Failure risks of mine excavators in ranking control levels

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Abstract. The paper gives the analyses of various approaches to the definition of the risk concept. The theory of catastrophes is determined to use the term “risk” in order to describe accidents and natural disasters, the theory of reliability interprets this concept as the probability of failure. It is established that there is a variety of factors that are the cause of of mining excavators failures as complex technical systems. The authors propose to establish causal relationships between the occurrence of career excavator failures, for example, using the method of event trees (failure trees) or Ishikawa diagrams.

1. Introduction
The concept of «risk» always implies the probabilistic nature of some event or phenomenon. The word "risk" means the likelihood of an adverse outcome of an action.

Depending on the field of study, the interpretation of the concept of «risk» may be partially different from each other. Summarizing the various definitions of the term «risk», it is accepted that risk is the product of the frequency of an undesirable event to the damage caused by this event. This definition is mathematically expressed as follows:

\[ R_A = \lambda_A \cdot Y, \]

where \( R_A \) is the amount of risk, 1 / year (or rubles / year); \( \lambda_A \) - the frequency of the accident of the type in question, 1 / year; \( Y \) - damage from an accident, without dimension or rub.

Failure risks appear in standards and methods of risk analysis in the following areas: in technological systems - standards of GOST R 51901 «Risk Management» and methods for analyzing types and consequences of failures, analyzing the "event tree" and "fault tree", structural reliability diagram, Markovskii methods; in information security [1].

In RD 03-418-01 «Guidelines for conducting risk analysis of hazardous production facilities», a definition of technical risk is given, probability of technical device failure with consequences of a certain level (class) for a certain period of functioning of a hazardous production facility [2].

The risk arises under the following necessary and sufficient conditions:
- the existence of a risk factor (source of danger);
- the presence of a given risk factor in a certain, dangerous (or harmful) for the objects of exposure measure;
- susceptibility (sensitivity) of exposure objects to hazards.

The work [4] gives the analysis of various approaches to risk determination. Catastrophe theory uses the term “risk” in order to describe accidents and natural disasters. In the theory of reliability, risk is the probability of failure.
Failures are divided into two groups: sudden – the failures, characterized by abrupt changes in the values of one or several specified parameters of the object, and gradual – the failures, characterized by gradual changes in the values of one or several specified parameters of the object.

A sudden failure is not preceded by a directional change of any of the observed operational parameters of the object, and therefore the prediction of the occurrence moment of a sudden failure is almost impossible. The reasons for such a failure are breakdowns, deformation, loss of tightness, rupture of equipment elements (parts and assembly units).

Sudden failures occur as a result of various factors, so the place and time of their manifestation is almost impossible to establish, in the result this type of failures causes damage to other objects operating in the system. The object restoration after an accidental breakdown is accompanied by the attraction of the resources maximum amount (labor, material).

Gradual failures depend mainly on the duration and conditions of equipment operation, on specific levels of loads. They arise as a result of gradual changes in the characteristics of the components of the equipment (parts, assembly units) due to aging and wear.

The studies [5] defined the concept of an emergency risk, which is a measure of danger characterizing the possibility (likelihood) of an emergency on a mining excavator and the amount of damage from its consequences for a certain period of time.

The following studies [6] solve the actual problem of constructing a model for assessing the possibility of the failures of a single-bucket hydraulic excavator and identifying the category of possible failures. The solution to this problem will allow quickly finding "weak points" in the hydraulic system and, if necessary, carry out additional measures or adjust the maintenance plan.

The process of the emergence and development of failure risks in the operation of mining excavators is influenced by many factors and conditions:
- failure of the systems and units due to their design flaws, poor quality manufacturing;
- violations of the instruction manual, including exceeding the design loads during operation;
- drivers’ and attendants’ errors;
- external influences, etc.

2. Methodology
The variety of factors causing failures of mining excavators as complex technical systems, does not allow to compile their absolutely complete list. Failures can occur for rather trivial reasons, for example, improper assembly of elements, poor contact of conductors, etc. The most common cause of failures are defects in minor parts of the equipment. The required malfunctions can be classified depending on the nature of the damaging effects (chemical, thermal, mechanical, electrical) and the type of destruction: creep, corrosion, fatigue cracks, etc. [7-9].

The number of production errors that cause failures can be reduced due to high-quality process control. Violations of technology during the assembly process are a particular cause of failures.

The causal relationships of the career excavator failures are established, for example, using the event tree method (failure trees) or Ishikawa diagrams in the form of graphical logical constructs, which are then subjected to quantitative and qualitative analyzes. This method is a logical method of localizing the most dangerous parts of the system.

When building a tree of failures, combinations of equipment failures, personnel errors and external (natural or man-made) impacts resulting in the main event (emergency situation) are detected. The method is used to determine the likelihood of an emergency and to calculate its probability (based on setting the probabilities of initiating events) (Figure 1) [10].
Figure 1. The general possibility of a career excavator failure.

3. Results
Modern mine excavators used in surface mining are high-performance, large-size electromechanical systems. When determining the category of failure, from the standpoint of system analysis, it is advisable to treat the electro-mechanical equipment of a career excavator as a system consisting of two subsystems: mechanical and electrical. Calculations of the reliability parameters of mine excavators were carried out in an impersonal form in order to establish the laws of the operating time distribution to failure of the electromechanical system in mine excavators. As a result, it was established that for all law subsystems of time distribution between failures is exponential (Figure 2, Table) [11-15].

Figure 2. Distribution of mine excavator:
a - Magnitogorsk Metallurgical Plant MMP; b - Uchalinsky MCC.

Table. Parameters of the time distribution law between failures of electromechanical system in mining excavators.

| System elements | Failure density $\lambda \cdot 10^{-3}$, 1/h | Average time between failures $t_0$, h | Distribution law |
|-----------------|------------------------------------------|---------------------------------|----------------|
| Electrical      | 78.1                                     | 12.8                            | Exponential   |
| Mechanical      | 30.3                                     | 32.9                            | Exponential   |

4. Conclusion
The analysis of the excavator failures by unites allows determining the least reliable elements in the electromechanical system of the excavator and making recommendations for improving the used maintenance systems, the main purpose of which is to prevent failures and unplanned downtime.

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