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ENVIRONMENTALLY SAFE TECHNOLOGY FOR INCREASING THE DURABILITY OF HYDRAULIC HAMMER PARTS[7]

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Abstract. *The object of research is the processes of detonation spraying of important parts of hydraulic hammers with the formation of special structures and properties of surface layers of parts to increase durability in difficult operating conditions. The purpose of the work is to solve the scientific and technological problem of increasing the durability of the working parts of heavy-duty machines based on the use of detonation spraying for contacting surfaces of hydraulic hammer parts. Research method – metallographic, microscopic and X-ray studies, bench tests of the durability of hydraulic hammer parts. In the work, studies on the application of this method were carried out. Test results of parts strengthened by this method are shown , which indicate an increase in the wear resistance of parts by 1.3 times compared to the original version. Structural changes that occur during the test in the surface layers of the parts are characteristic of the phenomena of secondary hardening with a lower level of hardness than on the parts of the previous options.*

Keywords: *hydraulic hammer , detonation spraying , wear resistance, surface treatment, hardness, durability.*

ЕКОЛОГІЧНО БЕЗПЕЧНА ТЕХНОЛОГІЯ ДЛЯ ПІДВИЩЕННЯ ДОВГОВІЧНОСТІ ДЕТАЛЕЙ ГІДРОМОЛОТА

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Анотація. *Об'єктом дослідження є процеси детонаційного напилення відповідальних деталей гідромолотів з формуванням особливих структур і властивостей поверхневих шарів деталей для підвищення довговічності в складних умовах експлуатації. Метою роботи є вирішення науково-технологічної проблеми підвищення довговічності робочих органів важконавантажених машин на основі використання детонаційного напилення контактних поверхонь деталей гідромолотів. Метод дослідження – металографічні, мікроскопічні та рентгенівські дослідження, стендові випробування на довговічність деталей гідромолотів. В роботі проведені дослідження щодо застосування даного методу. Наведено результати випробувань деталей, зміцнених цим методом, які свідчать про підвищення зносостійкості в 1,3 рази в порівнянні з вихідним варіантом. Структурні зміни, що відбуваються при випробуванні в поверхневих шарах деталей, характерні для явищ вторинного зміцнення з меншим рівнем твердості, ніж на деталях попередніх варіантів.*

Ключові слова: *гідравлічний молот, детонаційне напилення, зносостійкість, обробка поверхні, твердість, довговічність.*

Introduction

The problem of effective development industries industry of Ukraine, especially the machine-building complex, includes 2 main ones directions.

The first is this development new ones materials that combine in themselves different properties, for example, high coefficient friction with low intensity wear and tear, high strength with plasticity. For systems that work in extreme the necessary conditions materials with special properties - corrosion, wear, radiation - resistant.

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[7] Робота виконана під керівництвом професора Глушкової Д.Б.

Second the direction is modern technologies processing, with the help of whose you can provide in detail the necessary combination necessary properties, leaving from operating conditions.

Currently, they are practically absent reliable criteria for optimizing the composition and structures coverage, in particular, obtained at high-energy influences, and prognostication him working capacity in conditions friction, because of dependencies strength and wear resistance coatings in id many factors related with properties are connected materials and technology parameters their application, often occurs necessity determine the values of the quantities are experimental.

In touch with hereby installation theoretical and technological foundations of formation predicted structures and properties of important parts of construction machines at high-energy influences to increase their wear resistance and durability is important and an actual problem.

The solution given problems will open wide opportunities forecasting and management functional characteristics of important parts of construction machines in a wide range of operating conditions and will provide significant increase their longevity.

Working principle and requirements for the hydraulic hammer

Hydro hammer irreplaceable when destroyed solid rocks, concrete, frozen soil and brick buildings (fig. 1). At the same time productivity variable equipment determine energy and the beat frequency.

The analysis of the work of the hydraulic hammer showed that the longevity of its operation depends on the main working tools: picks, hammer, bushings and the body of the hydraulic hammer (fig. 2).

The body of the hydraulic hammer - the pickaxe - is prone to wear. The tip of a hydraulic hammer can have different shapes: conical, pyramidal, shovel, chisel. The choice of the shape of the peak depends on the type of material to be destroyed.

