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INVESTIGATION OF WEAR-RESISTANT MATERIALS WORKING UNDER SHOCK-ABRASIVE WEAR CONDITIONS AND TEST CONDITIONS

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Abstract: During operation, static and dynamic loads, as well as various types of friction and wear, can simultaneously act on parts of machines and mechanisms. In these cases, as a rule, the problem of ensuring the wear resistance of parts is secondary, since, first of all, it is necessary to give structural elements strength, to exclude destruction and crushing. However, for a more significant increase in the service life of parts, it is necessary to apply comprehensive measures that allow solving these problems together. The mechanism of impact-abrasive wear of materials is primarily determined by their chemical composition and structure. A study of the nature of wear of hardened iron-carbon rolled steels shows that with a change in carbon concentration, the mechanism of impact-abrasive wear also changes. With an increase in the carbon content, the hardness of the metal increases, the depth of the holes from the introduction of the abrasive gradually decreases, however, the wear changes according to a more complex relationship: it decreases with an increase in the carbon concentration to 0.7 + 0.8%, and with a higher content, it increases.

Keywords: *structure, carbon, shock-abrasive, composition, material, sintering, wear resistance.*

Introduction. Wear to eutectoid steels, which have relatively low hardness and sufficient ductility, occurs as a result of repeated introduction of the abrasive into the surface, which causes the accumulation of plastic deformation (hardening of the metal), its hardening, and the separation of local fragments from the surface. With an increase in the carbon content, the plastic properties of steels decrease, and impact-abrasive wear occurs due to brittle chipping of metal particles [1].

He authors of [1] in the study of wear of steels 45, У7, У8, У12 showed that in order to increase wear resistance, the carbon content should be selected taking into account external force conditions of influence: dimensions, hardness and thickness of the layer of abrasive particles, speed and impact energy at the contact, as well as sample shapes.

The relationship between the mechanical properties of compact steels and their impact-abrasive wear resistance was studied in detail in [1]. When studying the influence of the mechanical properties of steel 45 and Д7ХВНШ on impact-abrasive wear resistance, it was found that hardness, impact strength, relative elongation and relative narrowing do not have an unambiguous relationship with wear intensity. Various mechanisms of impact-abrasive wear in the ductile and brittle regions (separation of which was carried out according to the orientation of the fracture site of the samples! at central bending) were revealed. It has been established that in the brittle region of fracture with an increase in hardness, a decrease in ductility and impact toughness, the wear resistance of steel increases, and in the ductile region an inverse relationship is observed. Samples with a structure corresponding to the transition from the ductile nature of fracture to fragile.

Similar results were obtained in the study of shock-abrasive wear of the surfacing material of the Fe-C-Cr system. A different nature of the influence of the mechanical properties of steels of pearlitic and austenitic classes on impact-abrasive wear resistance is noted. For austenitic steel 1ЮГ and 13Л, the change in impact strength, relative narrowing and elongation does not significantly affect wear resistance, and the tensile strength has a direct relationship with wear.

The well-known principle of increasing the wear resistance of steels and alloys when sliding over an abrasive by creating an austenitic-martensitic structure was applied to materials subject to impact-abrasive wear.

When testing powder materials according to the specified method, it is possible to reduce the accuracy of the results due to the residual porosity in the samples. In the process of washing, it is possible to get washing liquids into the open pores, which can remain in them after drying and increase the real mass of the samples. It is also necessary to correct the processing modes, as porous metals can be compacted under by the action of loads.

Taghiyev and Gahramanov found that one of the priority areas for the development of wear-resistant surfacing to the conditions of shock-abrasive wear is the creation of an austenitic-martensitic structure in the Fe-C-Cr-Ni and Fe-C-Cr-Mn systems with the addition of molybdenum, tungsten and vanadium carbides [2]. During tests with high impact energy (more than 25 J), a part of the austenite is transformed into deformation martensite, which has greater hardness and strength, which ensures an increase in wear resistance.

Iron-based alloys containing 1.2-4.8% carbon, 5-45% chromium, 1% nickel, 2% vanadium with a structure of austenite, martensite, vanadium carbide and various modifications of chromium carbides according to grain edges [2].

