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SYSTEM ANALYSIS OF THE ACCIDENT RISK OF SURFACE MINING OBJECTS AS A BASIS FOR THEIR SAFE OPERATION

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Purpose. Making one of the reliability assessment methods of structural elements of objects surface mines as a system of risk analysis of possible defects in the construction of structures and organizational reasons that can lead to an accident, allowing to manage security in the operation.

Methodology. Developed the analytical model for determining the accident risk assessment of structures (structural collapse), in which made the diagnostics of the technical state of the object surface mines and found the value of the actual degree of survivability. To determine the risk standard levels an object is represented as a system consisting of connected groups of the same type of bearing elements. During the simulation are considered the main parameters: technical, human and organizational factors, as well as the cost of the work related to improving security**.**

Scientific novelty. The scientific novelty of proposed method is an adequate description of reliability degree of bearing elements of the object surface mines, which will take its place among the new modern experimental studies of the structures of the industrial site.

Practical significance. Made the methods for system risk analyses of possible structural defect, which allows to determine the reliability of an object at a particular time and safe residual life. As a result of the proposed measures increased assessment of costs and benefits from implementation of measures to reduce the risk of an accident based on the hazard identification. Developed the final recommendations for the safe operation facilities using the existing regulatory framework on labor protection.

Results. Identified three areas of risk like negligible risk, acceptable risk (which is not so small to be ignored, but not large enough to consider it excessive) and unacceptable risk (so large that it is considered excessive). Obtained the model that allows to perform systematic risk analyses of possible structural defects in construction, by comparing with its actual acceptable boundaries. The proposed method can be used in practice to assess the survivability degree and safe residual life of the object**.**

Key words: risk, accident, reliability, safety, residual life.

Introduction. The high level of injuries and especially accidents involving fatal injuries in Ukraine raises the issue of improving the methods of prevention. In recent years, production in the world is estimated based on safety adverse event risk. The international organizations ISO, IMO and others have developed theoretical bases and methods of risk assessment and decision on the basis of their technical solutions for the prevention from accidents and injuries in the workplace [1-3]. Experts from various industries in their reports constantly operate not only the definition of "danger" but also such a term as "risk".

In the scientific literature there are various interpretation of the term "risk" and its definitions sometimes differ from each other by content. For example, the risk in the insurance terminology is used to refer to the insurance object (industrial enterprises or firms), the insured event (flood, fire, explosion, etc.), insured sum (risk in monetary terms) or as a collective term to refer to unwanted or uncertain events. Economists and statisticians, faced with these issues, understand the risk as a measure of the possible consequences, that will emerge at some point in the future. In psychological dictionary, risk is interpreted as an action aimed at attractive goal, the achievement of which involves elements of danger, risk of loss, failure, or as a situational characteristic of activity consisting in uncertainty of its outcome and possible adverse consequences in case of failure, or as a distress measure with non-success in the activities, defined by the combination of the probability and magnitude of adverse effects in this case. A number of interpretations reveal the risk as a probability of accident occurrence, danger, accident or disaster under certain conditions (state) of production or human environment. These definitions emphasize the value of the vigorous activity of the subject and objective properties of the environment.

As a common in all the above views is that risk involves the uncertainty of whether either an undesirable event or the adverse condition will occur. Note that in accordance with modern views the risk is usually interpreted as a probability measure of man-made or natural phenomena, accompanied by the emergence, formation and action of the dangers and the damage at social, economic, environmental and other types of damage and harm.

By the risk should be meant an expected frequency or a probability of hazard occurrence of a certain degree, or the amount of possible damages (loss, harm) against undesirable event, or some combination of these values.

The use of the concept of risk thus allows to consider the risk as a category of measurable categories. The risk, in fact, is the measure of danger. The often use of the term "risk" (level of risk) essentially doesn't differ from the concept of risk, but only emphasizing that it is about the measurand.

All of these (or similar) interpretations for the term "risk" currently used in the analysis of hazards and safety management (risk) of technological processes and production in general.

The risk occurs under the following necessary and sufficient conditions:

-existence of a risk factor (source of danger);

-the presence of this risk factor in a dangerous (or harmful) dose for the object of impact;

-exposure (sensitivity) of the impact objects to factor dangers.

