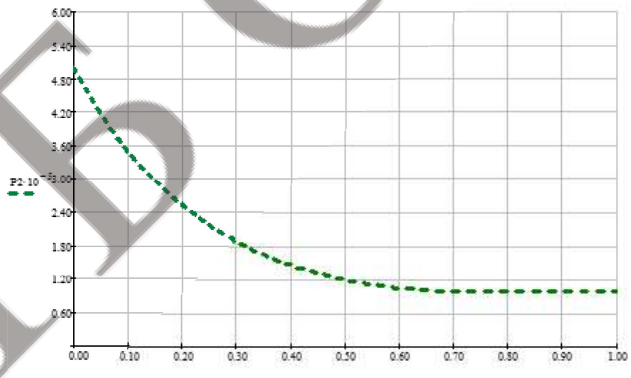


Fig. 15. Schedule of pressure relief from the cavity S_2 pressure, bar

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:

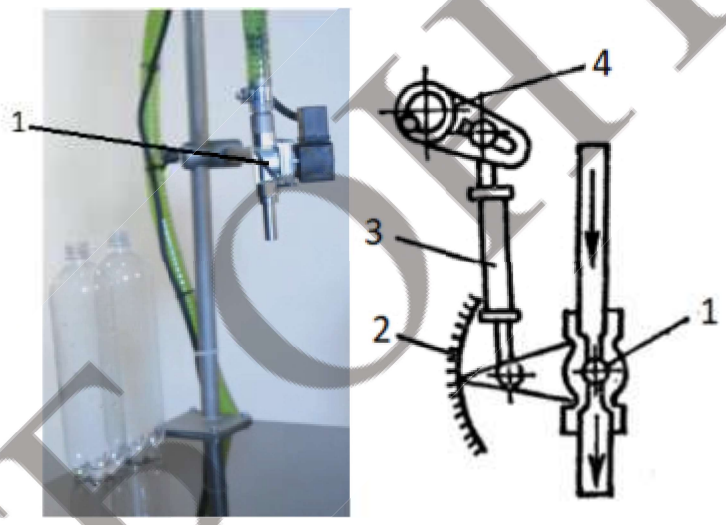


Fig. 16. Installation for the batcher of continuous action:
1 – the electromagnetic valve; 2 – scale; 3 – traction; 4 – rocker arm

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.

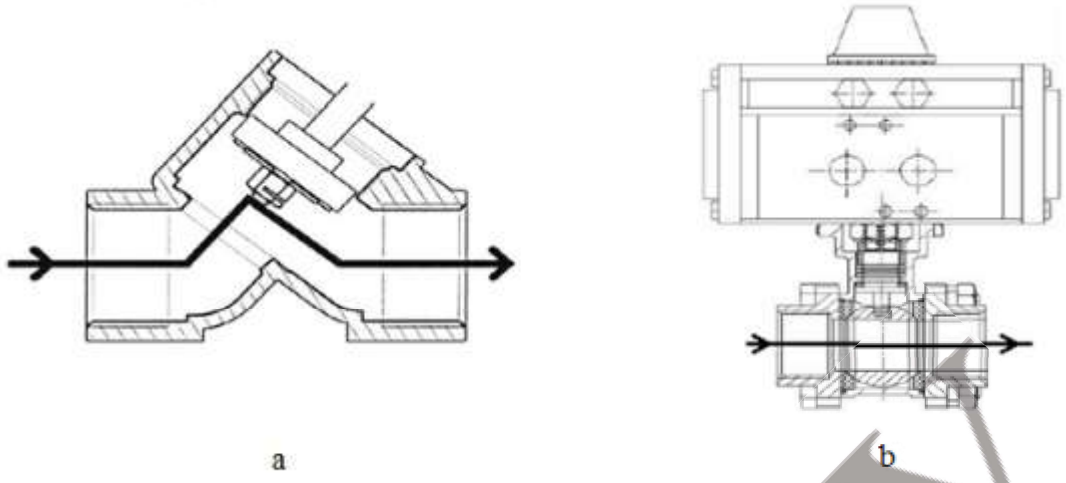


Fig. 17. The direction of the product when passing through: a – saddle valve, b – ball valve on the right

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.