Product assemblability analysis. When studying the impact-abrasive wear of a surfacing alloy based on Fe-C-Mn, it was found that surfacings that are on the border of ductile and brittle fracture have the best wear resistance: for example, an alloy of eutectoid composition with a content of 6-8% manganese with -martensitic structure [3].

The highest wear resistance was observed in alloys with a carbon content of 0.55-4.19%, chromium 8-42% and boron about 2.5%. With an increase in the chromium content, the wear increased due to the formation of an excess ferrite phase, which reduces the hardness of the deposit to 45-48 HRC. The hardness of the tested alloys was 50-35 HRC. Also in this work it is shown that for the study of impact-abrasive wear, it is necessary to use special test equipment, since the properties of materials do not have sufficient correlation with impact-abrasive wear resistance.

The effect of volumetric reinforcement of compact alloyed steels is considered in detail in [4], where it is substantiated that in unstable austenitic steels with a high carbon content and moderate kinetics of martensitic transformation during shock-abrasive wear, 30-40% of deformation martensite is formed, which strengthens significant volumes of material. The developed steel 70Х5Г9ФТМ is recommended for the production of rock cutting tool parts.

In [5], the influence of heat treatment parameters on the impact-abrasive wear of white cast irons containing 19–21% chromium was studied. In the cast state, such materials have low wear resistance. The use of hardening and tempering can significantly reduce weight loss. It is shown that under the action of impact-abrasive wear, phase transformations occur in the cast iron structure, redistribution of alloying elements due to the decay of residual austenite. There is also an increase in the microhardness of the decomposition products and the overall hardness of the test surface of the samples. The best combination of properties had cast iron containing 21% chromium, the austenization of which took place at a temperature of 950°C for 1.5 hours.

The only mention of the impact-abrasive wear resistance of hard alloys is given in [6]. In comparative tests of alloys of the ВК3, ВК4, ВК4-В, ВК6, ВК6-В and ВК8 series, it was found that these materials had wear resistance 2-8 times less than steel 45 with a hardness of 52 HRC

Analyzing the results of the presented works, we can conclude that the issues related to the impact-abrasive wear of powder steels are not covered enough. From the analysis carried out, it was found that the impact-abrasive wear resistance of steels and alloys is determined mainly by the strength properties of the surface layer. Since the residual porosity of powder steels and alloys contributes to a decrease in strength, both on the surface and in the entire volume of the material [7, 8], it is possible that sintered steels will have low wear resistance under shock-abrasive wear. n addition, in porous materials, the effect of caricaturing by abrasive particles is possible, which was revealed when sliding over an abrasive in works [9].

Thus, based on a review of the studies performed on the influence of various factors on the impact-abrasive wear resistance of steels and alloys, we can propose the following ways to create powder steels that are resistant to fracture under such conditions.

For the selection of washing liquids and the drying time, the sintered samples made of ПЖВ 3.160.26 powder with a final porosity of 5 and 35% were washed with gasoline brand "Premium-95" according to ГОСТ 51105-97 and technical acetone of the 1st grade (ГОСТ 2768-84) during 30 sec. Then the samples were wiped with a filter-napkin, weighed for 1 min, and then every 5 min.

The remaining fraction of liquid (C_m) in the powder was calculated according to the formula (1) [8]:

$$C_m = \frac{m_2 - m_1}{m_2} \cdot 100\% \quad (1)$$

Where, m_2- is the mass of the sample after washing, m_1- sample mass before washing

Based on the calculated data, the dependence was built (1).