Fig. 1. Configurations of hydraulic hammer peaks

Fig. 2. Broken spade

In addition to various design features, the strength and durability of the tool are significantly influenced by the choice of material from which it is made, and how correctly the heat treatment is performed. So, the main reasons for the breakdown of the worker tool hydraulic hammer is:

- Pare diverse lateral load in progress works that create bending;
- Incorrect working angle (non-perpendicularity tool surface is collapsing material);

- " Idle " work;
- Low temperature;
- Mechanical and thermal damage;
- Unqualified surfacing or sharpening;
- Shortage lubricants;
- Corrosion;
- Wear and tear;

Important parts hydraulic hammer is working peen and guide bushings.

Peen is the main element of the hammer. A fight is this certain mass m, which is required move to some distance from tool and to disperse to given speed V to the side tool [1]. In order to disperse fight to the right speed, to him necessary to attach the corresponding force, the magnitude of which is defined pressure working family and the area on which it acts this pressure as well gas pressure in the pneumatic chamber and appropriate area the end of the striker on which it acts gas pressure.

One with the main causes of destruction fights is fatigue metal, specialists allocate sufficient attention study and determining the reasons for leaving failure of the relevant parts of the hydraulic hammer, as well as on the increase their reliability and durability (fig. 3). On these properties hydraulic hammer has a great impact are doing applied materials, technology production and constructive features [2-5].

Fig. 3. Hammer striker (general view) and fatigue failure of the hammer striker in the process operation

In series and works show that chemical and thermal processing workers surfaces hydraulic hammer allows solve only private tasks

Study experience application high energy sources energy, as well as new ones made up coatings for workers surfaces allows assume docility their use for promotion term services responsible parts of hydraulic hammers.

Research methods

Methodology for determination of hardness and microhardness of coatings.

To detect changes in the surface areas, as well as to control the quality of the coating, hardness measurements were carried out. This method makes it possible to carry out 100 % control of parts, tests are not destructive, measurements can be carried out directly on the parts. The Rockwell method was used for the study, which is usually used to study heat-strengthened material.

To determine the hardness of individual particles, as well as its anisotropy in different areas of the coating, the microhardness measurement method was used in the work.

When choosing the load, we were guided by the fact that the minimum thickness of the coating should exceed the depth of the impression by no more than 10 times. If the thickness of the coating is unknown, several measurements were taken, successively increasing the load. If the material of the base metal does not affect the measurement result, then the obtained microhardness values of the coating will be close.

Determination of the depth of the riveted layer of the friction surfaces was carried out using the PMT-3 device. The essence of the technique is that the measurement of the microhardness of the friction surface is carried out under different loads on the diamond pyramid from 0.02 HV to 2 HV, while the depth of the introduction of the pyramid h is determined by calculation:

$$h = \frac{z}{7},$$

where z - is the length of the diagonal of the diamond pyramid imprint.

Metallographic, electron microscopic and X-ray studies.

When choosing the number of samples, their sizes, location and plane of cuttings, they are guided by the tasks of microstructural analysis. Transverse samples are usually cut out, the plane of study of which is located perpendicular to the coating.

When cutting the samples, the cutting tool moved from the restored layers to the base metal. Otherwise, the probability of delamination of the coating increases due to the occurrence of tensile stresses when the tool reaches the surface. It is required that the samples are not heated to high temperatures during cutting, as the occurrence of additional stresses caused by the temperature gradient leads to cracking of the coating or its peeling. In addition, it is possible to change the structure of the base metal due to heating or defamation.

Polishing was carried out with diamond pastes. Etching of the examined surface - with a 4% solution of nitric acid to detect the border between the base and the coating.

The structures were studied and photographed on a MIM-7 microscope at magnifications of × (70-1000) times.

To detect the structures of bronze coatings and cast bronze coatings, cast bronzes were used pickling agents of the following compositions:

1. Iron chloride - 3,5 г; hydrochloric acid - 35 ml; ethyl alcohol - 75 ml.
2. 10% aqueous solution of ammonia with washing with methyl alcohol.
3. 10% aqueous solution of ammonium persulfate.

The structure of coatings and powders from chromium-nickel alloys was revealed by a 50 % solution of HCl in alcohol, as well as by electrolytic etching in a 10% aqueous solution of chromic anhydride.

The structures were studied and photographed on a MIM-7 microscope at a magnification of (70 - 1000) times. The structure of the steel-molybdenum coating was revealed sequentially by etching steel particles and molybdenum particles with various reagents. For steel particles, a reagent was used: 30 ml of nitric acid, 40 ml of hydrochloric acid, 40 ml of water; for molybdenum particles - 10 гred blood salt, 10 ml - caustic soda, 100 ml of water.

