

## TRANSPORT, MINING AND CONSTRUCTION ENGINEERING

DOI: 10.32743/UniTech.2022.102.9.14214

STUDY OF INDICATORS TO QUANTIFY THE RELIABILITY  
OF MINING EQUIPMENT COMPONENTS**Sherzod Makhmudov**

*Candidate of Technical Sciences, Associate Professor  
of Department "Mining electromechanics"  
Navoi State Mining and Technological University,  
Republic of Uzbekistan, Navoi  
E-mail: 1yy2@mail.ru*

**Behruz Rashidov**

*Undergraduate  
at Navoi State University of Mining and Technology,  
Republic of Uzbekistan, Navoi  
E-mail: a.k.bek1452@gmail.com*

ИССЛЕДОВАНИЕ ПОКАЗАТЕЛЕЙ ДЛЯ КОЛИЧЕСТВЕННОЙ ОЦЕНКИ НАДЕЖНОСТИ  
РАБОТЫ КОМПОНЕНТОВ ГОРНОГО ОБОРУДОВАНИЯ**Махмудов Шерзод Азаматович**

*канд. техн. наук,  
доц. кафедры «Горная электромеханика»  
Навоийского государственного горно-технологического университета,  
Республика Узбекистан, г. Навои*

**Рашидов Бехруз Валижон угли**

*магистрант  
Навоийского государственного горно-технологического университета,  
Республика Узбекистан, г. Навои*

## ABSTRACT

The paper outlines reliability indicators of mining equipment such as "MTBF" (mean time between failures) and "MTTR" (mean time to repair). Formulas for determination of probability, mean time between failures, availability factor of mining equipment, parameters of flow of failures which influence indicators for quantitative estimation of reliability of operation of components of mining equipment are given.

## АННОТАЦИЯ

В работе изложены показатели надежности горного оборудования такие как, "MTBF" (среднее время между отказами) и "MTTR" (среднее время ремонта). Приведены формулы для определения вероятности, средней наработки на отказ, коэффициента готовности горного оборудования, параметры потока отказов, которые влияют на показатели для количественной оценки надежности работы компонентов горного оборудования.

**Keywords:** indicator, reliability, failure, operating time, system.

**Ключевые слова:** показатель, надежность, отказ, наработка, система.

Mining equipment at mining enterprises is operated in conditions determined by non-stationary modes of its loading, gas contamination and sometimes high air humidity, sharp temperature fluctuations, atmospheric precipitation, instability of physical and mechanical properties of rocks, etc.

It is known that the initial reliability of a product is formed at the stage of its design, is ensured by the level of production and installation technology, and is realized in the process of operation. The reliability of the product is constantly decreasing in the process of operation, but can be restored after repair operations.

In order to ensure that mining equipment operates reliably and perform its intended function, all components must work reliably, and the greatest attention must be paid to the power equipment. The power equipment used in mining machines differs in purpose, operating principle, power, operating mode and other parameters.

The efficiency of equipment operation largely depends on its reliability and, therefore, it makes sense to refer to canonical definitions of its essence and terminology accepted in the world practice of machine and equipment engineering [1,2,3], which we applied in our research.

Reliability is the ability of a system or component of a system to perform the required functions under certain circumstances for a given period of time.

Readiness is the degree to which a system or component is available to operate when needed. It can be thought of as the probability that a system or component is capable of performing the required functions under specified conditions at a given point in time. Readiness is defined by the reliability of the system and the amount of time it takes to recover in the event of failure.

The MTBF, or mean time between failures, is a basic indicator of system reliability. It is usually expressed in hours. The higher the MTBF value, the higher the reliability of the product. The MTBF affects both reliability and availability. Often more attention is paid to availability, because in the event of a failure the most important parameter is how quickly the system can be restored to working order [4,5,6].

The reliability of equipment, aka the probability of its failure-free operation, is defined as

$$P(t) = e^{-t/T}, \quad (1)$$

where  $T$  - is the MTBF equivalent,  $h$ ;  $t$  - is the number of engine hours worked.

MTTR, or the average time to recover from a failure, which can include the time required to diagnose a fault, to call a technician on site, and the time required to physically repair the system. In the event of a failure, the amount of time required to bring equipment and production processes back into operation in order to minimize downtime as much as possible becomes the deciding factor.