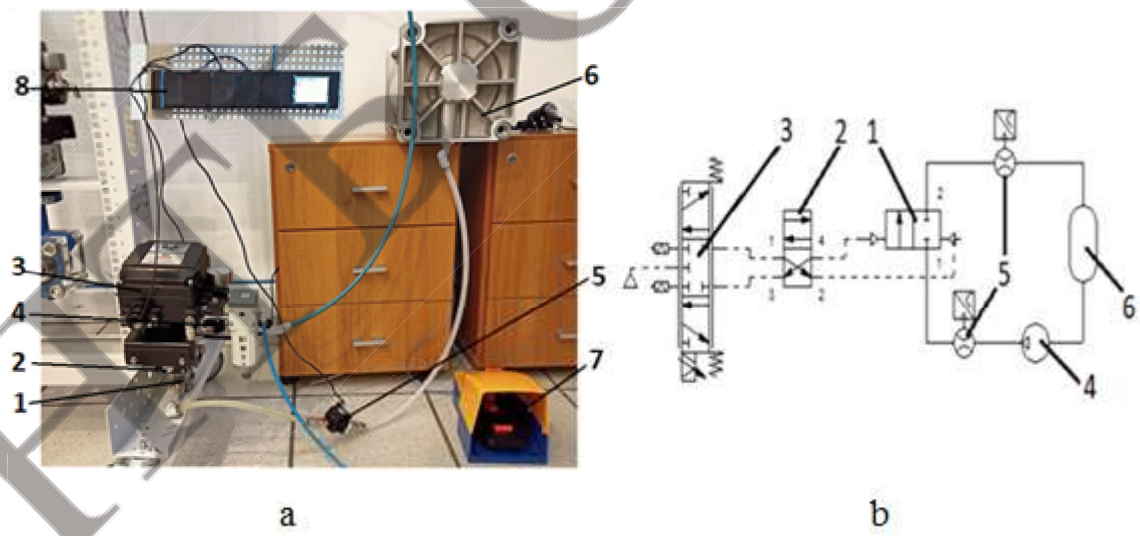
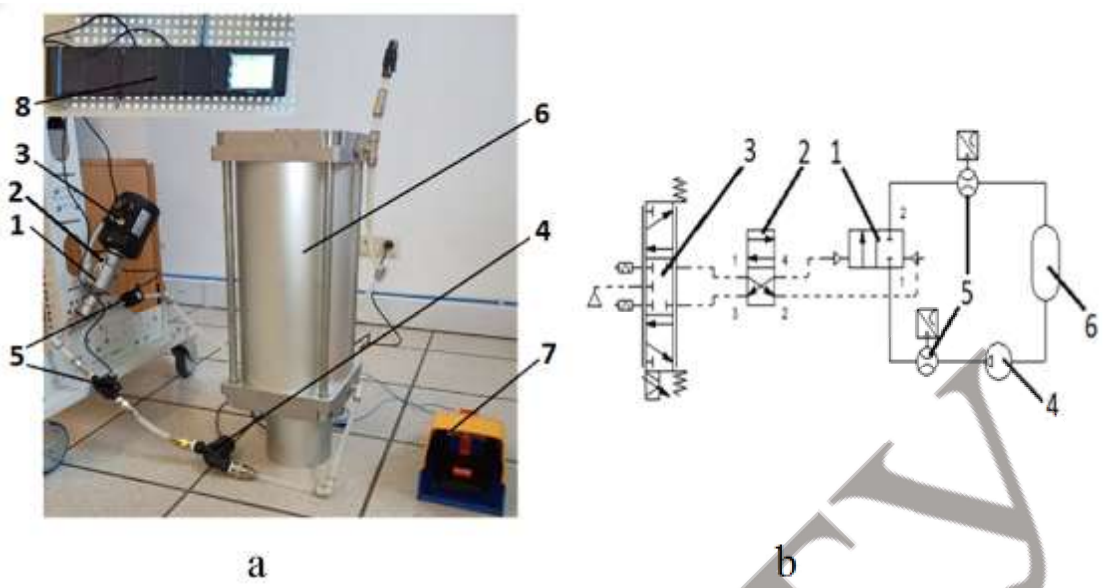


Fig. 18. Experimental installation №1 (a) and its scheme (b) for testing a ball valve: 1 – ball valve; 2 – pneumatic drive; 3 – electropneumatic positioner; 4 – pump; 5 – flow meter; 6 – receiver; 7 – the button; 8 – control and measuring device



a b

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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