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CONTROL OF RISKY SITUATIONS AND CHOICE UNDER UNCERTAINTY

Correct estimation of risks for different technological situations faced in the potentially dangerous technological processes is very important and complicated problem. This problem can't be adequately solved within the capabilities of classical mathematics. The original methodology for correct estimation of risks in risky situations for potentially dangerous technological processes is developed on the base of combining two models – the model of choice under uncertainty and the classical mathematical model of decision-making. Such methodology enables to form the base for mathematical, informational and programming support of the decision support systems for explosion-proof of potentially explosive objects (such as the grain processing enterprises of different types). These decision support systems exclude participation of evaluators and are included in the control systems of the grain processing enterprises.

There are lots of technological processes which can lead (under certain conditions) to accidents with after-effects of varying degrees of severity. These processes are usually called potentially dangerous processes. By the way such technological processes are often connected with objects of chemical-technological types (from grain processing enterprises to powder factories).

One of the main aims of automatic and automated control systems for potentially dangerous processes is to prevent accidents with severe after-effects which lead to great losses and (sometimes) to human deaths. The major problem is to evaluate correctly hazards of accidents. Underestimation of the level of danger leads to tragic consequences. Overestimation of the risk level can become the reason of ineffective operations. The purpose of this work is to develop a methodology for correct estimation of risks for potentially dangerous processes.

Let us consider potentially dangerous process, which is determined by n parameters $p_1, p_2,\dots, p_n$. A specific set of these parameters defines situation $S(p_1, p_2,\dots, p_n)$. Situation S describes the state of technological processing at the moment. Let us call situation S_{cr} a critical situation if it can result in an accident merely by random events. Let us call situation S_r a risky situation if it can lead to a critical situation in some cases of the technological process realization. Put simply, risky situation is a situation when it is necessary to begin to think about prevention of accidents. The aim of control of a risky situation is to prevent emergence of critical situations.

Criticality of situation is characterized by m values Cr_i $(i=1,\dots,m)$. Let us suppose that it is known the area of the n-dimensional space $\{Cr_1,\dots, Cr_n\}$ in which values Cr_i correspond to a critical situation.

The proposed methodology for estimation of risks includes the following items.

1. Finding of mathematical dependences between Cr_i $(i=1,\dots,m)$ and p_i $(j=1,\dots,n)$, i.e. construction of functions $Cr_i=f_i(p_1, p_2,\dots, p_n)$ $(i=1,\dots,m)$; there are m functions of n variables. Solving of this problem is the most difficult part of the proposed method realization. It requires deep knowledge of the technological process, mathematics and special sciences (mechanics, physics and/or chemistry).

Formally it is enough to define Cr_i $(i=1,\dots,m)$ for specific set of parameters $p_1, p_2,\dots, p_n$ and to find out if these values Cr_i belong to the area of the n-dimensional space, which describes critical situations S_{cr}. Calculating values Cr_i for different possible (for development of the risky situation S_r) sets of parameters $p_1, p_2,\dots, p_n$ makes it possible to find the way of technological process (to make a decision) to prevent critical situations. Described above process is based on classical model for decision-making. But this model is applicable for decision making concerning only rather "simple" systems, while modern technological processes are very complicated. Accuracy for determining of the critical area boundaries is not "good enough". The same can be said about accuracy for determining of specific values of parameters $p_1, p_2,\dots, p_n$. So it is necessary to combine the model of choice under uncertainty with classical model for decision-making.

2. Finding of intervals $[p_i^{min}, p_i^{max}]$ for possible changes of p_i $(j=1,\dots,n)$. p_i^{min} is minimum value of p_i for the technological process as a whole. Accordingly, p_i^{max} is maximum value of p_i for the technological process as a whole. As a rule, p_j^{min} and p_j^{max} are determined by production regulations and technical capabilities of equipment.

3. Replacement of values $p_1, p_2,\dots, p_n$ with the corresponding intervals $[p_i^*, p_i^{**}]$ $(j=1,\dots,n)$, where the inequalities $p_i^* < p_i^{**}$, $p_i^* < p_i^{max}$ and $p_i^{min} < p_i^{**}$ take place, but the inequality $p_i^{min} < p_i^* < p_i^{**} < p_i^{max}$ is not always correct. Usually the length of interval $[p_j^*, p_j^{**}]$ is much less than the length of interval $[p_j^{min},$

p_i^{max}], i.e. $p_i^{**} - p_i^{*} << p_i^{max} - p_i^{min}$ ($j=1,\dots,n$). The nature of intervals [p_i^{*}, p_i^{**}] is defined by methods for determination of p_i ($j=1,\dots,n$). Value p_i can be determined by measurements or by calculations. In the first case the interval [p_i^{*}, p_i^{**}] displays the measurement error, in the second case this interval displays either calculations errors or model biases (or, may be, a combination of these two kinds of errors). The cases when $p_i^{*} \le p_i^{min}$ or $p_i^{max} \le p_i^{**}$ are of great importance.

