Weather conditions as a factor affecting the performance of modern powerful mining excavators

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Abstract. The article discusses various factors that have a significant impact on the performance of EKG-32R type powerful mining excavators. It was revealed that the most adverse effects are weather conditions that are different from the nominal ones for which mining machines are designed. The climatic factor includes the impact of solar radiation, low and high air temperatures, wind speed, humidity, fog, snowstorms, snow storms etc on mining equipment. The transformation of the properties of structural materials is also determined by the intensity and duration of exposure to these factors and their combination. A methodology is proposed for assessing the influence of weather conditions on the operation of mining equipment, which allows one to analyze the influence of each climatic parameter separately and evaluate the complex effect. It is proposed to take into account the influence of the climatic factor on the performance of mining excavators through a complex indicator - the weather stiffness index, which takes into account the parameters of any type of climate for the entire calendar period of the excavator exploitation.

1. Introduction
Modern mining engineering is focused on the development and implementation of large unit capacity mining excavators at large mining enterprises. Since a mining excavator is the main link in the open-pit mining chain. Maintaining it in a healthy condition is an important production task, the solution of which will ensure uninterrupted operation of the entire technological chain of mining and processing of rock mass. As practice shows, up to 30% of the working time fund during the exploitation of excavators is the loss from their failure during operation [4, 5, 6].

External factors, which can be divided into three groups (figure 1), have a significant impact on the operational efficiency of mining excavators:

- ergatic factor;
- maintenance and repair activities;
- factors of natural and technogenic nature.

According to the manufacturer, the greatest downtime is caused by failures of transmissions, as well as by working equipment: handles, mounting of a saddle bearing, ropes [3, 7].

This paper presents an analysis of the climatic factor impact on the reliability level of mining excavators, as one of the group-factors of natural and technogenic nature.
2. Assessment of the impact of weather conditions on the performance of mining excavators

Mining excavators are exploited in various climatic conditions, both extremely cold and extremely hot [8]. Most significantly, mining equipment is affected by temperature and humidity, wind speed, solar radiation, precipitation and others. The transformation of the properties of structural materials is also determined by the intensity and duration of exposure to these factors and their combination.

Air temperature indicators have a very significant effect on the reliability of the machine, as they affect the properties of structural and operational materials. Under the influence of solar radiation, the temperature of the machine elements and the volumes of air contained in them increase, in turn, high air humidity combined with increased temperature contributes to the intensification of metal corrosion, oxidation of electrical contacts, as well as the rapid aging of rubber products [1, 2, 9]. The intense movement of air in the form of wind creates additional loads in the metal structures of machines.

To assess the influence of the climatic factor on the reliability of machines, it is necessary to reduce the set of influencing climatic parameters into one integral indicator, for example, the weather stiffness index ($I_W$). It allows you to evaluate the impact of the climatic factor on the operation efficiency of a mining excavator of large unit capacity in real production conditions over the entire period of exploitation of the machine and to predict the exploitation time of the mining machine.

\[
I_W = \left(0.75\frac{t_{\text{min/\text{max}}}}{t_{\text{min}}/t_{\text{max}}} - 8\right) + 0.25\left(t_{\text{min/\text{max}}} - 2\right)(1 + 0.015\sigma)(1 + 0.07\nu)(1 + 0.26\varphi)(1 + 0.01Q)(1 + 0.014n)(1 + 0.022\tau)
\]

where $t_{\text{min/\text{max}}}$ – monthly average temperature, °C; $t_{\text{min}}/t_{\text{max}}$ – absolute temperature max/min, °C; $\sigma$ – average non-periodic amplitude of daily fluctuations in air temperature, °C; $\nu$ – average wind speed, m/s; $\varphi$ – average value of relative air humidity, fraction of a unit; $Q$ – average monthly amount of total solar radiation, kcal/cm²; $n$ – monthly average number of days with snowstorms, fog and dust storm; $\tau$ – duration of positive/negative temperatures in months.

3. Conclusions

The analysis of the work of EK-G32R mining excavators of large unit capacity manufactured by IZ-KARTEX LLC, operated by JSC UK Kuzbassrazrezugol in the period from 2011 to 2015 under the conditions of the Siberian Federal District showed that such excavators are designed for moderate climates, which corresponds to a temperature range from $-40$ °C to $+40$ °C. Comparing the calculated values of the weather stiffness index for a four-year period of operation with air temperature in the same period, a graph of the correspondence of these parameters is obtained.

Figure 2 shows that the temperature operating conditions for mining excavators for the Siberian Federal District go beyond the nominal values established by the project, with a weather severity index of more
than 55 in the warm season and more than 65 in the cold season. Thus, the exploitation conditions of excavators with a weather severity index of more than 55 are the most unfavorable.

Figure 2. Correspondence of the weather stiffness index to temperature values.

Figure 3 shows the change in the weather stiffness index during the exploitation of mining excavators in the considered conditions.

Figure 3. Change in the weather stiffness index in the Siberian Federal District.

The analysis of the diagram shows that the greatest value of the weather stiffness index, characterizing the least favorable conditions, falls on the cold season.

To assess the influence of the climatic factor on the exploitation of excavators, the weather stiffness index was calculated for the conditions of the Siberian Federal District, where mining excavators of large unit capacity are exploited.

According to the results of the analysis, the distribution of the working time of career excavators of the EKG type during their exploitation for various weather stiffness indices was obtained.
The longest operating time, which corresponds to 25% of the total operating time of the machine, falls on the interval of the weather stiffness index 30-40. In adverse climatic conditions, namely when the values of the weather stiffness index are more than 55, excavators are exploited 30% of the total time, which allows us to conclude that the climatic factor has a significant effect on the exploitation of EKG-32R excavators in the conditions under consideration.

Based on the revealed patterns, the distribution of the number of malfunctions of the EKG-32R career excavator among the nodes was also obtained, namely: electric motors, control devices, ropes, transmissions, bucket teeth, working equipment and the undercarriage as a function of the weather stiffness index, which are presented in figure 5.

**Figure 4.** Distribution of operating time of excavators in the framework of the current weather severity indices.

**Figure 5.** Reduced number of malfunctions in the weather stiffness index function.
The above diagram shows that the most severe weather conditions affect the malfunctions of the working equipment and the undercarriage. There is also a trend that with an increase in the weather stiffness index, the number of malfunctions increases.

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