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APPLICATION OF FRACTAL FORMALISM FOR EXPRESS ANALYSIS OF MECHANICAL PROPERTIES OF PARTS[1]

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Abstract. *The method of comparative evaluation of the effectiveness of strengthening technologies for increasing the durability of hydraulic hammer parts by means of detonation spraying is considered. For an express analysis of the mechanical properties of the striker and the peaks of the hydraulic hammer after detonation spraying, the fractal formalism is used to predict the mechanical properties. The fractal dimension of the microstructure was calculated at a magnification of 100.*
Key words: *detonation coating, surface, fractal, strength, hydraulic hammer, mathematical model.*

ЗАСТОСУВАННЯ ФРАКТАЛЬНОГО ФОРМАЛІЗМУ ДЛЯ ЕКСПРЕСНОГО АНАЛІЗУ МЕХАНІЧНИХ ВЛАСТИВОСТЕЙ ДЕТАЛЕЙ

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Анотація. *Розглянута методика порівняльного оцінювання ефективності зміцнювальних технологій підвищення довговічності деталей гідромолота шляхом детонаційного напилення. Для експрес-аналізу механічних властивостей бойка і піки гідромолота після детонаційного напилення застосовано фрактальний формалізм, для прогнозування механічних властивостей. Фрактальна розмірність мікроструктури розраховувалася при збільшенні 100.*
Ключові слова: *детонаційне покриття, поверхня, фрактал, міцність, гідромолот, математична модель.*

Introduction

The choice of processing methods plays a decisive role in the formation of the set of properties of the original part, especially the methods of surface processing [1-3]. Detonation coatings, as a type of gas-thermal coatings, due to the highest characteristics, are increasingly used in various industries. Due to the highest characteristics (substrate adhesion strength up to 250-280 MPa), detonation spraying [4,5] can be better for strengthening and restoring the most responsible and loaded parts and assemblies. Detonation spraying increases the mechanical properties of various parts of a responsible purpose, the surface of which wears out during operation.

Purpose and setting of the task

To carry out work on the comparative evaluation of the effectiveness of detonation spraying on increasing the durability of hydraulic hammer parts, as well as to obtain mathematical models that will make it possible to make an operational forecast of the mechanical properties of the parts based on the analysis of their fractal structure.

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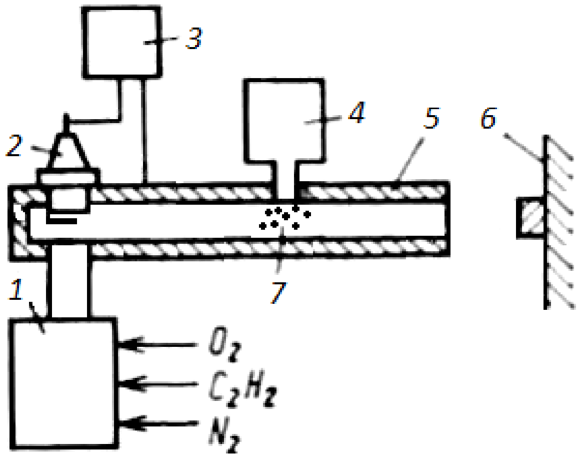
[1] Робота виконана під керівництвом професора Глушкової Д.Б.

Research materials and methods

Evaluation of the mechanical properties of parts after detonation spraying using non-destructive control methods based on structure analysis is complicated due to the complex configuration of the shape of its components. A heterogeneous and geometrically complex structure is characteristic of many surfaces after various types of spraying [6-8].

It is proposed to apply the theory of fractals to estimate the mechanical properties of hydraulic hammer parts [9-11].



1 - block from which the gas mixture is supplied; 2 – igniter; 3 - ignition unit; 4 – unit of the dosing device; an employee for the formation of the necessary gas mixtures; and lighter; of the barrel 5 – the barrel (a pipe with a diameter of 20-50 mm, a length of 1-2.5 m), 6 - the surface of the part, 7 - sprayed particles

Fig. 1. The scheme of the detonation device consists of

In a general form, detonation installations consist of unit 4 of the supply of dusting powder, which includes a powder feeder and a dosing device; unit 1, serving to form the necessary gas mixtures and fill the barrel of the detonation device with them at a given speed; ignition unit 3 and igniter 2, designed to initiate the explosion of the working mixture; barrel 5, which is a pipe with a diameter of 20-50 mm, a length of 1-2.5 m and intended for the directed propagation of an explosive wave towards the open end of the barrel.