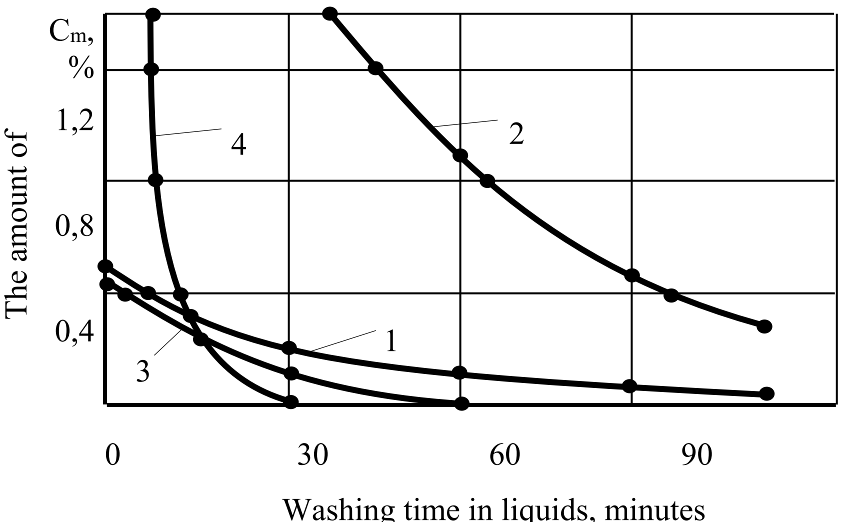

Figure1. Dependency residual share gasoline (1.2) and acetone (3.4) in samples with residual porosity, %:

As can be seen from fig. 1 the amount of absorbed liquid and the intensity of its evaporation from the surface of the samples is proportional to their residual porosity. For example, after 2 min. After drying, samples with a residual porosity of 35% contained more than 3% C_m, and with a porosity of 5% - about 0.45%. After 120 min. drying samples with a porosity of 5% contained up to 0.1% gasoline, with P = 35% more than 0.4%) C_m. In all cases, acetone evaporated from the surface of the samples more intensively, complete evaporation took place within 1 hour.

In the works of Xarlamov Y.A. and Sidorov S.A. [1,3] it is noted that the duration of the stage of formation of a characteristic relief from impact-abrasive action is determined by many factors. Since porous powder materials can be compacted under the action of external loads, it is necessary to optimize the running-in conditions when testing for impact-abrasive wear resistance. The effect of the test duration on the wear rate was studied on samples with different hardness from sintered steel ЖГр-1-6,6 with a carbon content of 0.8% and rolled steel 45.

Wear of samples from rolled steel 45 with different hardness systematically decreases in the first 300÷400 strokes and then the wear rate stabilizes (Fig.2). At the initial stage (up to 200 impacts), the powder steel specimens showed an increase in wear, and then a decrease. A constant wear rate of sintered specimens was observed after 600÷900 impacts.

The increase in the intensity of the wear of powder samples at the beginning of the test is connected with the compaction processes. Under the action of shock loads, the flattening of the sample and the chipping of material particles along the perimeter of the wear surface occur (Fig. 3.).

To evaluate the performance of the developed installation, samples were prepared from steel bar 45 and sintered blanks from ПЖР 3.160.26 iron powder with the addition of 1% (wt.) carbon to the charge. Samples made of steel 45 were subjected to heat treatment (quenching at 840°C in water and low tempering at 200°C), and for the production of powder samples, the charge was pressed in a cylindrical press at a pressure of 600 MPa, after which the pressings were sintered in a protective environment at 1150°C in the course of 2 h.

Table 1. Pre-test and post-test hardness of samples

№	Sample material	Type of heat treatment	Hardness before test	Hardness after test
1	Stell 45 (Ст45)	Annealing	160÷165 HRB	230÷240 HRB
2	ЖГр1-6,6 (PA-ZhGrTSs 1-6,6)	After sintering	132÷168 HRB	241÷283 HRB
3	Stell 45 (Ст45)	Quenching and low tempering at 200°C	51÷53 HRC	54÷55 HRC
4	ЖГр1-6,6 (PA-ZhGrTSs 1-6,6)	Quenching and low tempering at 200°C	42÷54 HRC	51÷56 HRC