Among accidents in different industries you can notice the obvious similarities. Usually an accident is preceded by the accumulation of defects in the equipment or deviations from the normal course of processes. This phase can last for minutes, days or even years. By themselves, the defects or deviations do not lead to the accident, but prepare the ground for it. The operators usually tend to overlook this phase due to the neglect to regulations or a lack of information about the work object, so that they do not have a sense of danger. The next phase is sudden or rare event that significantly changes the situation. The operators are trying to restore the normal course of the process, but, not having full information, often only exacerbate the development of the accident. Finally, the last phase of another unexpected event - sometimes very little - plays the role of a push, after which the technical system ceases being governed by the people, and there is a disaster.

Risk is inevitable, concomitant factor of industrial activities. The risk is objective, it is characterized by suddenness, the unexpectedness of onset, which involves the risk forecast, its analysis, assessment and control - a number of actions to prevent risk factors or lessening the impact of hazard.

Construction, reconstruction and operation of facilities and structures on the surface of the mines belongs to the highest degrees of risk, due to the specifics of work performance (lack of permanent jobs and increased risk of production processes), as well as organizational factors. This requires the improvement of the preventive work to improve safety of construction production on the basis of existing risk assessment methods [4-9].

In this work, the aim is to use known technique for the analysis of potential accident hazards facilities (structural collapse), transforming it to conditions of construction.

Materials and methods. Human safety and environmental protection are the two related to problems of health and safety. International standardization organization (ISO) interprets safety as the absence of unacceptable risk associated with the possibility of damage [1].

On the basis of analysis and synthesis of the research results in the field of technogenic safety was developed a guide for formal safety assessment - Formal Safety Assessment (FSA) [2]. FSA is a structured and systematic methodology designed to increase security, including the protection of life and human health, of environment and property based on a risk assessment taking into account the required costs and benefits.

Most often risk is defined as the frequency of realization of the unwanted event - a quantitative risk assessment [3].

The FSA considers the term "risk" as a product of damage caused by accident, that is, the risk value can be calculated from the following equation

$$R = \lambda \cdot Y \quad (1)$$

where R- the estimated risk value, 1/year or UAH. /year.; λ - the frequency of accidents of this type, 1/year; Y- the damage caused by accident, without dimension or in UAH.

The dimension 1/year used in estimating a risk of human death (individual risk) and the dimension of the UAH. /a year in assessing a risk of material loss or environmental risk.

In accordance with the FSA [2] the scale of risk has three areas. In first, there is a negligible risk, the second risk is so great that it is considered excessive or inappropriate. Between these two areas is an area of acceptable risk, i.e. that risk, which is not so small to be ignored, but not large enough to consider it excessive.

In the general, acceptable risk is the level of anthropogenic activities which society is willing to accept for the resulting economic and social benefits.

In accordance with the criteria adopted in the world practice [2], is considered unacceptable individual risk exceeding 1□10-4 1/UAH. when during the year of this type of undesirable events killed 1 person in 10000.

Acceptable (valid) is the individual risk, if its level lies in the range 1□10-4-1□10-6 1/year. This area of risk requires the special measures to its control.

The risk value 1□10-6 1/year in developed countries is considered as the acceptable level of risk. An area of risk is less than this value suggests that the safety measures, made in the field of technological activity, are at a level that does not require special interventions for their improvement.

During the risk assessment should be considered the total damage caused by both the loss of life and material losses and the environmental damage. With this purpose it is necessary to consider the compliance of the material damage in monetary terms with the damage from the human death.

The used method is based on the concept of acceptable risk, and aims to identify hazards before resulting to accidents. This takes into account technical, human and organizational factors, as well as the cost of the work related to improving security.

Assessed the risk of an accident constructions (structural collapse). Implementation of the methodology includes several stages.

The first stage is the assessment of the degree of accident risk and risk identification of its occurrence.

To estimate the risk value is used the proposed method of determining the indices of frequency and damage caused by accidents with the use of a logarithmic scale, transforming it for conditions of our problem.