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), fuel oil or air is blown in specified portions - finely dispersed powder 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 through the barrel to the surface of the part 6 the particles 7 that are sprayed, with a speed determined by the geometry of the barrel and the composition of the gas.

Cleaned working surfaces of hydraulic hammer parts without preliminary treatment were strengthened by detonation sputtering of VK25 alloy (80%) and PT-NA-01 binder (Ni 91%, Al 9%). The VK 25 powder used is tungsten-cobalt carbide (WC-Co) containing up to 25% cobalt, and is used for fretting corrosion, abrasive wear at normal and elevated (up to 650°C) temperatures. Powder with a grain size of 20-100 μm was used; which was melted in an oxygen-acetylene flame and transferred to the surface of the part by the gas flow. The thickness of the sprayed layer is 0.1 mm. The ratio of oxygen content to acetylene content was 12; powder loading depth 300 mm, spraying distance 150 mm, powder weight 200 g, barrel length 1.6 m, barrel diameter 16 mm.

Research results and their discussion

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 R values of 4.8-5.4 on the body and sleeve and to 2.8-3.7 on the striker and peak.

The initial signs of failure of the reinforced layer were detected at the peak after 400 load cycles. Burrs in zones "M" and "F" on the striker (Fig. 2) appeared after 1300 cycles, on the sleeve after 1050 load cycles and on the body after 1700 cycles. The test was carried out in the amount of 1800 cycles. Measurements of the tested parts show that the indicated 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 a wear of 1.2 mm The appearance of damage to parts strengthened by detonation spraying is shown in fig. 2 and 3.

The location and nature of damage to the surfaces of the parts are identical to those observed on the previously investigated device sets. Such characteristic signs of degradation of the surface volumes of the material of the parts as wear, smearing, plastic deformation with the formation of radial grooves, surface oxidation are noted on the body and sleeve. In zone "A" on the case there is wear and tear, on the sleeve there are characteristic shear lines.

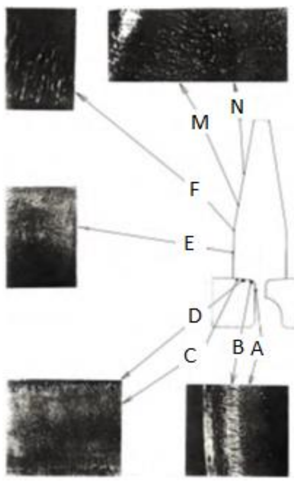


Fig. 2. Damage to the peak and sleeve strengthened by detonation spraying , ×3

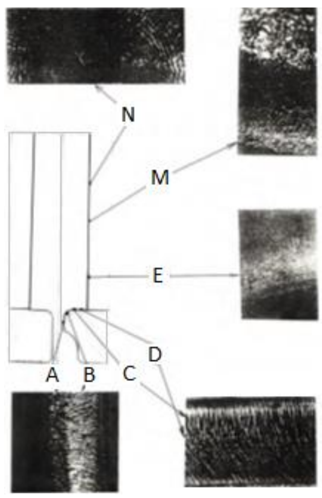


Fig. 3. Damage to the hull and striker, strengthened by detonation spraying , ×3

In zone "B" on the body there is a slightly pronounced fold-like relief, on the sleeve the relief of the furrow is smoothed to the base, so that a pattern of wave-like crumpling zones is observed. Peeling of the surface layers of the metal in the "C" zone differs on the sleeve, on the body - a smooth surface. In zone "D" there are traces of surface treatment.

The pattern of wear of the pick and pick is typical. In the presence of a central spot and grooves in the peripheral part of the "N" zone, a fold-like relief of the grooves in the "M" zone, wear and plastic deformation with the formation of a rough, flaking surface in the "F" zone and wear with slander in the "E" zone, it is noted less "roughness" of the terrain and greater smoothness for the fight and spades. In combat, the degree of damage is lower.