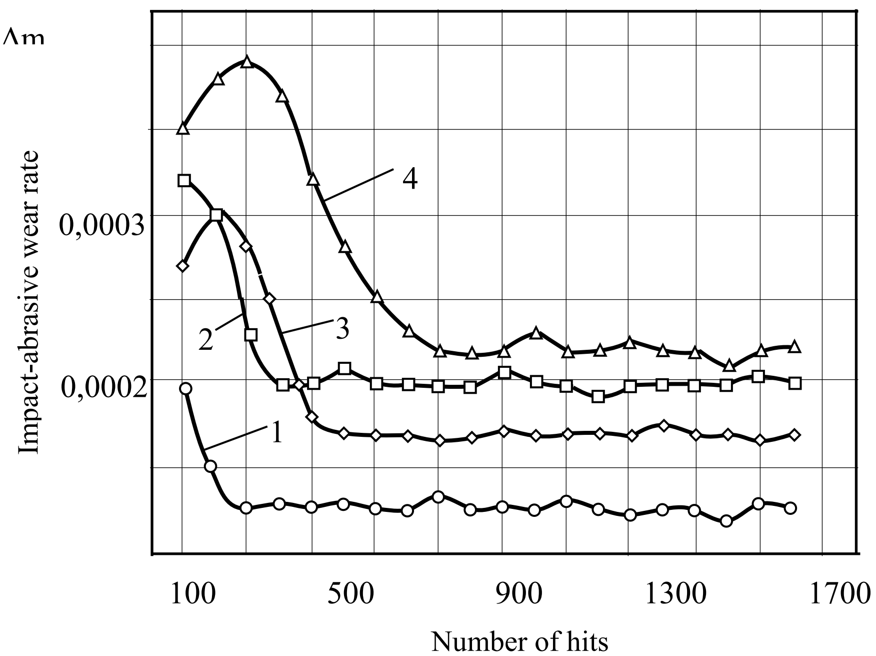

Figure 2. Dependence of the speed of shock-abrasive wear of samples on the duration of the test: 1- steel 45 (hardening + tempering); 2- steel 45 (after annealing); 3-ЖГр1 (forging+release); 4- ЖГр1 after sintering

In addition, an increase in wear with an increase in the content of graphite is apparently associated with the formation of additional pores in places where graphite was located, which actively dissolved in austenite during sintering. The high porosity of the samples intensifies the formation of cracks and the separation of dispersed particles from the wear surface. in which it is shown. That with a high content of graphite during sintering, it is intensively dissolved in iron, which causes the formation of additional pores, a decrease in strength, toughness and wear resistance of powder steel.

The decrease in the size of the holes on the surface of the samples with a high carbon content is associated with a change in the wear mechanism. It is known that with an increase in the carbon content in the steel, the hardness increases and the plastic properties deteriorate; therefore, the wear of the samples occurs mainly due to the brittle chipping of the solid structural components.

On fig. 4 shows the dependence of shock-abrasive wear and absolute deformation of the samples on the impact energy. For testing, springs with a stiffness of 0.8 and 1.65 N/mm were used, and combinations of them made it possible to provide an impact energy from 3 to 27.9 J.

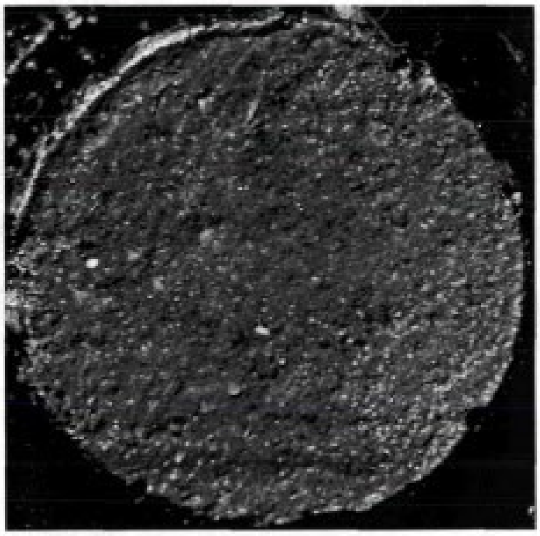

Figure 3. Macrorelief of the surface of the powder steel sample after shock-abrasive wear

Quartz sand with a particle size ranging from 0.1 to 0.63 mm was used as an abrasive. The samples were run-in in 500 strokes and wear in 100C strokes. Wear was defined as the difference between the weight of the samples after running in and testing.

