Study of steel hardness effect on the abrasive wear resistance

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Abstract. In the course of developing the territories of the shelf of the Northern seas, the Far East and Siberia, the problem of cold-breaking materials was particularly acute. More than half of the territory of the Russian Federation is located North of the January isotherm, which has a temperature of -20 °C. In such areas, the performance of equipment, especially in winter, falls sharply. Breakdowns of tractor and bulldozer parts in winter, compared to summer, occur more often up to 6 times, and excavator parts - up to 7 times. At the same time, it was revealed that the most dangerous period of starting machines after stops. To prevent major breakdowns at temperatures less than -35 °C, excavators, drilling rigs, and construction vehicles are stopped. And this is despite the fact that in accordance with the operating regulations, they must be operated throughout the year. The performance of mining equipment is greatly affected by wear. Unsatisfactory resistance of cast parts at low temperatures leads to large downtime and large economic losses. The relationship between hardness and resistance to abrasive wear is considered. Abrasive with different particle sizes was used for the tests. It is shown that there is no linear relationship between hardness and resistance to abrasive wear, that in conditions of low abrasive rocks it is enough to have average hardness values of the order of 47-50 HRS, and when working in highly abrasive rocks it is necessary to strive to obtain high hardness values of about 50-55 HRS.

1. Introduction
Active development of the Northern territories requires the use of materials that provide a complex of physical and mechanical properties. Taking into account the wide application of mining equipment, it is necessary to use materials with high performance on different soils and in a wide temperature range of equipment operation.

During the analysis of failures of teeth of buckets of excavators it is established that the main reasons of it are abrasive wear and fragile destruction.

The mechanism and intensity of abrasive wear depends on the mineralogical composition of the natural mineral and its mechanical properties-primarily on its hardness. The main features of abrasive wear processes are considered in [1-7].

Physical and mechanical properties of abrasives depend on many factors of structure-homogeneity, presence of defects, fragmented or monolithic state.

Rocks have almost no plasticity and residual deformation. In practice, it is customary to consider the aggregate hardness and hardness of the minerals that make up these rocks. It should be noted that with the
same aggregate hardness of different rocks, the hardness of the minerals in their composition can vary dramatically.

2. Materials and methods
The analysis of domestic and foreign practice of using steels for the teeth of excavator buckets allows us to establish the following limits of the chemical composition of steels, wt.\%: carbon - 0.30 - 0.40; chromium - 0.9 - 3.5; nickel - 1.0 - 2.0; silicon 0.3 - 0.5; manganese - 0.8 - 1.2; molybdenum - 0.2 - 0.60; vanadium - 0.10 - 0.15. To search for the composition of wear-resistant steel, we used the method of mathematical planning, which allows us to conduct a relatively small number of experiments in order to find the optimal concentration of chemical elements in the alloy. The experimental melts used were melted at Izhora Plants OJSC in an open high-frequency induction furnace with a main lining. The temperature of the steel at the outlet from the furnace is 1600-1610 °C, the casting temperature is about 1550 °C. The casting was carried out by filling pre-dried sand-clay forms. The bars were homogenized at a temperature of 1100 - 1120 °C for 0.5 hours, quenched from a temperature of 890-920 °C with cooling of oil, followed by tempering at a temperature of 200 °C and 600 °C.

To study the mechanical properties, standard proportional samples of the first type were used according to GOST 22706-77. All tests were carried out according to the standards adopted for these types of tests. Based on the analysis of existing methods for the study of wear resistance, the installation shown in Figure 1 and the test scheme of Figure 2 are adopted.

![Figure 1. Appearance of the installation](image-url)
3. Research results and discussion

The conducted abrasive tests of steels allowed to establish the degree of its wear resistance from the surface hardness of the samples. Figure 1 shows the dependence of abrasive wear (Z) of steel of different hardness on the size and size of abrasive particles.

The tests showed that at the initial stage, an increase in the hardness of the metal leads to a sharp increase in wear resistance (figure 3).

Further increase in hardness leads to a slowdown in the growth of wear resistance, and even some decline, which is associated with embrittlement of the material and its dyeing.

Figure 4 shows photographs of the surface of the samples after abrasive wear tests. As shown by fractographic studies, the decrease in the growth of wear resistance with increasing hardness values may be associated with a decrease in the depth of introduction of abrasive into the metal surface. This leads to a transition from micro-cutting (figure 4, a) to plastic repulsion (figure 4, b) and subsequent dyeing (figure 4, c).
Figure 3. Effect of steel hardness on abrasive wear resistance depending on SiO₂ particle size: a - 70 microns, b - 200 microns.
Figure 4. Fractograms of wear surface of samples of different hardness, x200: a – micro-cutting and plastic extrusion, hardness 35 HRC; b – plastic extrusion, hardness 48 HRC; c – surface painting, hardness 57 HRC

4. Conclusion

Thus, the analysis of tests showed that in the conditions of low-abrasive rocks it is enough to have average values of hardness of the order of 47-50 HRC, and when working in highly abrasive rocks it is necessary to strive to obtain high values of hardness of about 50-55 HRC.

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