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Promising model range career excavators operating time assessment in real operating conditions

Sergey L. IVANOV, Polina V. IVANOVA✉, Sergey Yu. KUVSHINKIN
Saint Petersburg Mining University, Saint Petersburg, Russia

The development prospects of the mining industry are closely related to the state and development of modern mining machinery and equipment that meet the technical and quality requirements of mining enterprises. Enterprises are focused on a quantitative assessment – the volume of mineral extraction, depending on the functioning efficiency of a promising series of mining machines, which include modern mining excavators. Downtime and unplanned shutdowns of mining excavators directly depend on the operating conditions of the mining machine, which has negative influence on the machine as a whole and its technical condition, which entails a decrease in the efficiency of using expensive mining equipment and economic losses of the mining enterprise.

The rationale for external factors that affect the operating time and technical condition of mining excavators is given. For a more detailed assessment of the influence of external influences on the efficiency of operation of mining machines, the influencing factors are divided into two groups: ergatic, directly related to human participation, and factors of a natural-technogenic nature, where human participation is minimized. It was revealed that factors of a natural-technogenic nature have the greatest influence. An algorithm is proposed for a comprehensive assessment of the technical condition and forecasting of operating time both in nominal and in real operating conditions, taking into account factors of a natural and technogenic nature.

It is proposed, based on the developed program for planning and evaluating the life of a mining excavator, to adjust the schedules for maintenance and repair (MOT and R) in order to minimize the number of unplanned downtime of a mining excavator and maintain it in good condition.

Key words: mining excavator; operating conditions; operating time; maintenance and repair; reliability

Introduction. One of the promising directions for the development of the mining industry is to increase the share of open pit mining. At present, in large mining enterprises, the main working equipment for quarrying is excavators of large unit capacity. With the development of mechanical engineering, there has been a steady tendency towards an increase in the unit capacity of the main mining and mining equipment, including excavators. With the increasing capacity of dump trucks, excavators with a bucket volume of 20 to 45 m^3 and a payload in the bucket of up to 63 tons are increasingly being used [1, 7, 15, 16, 18, 21, 23, 24].

The goal of any system is to obtain maximum benefits at minimum cost, with respect to mining excavators, the aim will be to maximize operating time at minimum cost when excavating rock mass. The annual increase in operating costs, along with a decrease in the operating time of the excavator and its residual resource, lead to inefficient use of the resources of mining enterprises. Thus, to achieve this goal it is necessary to assess the operating conditions of the machine and minimize the number of unplanned downtimes.

Formulation of problem. As practice shows, unplanned outages associated with failures of a complex system, which is a mining excavator, can reach up to 35 % of the working time fund [2, 8, 9, 17, 19, 20, 22]. The technical condition and life of these machines directly depend on the operating conditions and the influence of external factors. A large proportion of failures caused by technogenic, technical and ergatic factors is primarily associated with determining the response of the drive and control systems, the high rigidity of the drive itself and the design of the excavator and its working equipment, which causes a mining machine to respond when interacting with the face rock during continuous controlling bucket movement during excavator operation and associated control errors [6].