Electron microscopic and micro X-ray spectroscopic studies were conducted to establish the relationship between the conditions of recovery through worn layers, their microstructure and operational characteristics .

Electron microscopic studies were performed on a UEM 100 ML microscope using varnish replicas manufactured according to standard methods.

The structure of the surface before and after operation was studied using a SEM scanning electron microscope at an accelerating voltage of 30 kV in a wide range of magnifications from 20 to 10 thousand times. To analyze the phase composition of the base metal and coating, X-ray structural phase analysis was performed on the URS-50 unit.

The amount of residual stresses in the near-surface layers was determined on the DRON-2 installation by the method of repeated oblique surveys in the radiation of a copper anode with a graphite monochromator. Vacuum-annealed α-Fe and Ni powders were used as a standard. The profile of the diffraction line was constructed by points. The exposure time of one point was 20 s for ferrite and 100 s for titanium nitride.

Methodology of bench tests.

In order to determine the influence of different types of strengthening on the durability of the hydraulic hammer, its parts after strengthening by various methods were tested on the bench (fig. 4).

We studied the working parts of the hydraulic hammer , which were manufactured and heat-treated to a hardness of 42-44 HC. Tests were performed on the stand in the amount of 1000 load cycles. After every 250 cycles, the device was dismantled, inspected and the nature of damage to the working surfaces was recorded.

After 1000 load cycles, the reduced diameter of the casing channels in the shear zone increased to the point where 125,3 ммthe strikers in the "N" zone wore out by 0,3 мм, in the " F " zone - by 0,35 мм. Peak wear is 0.3 and , respectively 1,2 мм.

The initial signs of wear of the working surfaces of the parts in the form of small scratches appeared at the peak in the "F" zone after 250 load cycles, on the bushing in the "B" zone after 450 cycles, and on the upper parts (the striker and the body), respectively, after 300 and 500 cycles.

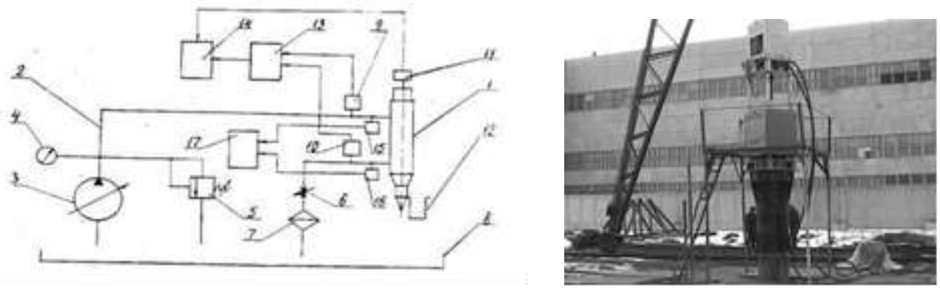

Fig. 4. Test stand hydraulic hammer (general look)

The tested parts of the device were cleaned of soot, washed in kerosene and subjected to metallographic studies.

The central part of the striker (zone "F") has the appearance of a diameter spot 40 ммwith a smoothed surface (fig. 5). Around the central spot, ring zones with a relief formed by intermittent short folds are visible, with a general radial orientation.

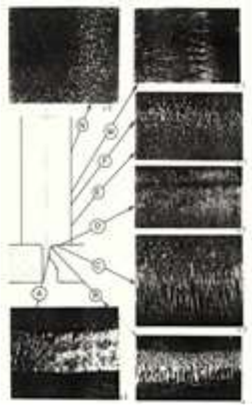

Fig. 5. The nature of damage to the surfaces of the hull and striker

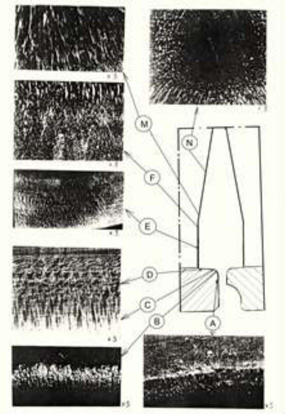

Fig. 6. Nature of damage to the surface of the pin and sleeve

The "M" zone, adjacent to the "N" zone, covers about half of the surface. They show the wear of surface volumes of metal in the form of protrusions and depressions (grooves).

Zone "B" extends to the lower part of the surface, and is characterized by intense metal plating with the formation of a shiny, smoothed, flaking surface.

Zone "E" is characterized by wear and slander of surface volumes of metal.