In practice, however, in the "wear and tear" operating mode, the MTBF is much shorter than the MTBF. Therefore, there can be no direct correlation between product lifetime and MTBF (or MTBF). It is quite possible to have a product with a high MTBF and yet a short MTBF. MTTR affects availability, but does not affect reliability. The higher the MTTR value, the worse the system condition, i.e. the longer it takes for the system to recover, the lower the system availability [4,7].

The availability factor  $K_A$  is the ratio of the number of engine hours worked  $T_W$  to the sum of the number of engine hours worked and the recovery time of the component  $T_R$

$$K_A = T_W / (T_W + T_R), \quad (2)$$

In order for Equations 1 and 2 to be applicable, a precise definition of failure and stipulation of assumptions must be made when analysing the MTBF value of the system. In our case, failure is the inability of the excavator as a whole to perform the required functions, and the assumptions are a group of conventions that limit the range of failures that, for one reason or another, should not be considered when assessing the MTBF of a particular system and machine. For example, failure resulting from lack of power or transport, consumables, improper use of equipment, damage to the machine by external influences, failure of the diesel, etc. may not be taken into account. All these conditions are usually stipulated in the equipment's operating contract between the manufacturer and the user. For irreplaceable elements and systems the main quantitative characteristics are: mean time between failures (mathematical expectation of time between failures) -  $T_1$ , intensity of failures -  $\lambda(t)$  and probability of no-failure operation (probability that within a given time  $t$  no failure occurs) -  $P(t)$ .

If each of the  $N$  objects of the same type has failed, and the time to failure of an object is defined as  $t_1, t_2, \dots, t_N$ , then

$$T_1 = \sum_{i=1}^N t_i / N, \quad (3)$$

Failure rate  $\lambda(t)$  is a conditional density of probability of occurrence of the object failure, determined under the condition that up to the considered moment of time the failure did not occur. To estimate the reliability of the reconstructed elements and systems we use the mean time between failures (reconstructed system) -  $T$ ; the parameter of the flow of failures -  $\omega(t)$  and the probability of no-failure operation -  $P(t)$ .

MTBF  $T$  is the ratio of the total operating time  $t_{sum}$  of the reconstructed object to the mathematical expectation of the number of its failures  $n$  during the time of this operating time, which is

$$T = t_{sum} / n, \quad (4)$$

If  $N$  facilities of the same type are observed, operating under the same conditions, it is permissible to combine the observations into a single statistical array

$$T = \sum_{i=1}^N \frac{t_{sumi} / n_i}{n}, \quad (5)$$

where  $t_{sumi}$  and  $n_i$  are, respectively, the total operating time and the corresponding number of failures of the  $i$ -th object ( $i = 1, 2, \dots, N$ ).

The failure rate parameter  $\omega(t)$  as the ratio of the mathematical expectation of the number of failures of the reconstructed object in a sufficiently small operating time  $\Delta t$  to the value of this operating time, is determined by the formula

$$\omega(t) = \lim_{\Delta t} \{M[n(t + \Delta t) - n(t)]\} / \Delta t, \quad (6)$$

where the difference  $n(t + \Delta t) - n(t)$  is the number of failures over the operating time  $\Delta t$ . In practical reliability

calculations, it is sometimes more convenient to use the "probability of failure" of an object  $q(t)$ , and since "no-failure" and object failure are opposite events,  $P(t)+q(t)=1$ .

For the simplest failure rate, the value of the failure rate parameter  $\omega(t)=\omega=\text{const}$  and is equal to the inverse of the average MTBF of the object, i.e.  $\omega = 1/T$ . If the object is non-recoverable, the failure rate  $\lambda(t)=\lambda = \text{const}$  and  $\lambda = 1/T_1$ . The failure rates  $\omega$  and  $\lambda$  are inverse dimensionality to the mean time to failure  $T_1$  or mean time to failure  $T$ . For  $T_1$  and  $T$ , with the dimensions hours, tons or cubic metres, the dimensions  $\omega$  and  $\lambda$  are  $\text{h}^{-1}$ ,  $\text{t}^{-1}$  or  $(\text{m}^3)^{-1}$  respectively.

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#### Conclusion

Thus, the main functional groups of sequentially interacting elements of mining equipment have been identified, which allows to organize the reception of statistical data on the reliability of all main systems of machines under specific conditions of their operation, to assess promptly and perform a comparative analysis of the reliability of various components and the readiness of equipment in general, and to define the nomenclature of indicators for quantitative assessment of various properties of the reliability of mining equipment in accordance with the existing standards.