Based on the theoretical and experimental studies, the results of the analysis of influencing factors that have a significant impact on the functioning of mining excavators, their technical condition and operating time are systematized and presented in Fig.1.
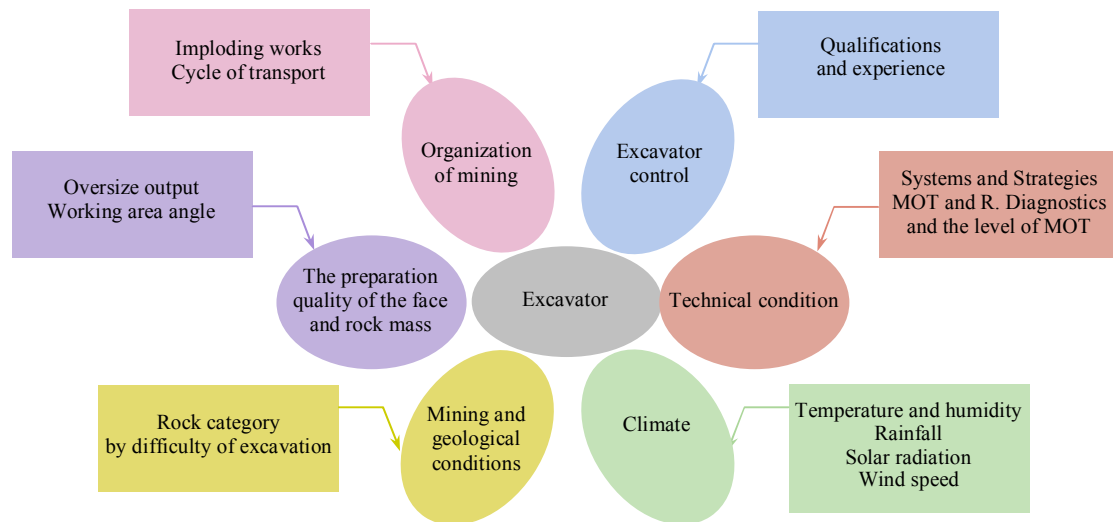
Fig.1. Factors determining the effectiveness of a mining excavator

All the variety of factors that affect the intensity of the excavator degradation processes during its life cycle by many reasons, can be divided into two large groups: ergatic, occurring with the participation of man; natural and technogenic, where there is no direct influence of the human factor or it is minimized [3, 4, 10]. The first group of factors includes the management of the excavator by the driver, the nature and level of mining operations, their organization in the implementation of mining technology, as well as the nature of the maintenance and level of work during maintenance and repair of the mining machine. The factors of natural and technogenic impact include: geological and climatic conditions, the quality of the preparation of the face and rock mass, the selected maintenance and repair strategy, and the natural aging factor of the equipment. The last factor is present here as some ideal process of natural aging of the excavator for the period of its service life, provided that the operation of the machine proceeds in the nominal (passport) operating conditions. Factors of these groups do not have the same effect on the intensity of degradation processes, as a result of which degradation processes can intensify the real aging process, if the nominal operating parameters are exceeded, or reduce this intensity when the operation occurs in more comfortable conditions compared to nominal ones. It should be noted that only one factor out of all the above is aimed at leveling degradation processes – this is the factor that determines the nature, quality and integrity of the implementation of measures for maintenance and repair of equipment [7, 10, 16, 20].

Obviously, as a result of different intensities of the manifestation of certain factors caused by natural and technogenic conditions, or conditions that determine the level of manifestation of ergatic factors, the same samples of mining machines and, in particular, excavators, will have different levels of degradation and residual life after an equal period of time or worked life.

As a result of the analysis of statistical information on the operation of a quarry excavator with a large unit capacity, the distribution of downtime caused by various factors was revealed (Fig.2). The total downtime of the excavator during the considered period of operation amounted to about 6000 hours, of which 43 % were aimed at maintaining an operating state, related to the implementation of planned maintenance and repair measures, in 24 % of cases the reasons were related to the organization of mining and the excavator drivers control (ergatic factor). Failures caused by exposure to natural-technogenic factors accounted for 33 % of all downtime.