With an increase in impact energy from 3 to 18 ÷ 19 J, the wear of samples made of steel 45 increased to 0.008 g and then changed slightly (Fig. 3.4, curve 1). At an impact energy of more than 24÷25 J, the mass loss again increases due to sample deformation. For powder samples, with an increase in impact energy from 3 to 6 J, wear decreases to 0.02 ÷ 0.022 g (Fig. 4, curve 2) as a result of sample compaction and hardening of the matrix. With a further increase in the impact energy from 6 to 24 J, the mass loss reaches 0.05 g, while the end of the sample is flattened and the edges are destroyed. The absolute deformation of powder samples increases monotonically from 0.07 to 0.6 mm with an increase in impact energy from 3 to 24.6 J. The residual deformation of steel 45 was no more than 0.1–0.13 mm.

The study of impact-hydroabrasive wear (Fig. 5) was carried out at an impact energy of 3 and 6.3 J, for which springs with stiffness of 0.8 and 1.65 N/mm were used. Changing the impact speed was carried out by installing additional loads (4.3; 8.6; 12.9 kg) on the impactor (impactor mass 4.3 kg). Impacts were carried out through a mixture consisting of quartz sand with a particle size of 0.1 to 0.63 mm and water. The mass fraction of sand in the mixture was 70%.

An increase in the impact speed from 0.7 to 1.8 m/s (E_{ud} = 3 J) leads to an increase in the wear of the steel 45 sample to 0.05 g, and the powder sample to 0.09 g.

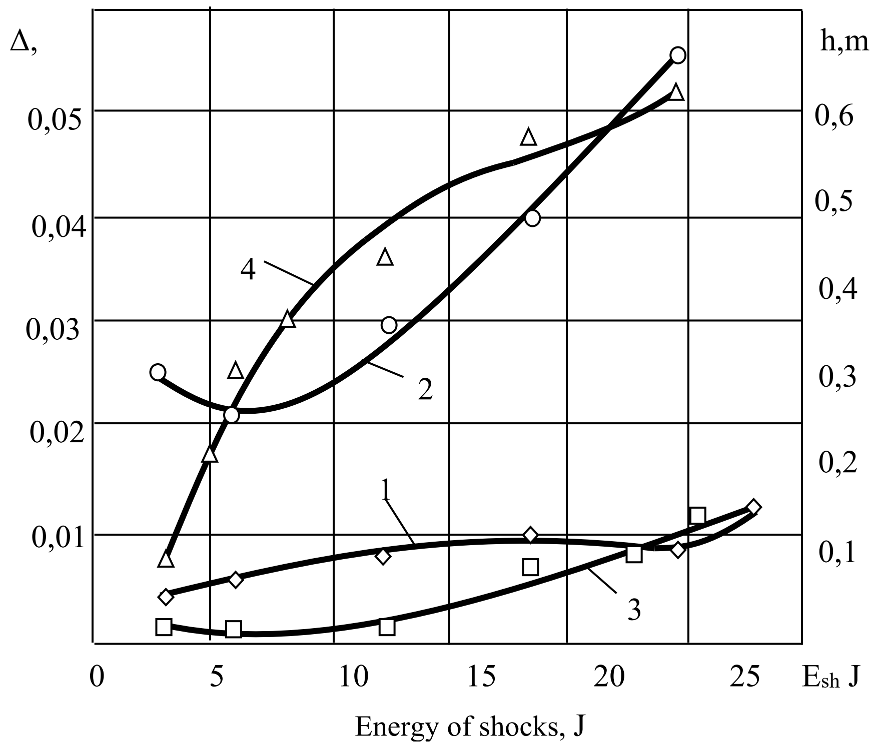

Figure. 4. Dependence of wear (1.2) and absolute deformation of samples (3.4) on impact energy during shock-abrasive wear: 1.3 - steel 45; 2.4 - ПЖГр1