According to the methodology: risk = frequency x damage or:

$$\lg R = \lg + \lg Y, \qquad (2)$$

then

$$R = 10^{[\lg\lambda + \lg Y]} = \lg\lambda \cdot \lg Y. \qquad (3)$$

By introducing the notation $\lg\lambda = (FI\text{-}6)$and $\text{l}\lg Y = (SI\text{-}3)$ we obtain an equation for estimating the risk value

$$\lg Y = (SI\text{-}3). \qquad (4)$$

where *FI* - the frequency index of accidents (the Frequency Index); the number 6 is subtracted from the frequency index corresponds to the frequency value of 1.0 1/year (tabl.1); *SI* - the index of damage caused by the accident (Severity Index); the number 3 subtracted from the index of damage corresponds to the relative damage of 1.0 (table.2); *RI* - the accident risk index (Risk Index), the values of which are given in table.3.

As you can see, the value of (-9) in the exponential expression (*RI*-9) of formula (4) corresponding to the frequency of accidents is 1 per year, with the relative damage of 1.0 is taken as the base in determining the risk *R*. The risk value for other combinations of *FI* and *SI* is determined on the basis of statistical data or expert method using the table.1-3 [9-13]. In table.3 accident risk indices (*RI*) are the summation of the indices of damage (*SY*) and the frequency of accidents (*FS*). Identified with the help of tables the risk index according to the formula (4), it is possible to set the numeric value of accident risk, to compare it with valid values and to make a conclusion about the level of considered risk.

Table 1. Accidents Frequency Indices

FI	Accident frequency	Determination method	□(at one facility per year)
1	Extremely rare	Once in 100 years, at one of the 1000 facilities	10-5
2		once in 10 years, at one of the 1000 facilities	10-4
3	Rare	once a year, at one of the 1000 facilities	10-3
4		once a year, at one of the 100 facilities	10-2
5	Moderately	once a year, at one of the 10 facilities	10-1
6		once a year, at 1 facility	1,0
7	Frequently	once a month at one facility	10

Table 2. Severity Indices

SI	Damage from the accident	Human exposure	Influence on construction	Relative damage
1	Low	Individual or minor injuries	Local damage to the equipment	10-2
2	Significant	Numerous or serious injury	Insignificant damage to facilities	10-1
3	Severe	A single death or numerous injuries	Severe damage to facilities	1,0
4	Catastrophic	Numerous deaths	Complete destruction of facilities	10

Table 3. Accident Risk Indices RI

FI	Accident frequency	The severity (damage) caused byt (SI) acciden			
		1	2	3	4
		low	significant	severe	catastrophic
1	Extremely rare	2	3	4	5
2		3	4	5	6
3	Rare	4	5	6	7
4		5	6	7	8
5	Moderately	6	7	8	9
6		7	8	9	10
7	Frequently	8	9	10	11

In our case, on the basis of statistical data, we assume that an accident (full collapse) may occur once a year at one of the 100 structures, i.e., *FI*=4. This accident is usually accompanied by numerous deaths and causes severe structural damage, it refers to a severe *SI*=4. Then, on the basis of the data in the table 3 is determined the accident risk index *RI*=7.

Substituting the found value of RI in the formula (4), we determine the risk value of an accident

$$R=10^{[Ri-9]}=10^{[R7-9]}=10^{-2}\ 1/hour$$

Results. Comparing the obtained value risk with its permissible limits, we conclude that the risk of an accident facilities (structural collapse) is unacceptable (10-2 1/year>*R* acceptable 10-4 1/year) and requires for additional measures to reduce the risk [14, 15].

For this purpose, we carry out the identification of accident risk and evaluation of factors influencing the risk value. This goal can be achieved by constructing a risksharing tree (tree of events and hazards).

The goal of the next phase is the selection of measures to reduce the accident risk based on the hazard identification.

The third stage involves the assessment of the costs and benefits of measures implementation proposed of the previous stage.

At the final stage produced final recommendations on the management safe operation of facilities using the existing regulatory framework on labor protection.

Conclusions. Thus, a systematic analysis of the risk of possible structural defects and organizational reasons causing an accident, allows to control safety in its operation.

In this direction are conducted a lot of research and development. It is hoped that the more detailed studies carried out by us, and this methodology could be applied in risk analysis of any process in the construction, repair and maintenance of buildings and structures on the surface of the mining enterprises.

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