Quarry excavators, like other mining machines, are designed for specific operating conditions, which will be nominal for them, while regulating as follows: the category of rock by the difficulty of excavation, the average size of the piece, the permissible slope of the working platform, climatic operating conditions, etc.
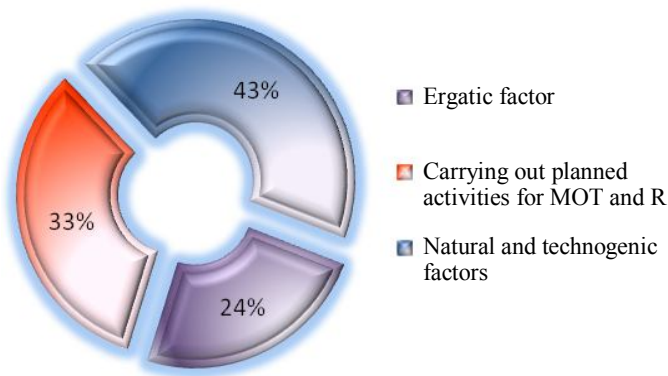
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Fig.2. Distribution of downtime for high-capacity mining excavators

- Ergatic factor
- Carrying out planned activities for MOT and R
- Natural and technogenic factors

In relation to mining excavators of the EKG-32R model of domestic production, by the manufacturer of IZ-KARTEX named after P.G.Korobkov the following nominal conditions are set:

• climatic conditions – macroclimatic regions with a temperate or cold climate according to GOST 15150-69;

• ambient temperature from −40 to +40 °C;

• height above sea level no more than 1000 m;

• non-explosive environment;

• allowable fluctuations in the supply voltage supplied to the excavator, from −5 to +10 %;

• permissible angle of inclination of the excavator during operation no more than 5°;

• designed for the development of rocks category III, IV and V; development is carried out with preliminary loosening, which ensures the free placement of pieces of rock in the bucket; allowed to use for the development of rocks category I and II without prior loosening;

• weighted average piece size in diameter up to 300 mm;

• oversized bucket fraction (more than 2/3 of the smallest size of the bucket pharynx) should not exceed 2 %.

Influence assessment of natural-technogenic factors and prediction of the operating time value. Since the mining excavator is operated in various climatic, mining and mining-geological conditions that differ from the nominal values recommended by the manufacturer, it is necessary to assess the external impact of natural-technogenic factors on the machine that have a significant impact on the efficiency of mining machines [14, 16]. To assess the weight of each factor of a natural-technogenic nature, an algorithm was developed (Fig.3), which allows to comprehensively assess the influence degree of external conditions and take into account precisely the effect of the influence of each factor, thereby it becomes possible to determine the level of decrease in operating time from the influence of a particular factor when it deviates from the face value, if other factors remain unchanged [19].

In practice, as the total operating time of mining machines increases, the rate of equipment failure rises, which entails a time increase to resolve the consequences of these failures and, as a consequence, a decrease in the excavator output [5]. In order to minimize the number of unplanned downtime of a career excavator and increase its reliability, it is proposed to carry out correction of the schedules for maintenance and repair (MOT and R) based on the developed algorithm, taking into account the operating conditions of the machine in which it operates.

Based on the developed algorithm, an information model and a computer program for planning and evaluating the operating time of a mining excavator in specific operating conditions were created with the subsequent recommendation of adjusting the schedule for routine maintenance aimed at maintaining the working condition of career excavators [11-13].

The forecast of annual operating time in the nominal and considered operating conditions is proposed to be determined by the formula

$$Q = 3600\,t_{\text{c}}^{-1} ETK_{\text{e}}K_{\text{MOT and R}}\,K_{\text{oversize}}K_{\text{PA}}K_{\text{SI}}(1 - 5{\cdot}10^{-4}Y^2 + 6{\cdot}10^{-4}Y),$$

where t_{c} – cicle time, c; E – bucket capacity, m³; T – time fund, h; K_{e} – excavation coefficient taking into account mining and geological operating conditions, rock category by excavation difficulty; $K_{\text{MOT and R}}$ – coefficient strategy of MOT and R; K_{oversize} – oversized coefficient taking into account the quality of preparation of the face and rock mass; K_{PA} – platform angle coefficient; K_{SI}

– coefficient taking into account the impact of the weather factor is determined according to the weather severity index for specific operating conditions [8]; Y – number of years of mining excavator operation.