4. Shift away from "clear" values $p_1, p_2,\dots, p_n$ towards fuzzy values P_1, P_2, …, P_n (fuzzification). This fuzzification is based on the intervals [p_i^{min}, p_i^{max}] and the corresponding intervals [p_i^{*}, p_i^{**}] ($j=1,\dots,n$). Exactly from the positions of fuzzification the cases when $p_i^{*} \le p_i^{min}$ or $p_i^{max} \le p_i^{**}$ are so important. The last step of this fuzzification may be shift away from fuzzy values to linguistic variables (but sometimes it is not necessary).

The essential principle of the described above fuzzification lies in fuzzifying all input values into fuzzy membership functions by using formulae obtained by methods of classical mathematics or by using experimental data. Mathematical equations for mechanical, physical or chemical processes are considered only as approximate estimates. These equations form basis for inequalities. Those inequalities, in their turn, form the base for constructions of fuzzy membership functions. The supposition of the approximate character of mathematical equations for complicated processes (mechanical, physical, chemical, etc.) is fully justified because of the errors of appropriate theories and inaccuracy of the input data (obtained, as a rule, from different experiments which are almost always not accurate). This way of the definition for fuzzy membership functions makes it possible to avoid bringing evaluators in and (as a result) to avoid all problems and weaknesses connected with evaluators and their interaction and cooperation with decision-makers.

5. Shift away from "clear" values $Cr_1,\dots, Cr_m$ towards appropriate fuzzy values $C_1,\dots, C_m$ (fuzzification). This fuzzification is based on functions $Cr_i=f_i(p_1, p_2,\dots, p_n)$ ($i=1,\dots,m$) and on the fuzzy values P_1, P_2, …, P_n. As a result fuzzy functions $C_i=g_i\, P_1, P_2, \dots, P_n)$ ($i=1,\dots,m$) must be obtained. The last (but sometimes unnecessary) step of such fuzzification may be transition to linguistic variables.

6. Fuzzification of the critical area boundaries and formation of fuzzy criteria for determining situation $S(p_1, p_2,\dots, p_n)$ as a critical situation S_{cr}.

7. Verification of the conformity of the specific sets of parameters $p_1, p_2,\dots, p_n$ with possible critical situations and making of adequate decisions.

Such methodology for estimation of risks is based combining of model of choice under uncertainty with classical model. This methodology is very useful for solving some problems of the explosion-proof (especially for the grain processing enterprises). Decision support system (DSS) for explosion-proof of the grain processing enterprises of different types (elevators, flour milling plants, compound feed plants) was enlarged and improved by consistent using described above items. This DSS gives opportunity to estimate the possibility of the primary explosion on the enterprise. It also gives opportunity to estimate the possibilities of the secondary explosion at any object of the grain processing enterprise in the presence of the primary explosion at the other object of this enterprise. These estimations are represented in decision-making software (DM software), i.e. in special computer applications that are used to help decision-makers to make choices and take decisions.

This DSS enables:

– to specify the most explosive objects of the grain processing enterprise either in terms of the primary explosion or in terms of the secondary explosion in presence of the primary explosion;

– to specify the most effective control actions (these control actions may be technical, technological or organizational, but in one way or another these actions are limited generally to changes of parameters $p_1, p_2,\dots$, i.e. changes of a dust concentration, humidity, pressure, temperature, etc.) for ensuring of the explosion safety of the grain processing enterprise;

– to specify the most effective control actions for suppression of the secondary explosions, such actions prevent development of explosions.

The following conclusions can therefore be drawn from the aforementioned.

– The original methodology for correct estimation of risks in risky situations for potentially dangerous technological processes is developed.

– This methodology is based on combining of the model of choice under uncertainty with classical model for decision-making.

– This methodology is adequate for modern technological processes. It is used successfully for enlargement and improvement of DSS for explosion-proof of the grain processing enterprises of different types. Original software for real time control of risky situations is created.

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