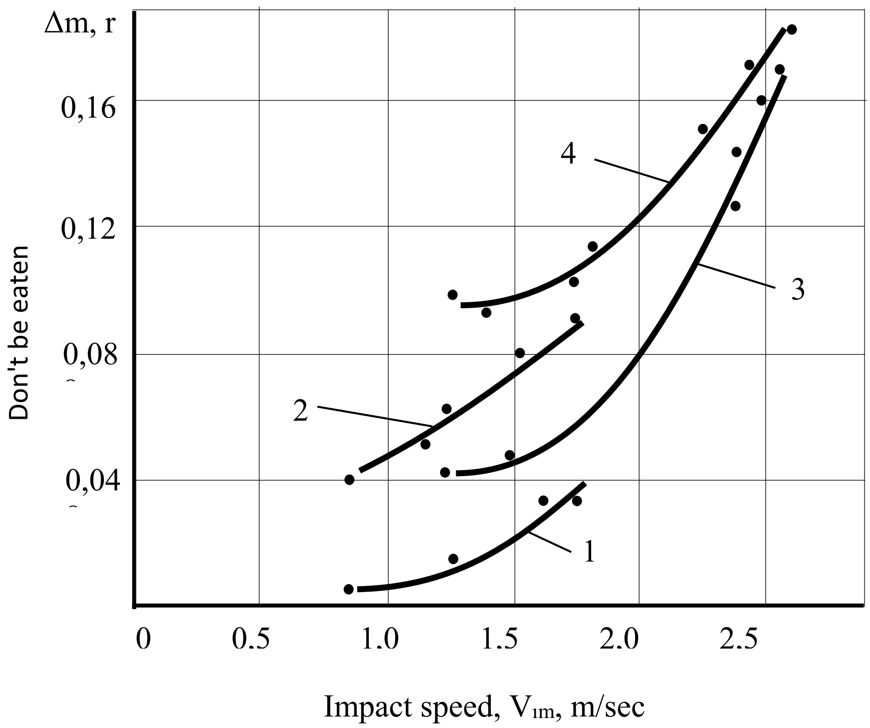

Figure. 5. Dependence of wear of steel 45 (1.3) and powder material ПЖГр1 (2.4) on impact velocity V_{im} at impact energy E_{im}, J: 1.2-3; 3.4-6.3

At the impact energy of 6.3 J, the change in speed from 1.3 to 1.9 m/s also slightly increases the wear of materials, for example, steel 45 from 0.046 to 0.06 g, and powder from 0.092 to 0.11 g. The further increase in the impact speed intensifies the loss of mass of the samples, which at 2.6 m/s for steel 45 is 0.17 g and powder-0.19.

It is established that the degree of wear of materials during shock-hydroabrasive wear is higher than during shock-abrasive wear (Fig. 4-5). This is explained by the fact that during shock-hydroabrasive wear, not only direct penetration of abrasive particles into the matrix occurs, as with shock-abrasive, but also their relative movement.

The compressed hydroabrasive mixture is pushed out of the collision zone and causes additional wear by microcutting. Such a wear mechanism agrees with the results of the work [5]. It is also established that when V_{ud} and E_{ud} are constant, the ratio of the amount of wear during shock-abrasive wear to Δm during shock-hydroabrasive wear is constant. Therefore, in the following experiments, only the shock-abrasive wear resistance of powder steels is investigated.

Thus, it is shown that to obtain reliable test results, it is necessary to take into account the physical and mechanical properties of powder steels. According to the results of the conducted research, it was established that for washing samples of porous metals, it is expedient to use acetone as a washing liquid, and at the stage of drying, the samples should be kept for at least 1 hour. The stage of processing samples from sintered steel should consist of no less than 1000 blows.

Conclusion. Increasing the strength, toughness and ductility of the matrix of powdered iron-carbon steels through the use of alloying additives. Ensuring a uniform distribution of alloying additives in steels with a given structure. Increasing the strength of powder steel by reducing residual porosity using various methods of pressure treatment of sintered billets. It has been experimentally established that powder steels containing 0.8÷1.0% carbon, 3.5÷4% chromium and 4÷5% nickel, which are evenly distributed in the matrix, have good wear resistance. When hardening powder steel with chromium carbides, the impact-abrasive wear resistance decreases due to the cracking of hard structural components. In powder steels, during shock-abrasive wear, pores are stress concentrators that contribute to the formation and propagation of cracks. Experiments have shown that the wear of materials decreases with the decrease of the final porosity according to the exponential dependence.

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