Fig. 7. Striker after operation: wear of the surface

On the cross-section of the case (from "A") it is observed formation nodes seizure metals, slander and wear and tear surface layer. In zones "B" and "C" defamation and micro cutting metal with education folded relief, oriented along the channel forming the hull (fig. 6). On the surface of the hull channel (zone "D") is observed wear, slander and shelling surface riveted layer.

On the surface of the hull channel, there are soot and colors variability (fig. 7).

Character of wear pike and bushings are almost identical damage upper parts. It is noted more intensive wear and tear peaks in the "M" and " F" zones in comparison with corresponding zones of the fight. Quality material of parts.

Table 1 - Mechanical properties material of parts at a temperature of 20 ºC

Name detail and	Directly in a row samples in	Mechanical and so on properties				
		σ_B, MPa	$\sigma_{0.2}$, MPa	δ, %	Ψ, %	KCV, J / cm ^{2}
1	2	4	5	6	7	8
Body and body (hull)	that 's it	1450–1460	1360–1370	14.0–15.0	56.0–59.0	48
	tangent - ts and alne	1460	1360–1370	13.0	45.0	40–42
Because he k	that 's it	1440–1450	1330–1370	13.0–14.0	54.0–56.0	34
	tangent - cial	1440–1490	1350–1410	12.0–13.0	42.0–43.0	34–82
Bushing	axial	1465–1480	1370–1390	14.0–16.0	54.0–59.0	46–48
	tangent - ts and alne	1475	1400–1410	13.0	48.0–	48
Work and tools (p and ka)	that 's it	1320	1250–1260	16.5–17.0	62.0–64.0	68–72
	tangent - ts and alne	1310–1320	1250	15.0–17.0	54.0–56.0	54–58

Material of the studied parts according to the chemical composition is satisfactory requirements operation.

Hardness material corps, fights and of peaks is almost the same in the cross section of the parts and is:

body - HRC 43–45; fight - HRC 43–44;
sleeve - HRC 42–44; p i ka - HRC 39–40.

Mechanical properties the material of parts was determined on cut samples axial and tangential directions at 20 °C (table 1). Results tests mechanical properties are listed in table. 2. Analysis of table 2 allows do conclusion that mechanical properties case material, striker, bushings and peaks at 20 °C satisfy requirements operation

When researching macrostructures it was established that the metal of the parts is dense, defects metallurgical origin absent (fig. 8-10).

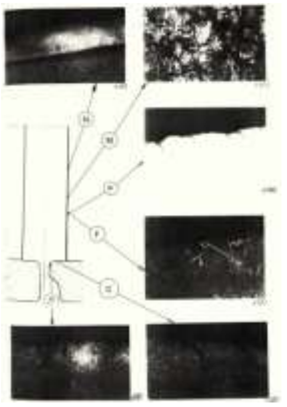

Fig. 8. Structural changes materials of the body and striker

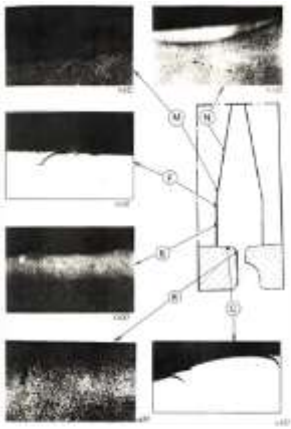

Fig. 9. Structural changes materials of picks and bushings

a b

Fig. 10. Macrostructure in the diametrical plane: a - housings; b - bushings

The microstructure is of the sorbite type, uniform in the section of the parts.

Pollution body metal, striker, bushings and pike non-metallic inclusions is almost the same, and is evaluated with a score of 1.5 GOST 1778-70 scale. They are observed sulfo-silicate and oxide inclusion.

Study of wear resistance of parts reinforced by detonation spraying

Conditions for strengthening treatment

Detonation coatings, which are a type of gas-thermal coatings, due to their higher characteristics, are increasingly being used in various industries. Due to the highest characteristics (adhesion strength to the substrate up to 250-280 (MPa) detonation spraying may be better for strengthening and restoring responsible and loaded parts and assemblies.

It has been established that coatings based on tungsten carbide from powders obtained by the spheroidization method have the highest adhesion strength with the substrate and high hardness. This is explained by the fact that the dissolution of WC in Co (Ni) partially occurs already when the powder is obtained.