Conclusion. Based on the simulation results using the proposed model for predicting and estimating the excavator operating time, the maintenance and repair regulations should be adapted and the maintenance and repair schedules of the EKG-32R excavator manufactured by IZ-KARTEX named after P.G.Korobkov LLC should be adjusted. Adaptation of the maintenance and repair schedules to the actual operating conditions allows increasing the uptime of a complex technical system.

The structure of the repair cycle is adjusted taking into account the natural aging of the excavator and the factors of natural and technogenic impact in operating conditions. It is proposed to evaluate the impact of external conditions and natural processes during the operation of mining machines using the appropriate factors: factor, taking into account the decrease in the operating time of a mining excavator in real conditions with respect to the nominal and aging coefficient. The latter takes into account the decrease in the operating time of a quarry excavator in nominal operating conditions taking into account the natural aging of the machine and is determined as the ratio of the projected operating time of the excavator in the considered year of operation to the predicted operating time in the first year of operation.
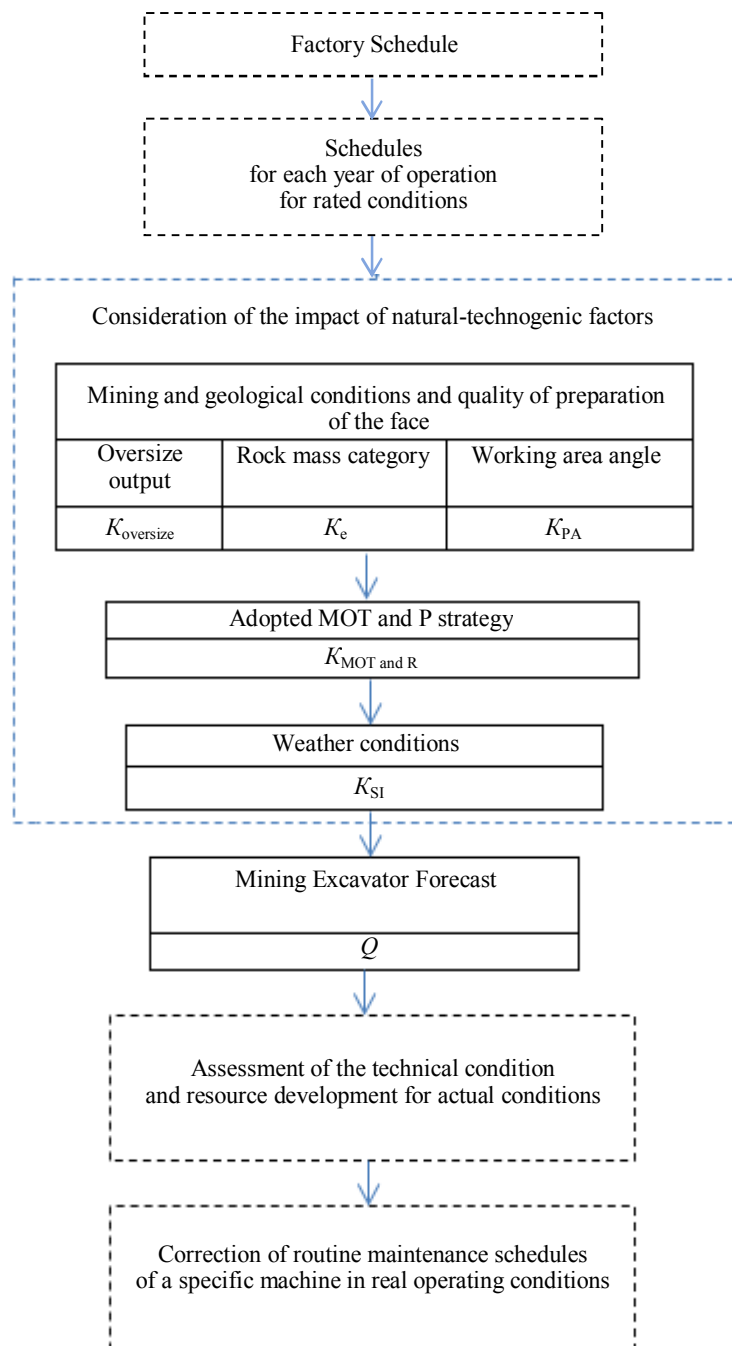