During sputtering, this process continues, as a result of which the solid solution has the maximum degree of saturation.

monocarbide decay occurs, which has a negative effect on the quality of the sputtered coating. In addition, brittle double carbides Co_3W_3C are formed, which deteriorate the properties of the sprayed layer. In powders obtained by the spheroidization method, the carbide component is better protected. Modes of the sputtering process also significantly affect the structural-phase composition of coatings and, therefore, their properties. The structure of the coating is most strongly influenced by:

- the composition of the working mixture of gases;
- place of introduction of powder into the barrel;

- the degree of filling of the barrel with the working mixture.

The adhesion strength of combined coatings with a sublayer of VK-25 to the substrate reaches 200-250 MPa, Rockwell hardness - up to 70 units.

A distinctive feature of detonation spraying is the cyclical nature of powder supply to the surface of the processed part at a speed exceeding the speed of sound. The cyclic sputtering process is obtained with the help of detonation units, the schematic diagram of which is presented in fig. 11.

The device includes a detonation gun, powder and combustible gas dispensers, and an ignition system. The protective chamber is formed by a part that is sprayed (4) and two covers (5, 6), one of which is installed on the barrel (1) of the gun and is equipped with an elastic element. The gun is mounted on a horizontal movement mechanism (7), it consists of a barrel, a combustion chamber (2) and an accelerating part (3).

The expansion part is formed by bending the end of the trunk along the radius to a right angle with a conical narrowing at the end with a ratio of diameters from 1/3 to 1/4. The barrel and the accelerating part of the detonation gun are located inside the sprayed part. The part is rotated by the mechanism (8). The possibility of detonation spraying of the internal surfaces of parts to increase their wear resistance is provided.

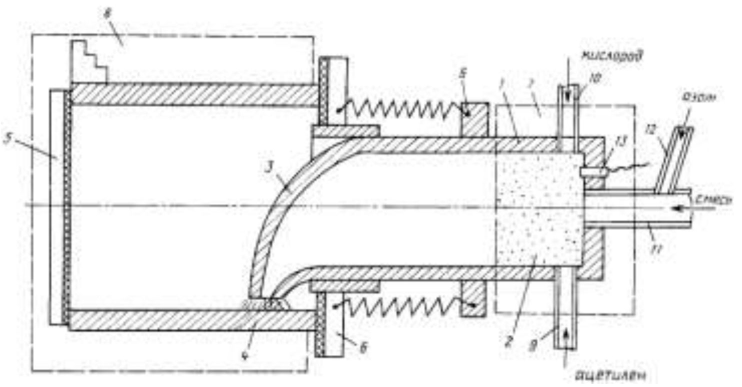

Fig. 11. Scheme of detonation devices

The principle of operation of the installation is as follows. From block 1, the gas mixture is fed into the barrel 5. At the same time, from the powder feeder through the dosing device (block 4), in specified portions, gas - nitrogen or air - finely dispersed powder is blown into the gas mixture immediately before its ignition, then the gas mixture is ignited with the igniter 2. As a result of ignition and movement along the channel of the combustible mixture, it explodes with the release of a significant amount of heat and the formation of a detonation wave, which accelerates and transfers the sputtering particle 7 through the barrel to the surface of the part 6 at a speed determined by the geometry of the barrel and the composition of the gas.

The process of forming coatings by detonation spraying is complex and insufficiently studied. In many ways, it is similar to the process of plasma sputtering. The similarity lies in the fact that the adhesion of particles to the substrate and to each other can occur in the molten and solid states. Bonding strength is ensured mainly by sputtering with molten and fused particles, which spread and crystallize on the surface of the substrate due to chemical interaction.

At the same time, the detonation sputtering process, unlike the continuous plasma sputtering process, is cyclical, the powder particles are given higher speeds, which determines the features of the coating formation mechanism.

In detonation sputtering, the speed of particles, unlike plasma sputtering (100-200 m/s), reaches 400-1000 m/s. Therefore, in addition to thermal activation, a significant influence on the mechanism and kinetics of the formation of sprayed layers is exerted by plastic deformation in the zone of collision between the particles and the substrate. However, the main contribution to the formation of coatings during sputtering is made by thermal activation.

The working surfaces of the parts were strengthened by spraying VK25 alloy (80%) and PT-NA-01 binder (Ni 91%, Al 9%). The thickness of the sprayed layer is 0.1 mm. The surface roughness of the parts before spraying was Ra 0.35–2.5. As a result of spraying, the roughness of the working surfaces of the parts increased to Ra values of 4.8–5.4 on the body and bushing and to 2.8–3.7 on the striker and pike. The wear resistance of parts reinforced by detonation spraying was studied by means of bench tests.

The initial signs of failure of the strengthened layer were detected at the peak after 400 load cycles. Risks-bumps in zones "M" and "F" for the fight, see (fig. 9) appeared after 1300 cycles, on the sleeve after 1050 load cycles and on the body after 1700 cycles. The tests were carried out in the amount of 1800 cycles.

Measurements of the tested parts show that the specified diameter of the channels in the cut zone has increased to 125.2 mm. The striker was worn by 0.25 mm, the peak in the "M" and "F" zones received wear of 1.2 mm.

Crack formation and characteristics of the structural state of the material of parts

During the test, cracks formed on all the examined parts of the device (fig. 12, fig.13). On the sleeve, cracks up to 0.05 mm deep are single and are observed only in the "C" zone. Cracks are visible on the body in zones "A", "B" and "C", with a depth of 0.25 mm, 0.4 mm and 0.1 mm, respectively. There are no cracks in zone "D". Cracks were also not found on the pique and pique in the "N" zone. There are cracks with a depth of 0.3–0.4 mm in the "M" zones of the striker and peaks. There are cracks with a depth of 0.1 mm in the "F" zone of peaks and 0.15 mm - a crack. Cracks were found both in the zones of structural changes and outside them.

In the working zones of all the investigated parts of the device during the test, almost complete wear of the detonation coating took place, only in the "M" zone of the case and the bushing are the remains observed coating up to 20 microns thick. The same single plots are on the battlefield in zone "F".

In the damage zones of all parts, structural changes of the base metal were detected. Structural transformations are observed on the body and sleeve in zones "A" and "B" to a depth of about 0.2 mm on the body and 0.15 mm on the sleeve.

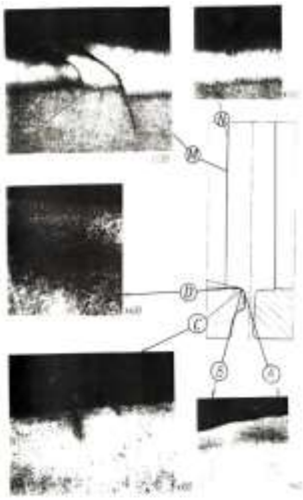

Fig. 12. Structural changes material of the case and striker, strengthened detonation spraying

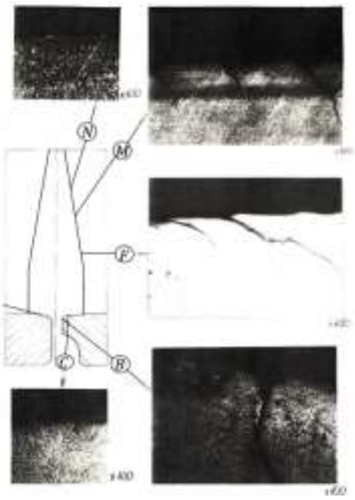

Fig. 13. Structural changes material pike and bushings, strengthened detonation spraying

Hardness the material of the parts is: sleeve – NRS 43; pika - NRS 33-40; corpus - HPC 42-43; fight - NRS 43.

Microstructure the material of fine-dispersed sorbite-type parts buildings.

The results tests mechanical properties the material of the tensile parts is given in (table 3). From table 2 it can be seen that mechanical properties material peaks after the test is not complete satisfy to the requirements that are presented.

Table 2 - Mechanical material properties of reinforced parts by detonation on sawing

Name details	Direction trimmings of samples	Mechanical properties			
		$\sigma_{в}$, MPa	$\sigma_{0.2}$, MPa	δ, %	Ψ, %
corps	axial	1480–1490	1350–1360	14.0	49.5
	tangent - cial	1490	1360	11.0–12.0	39.0
fight	axial	1490	1390	12.0	39.0–42.0
	tangent - cial	1480–1490	1360–1390	14.0	51.0
bushing	axial	1470–1480	1390–1400	12.0–12.5	45.0
	tangent - cial	1480	1400	13.0–14.0	52.0–54.0
physiognomy	axial	1320–1325	1250	15.0–16.0	54.0
	tangent - cial	1310	1230–1240	13.0	42.0–47.0

Conclusions

1. The test results of parts reinforced by detonation spraying show that an increase in wear resistance is achieved by 1.8 times compared to the original (not subjected to special strengthening) version.
2. Location of damage zones and their character on the details, strengthened detonation spraying, similarly observed on parts manufactured without additional strengthening
3. Damage to parts consists in wear and sprayed cover, slander, formation burr furrows.
4. Structural changes that observed in the surface layers of details, characteristic of phenomena secondary hardening

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