Fig.3. The sequence of assessing the influence of factors of natural and technogenic nature on the adjustment of schedules of routine work in specific operating conditions of the excavator

To clarify the technically justified overhaul periods during operation of the machine, it is necessary to be guided by the information obtained during computer modeling and the regulatory framework for maintenance and repair (Fig.4).

Since the coefficient of natural aging tends to decrease as the resource of a career excavator is worked out, to maintain it in working condition, it is necessary to reduce the overhaul periods, which will lead to an increase in the number of measures for MOT and R. Thus, to maintain the level of career excavator reliability unchanged, additional periodic measures for MOT and R should be introduced in the annual schedule of PPR (Fig.5).

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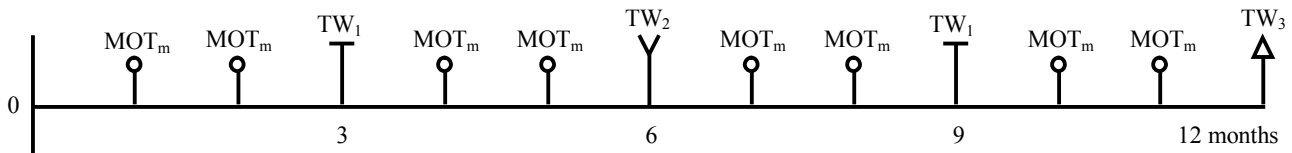
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Fig.4. The structure of the annual schedule of measures for MOT and P mining excavators of a promising model range recommended by the manufacturer for nominal operating conditions
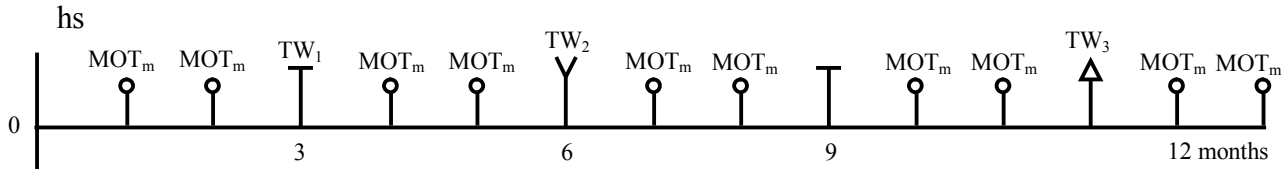

Fig.5. Adjusted annual schedule of maintenance and repair measures taking into account actual operating conditions

From Fig.5 it follows that in order to maintain the working condition of the mining excavator in real operating conditions, the structure of repair cycles has changed, additional maintenance measures have been introduced with the aim of timely preparation of materials, spare parts, mechanization tools, determining the composition of the repair team for subsequent planned repair actions and, as a result, minimization of unplanned downtime caused by failures of mining equipment.

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Authors: **Sergey L. Ivanov,** *Doctor of Engineering Sciences, Professor, lisa_lisa74@mail.ru (Saint Petersburg Mining University, Saint Petersburg, Russia)*, **Polina V. Ivanova,** *Candidate of Engineering Sciences*, *Head of the Department of Methodological Support of the Educational Process and Additional Competencies*, *polinapuh@yandex.ru* (*Saint Petersburg Mining University, Saint Petersburg, Russia*), **Sergey Yu. Kuvshinkin,** *Candidate of Engineering Sciences, Associate Professor, minermech@mail.ru (Saint Petersburg Mining University, Saint Petersburg, Russia).*