The body and the striker are characterized by the presence of darker colors of slop on the surface.

During the test, cracks formed in all the examined parts of the device. On the sleeve, the cracks up to 0.05 mm deep are single and are observed only in the "Z" zone (Fig. 4). On the case, cracks are visible in zones "A", "B" and "Z", respectively, with a depth of 0.25 mm, 0.4 mm and 0.1 mm (Fig. 5). There are no cracks in zone "D".

No cracks were also found on the battlement and peak in the "N" zone. There are cracks 0.3–0.4 mm deep 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 occurred (see Figs. 4 and 5), only in the "M" zone of the case and the bushing are observed the remains of the coating with a thickness of up to 20 μm. 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. On the body and sleeve, structural transformations are observed in zones "A" and "B" to a depth of 0.2 mm on the body and 0.15 mm on the sleeve.

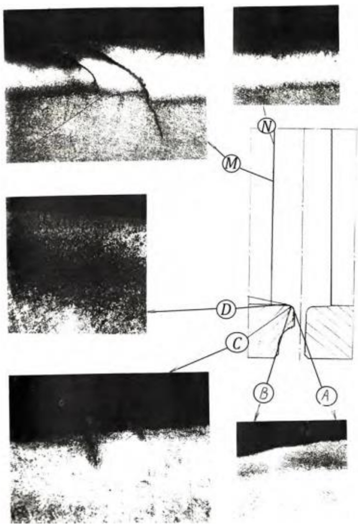


Fig. 4. Structural changes in the material of the case and striker, strengthened by detonation spraying, ×100

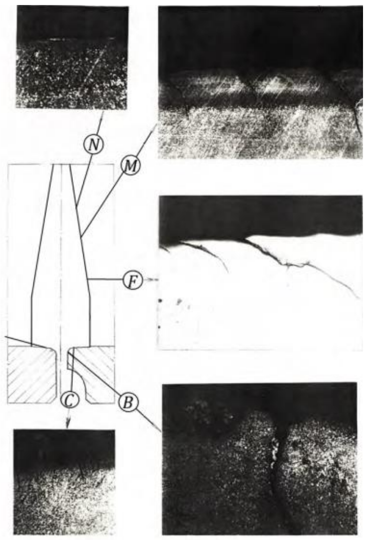


Fig. 5. Structural changes in the material of the peak and sleeve strengthened by detonation spraying, ×100

The hardness of the material in these zones on the body is HB 414-540 and HB 414-645 on the sleeve. In the "C" zones of the case and sleeve, the depth of structural transformations does not exceed 0.05 mm (HB 460–480). At the peak and peak, structural changes of the metal are observed in the "M" zone to a depth of 0.25–0.3 mm and in the "F" zone to a depth of 0.1–0.15 mm (for both) at a hardness of HV 340–475 (in places at the peak of HB 560-675). There are no structural changes in the "E" zones at the peak and peak and in the "N" zone of the peak. At the peak in this zone, the depth of structural changes is 0.15 mm (HV 340-560).

The fractal dimension *D* of the structure of the hammer and the peaks of the hydrohammer after detonation spraying at a magnification of 100 was calculated according to the Hausdorff formula [12]:

$$D = -\lim_{\delta \to 0} \frac{\ln N(\delta)}{\ln \delta}. \tag{1}$$

where $N(\delta)$is the number of cells with linear size *d* that cover the object under study.

The results of the fractal analysis of the structure of the peak and the body are shown in Fig. 6 and fig. 7.

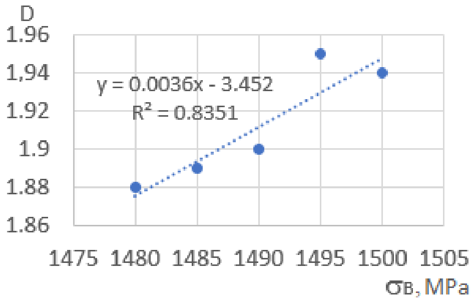


Fig. 6. The relationship between the fractal dimension of the body surface D and the strength limit s$_B$ for axial samples

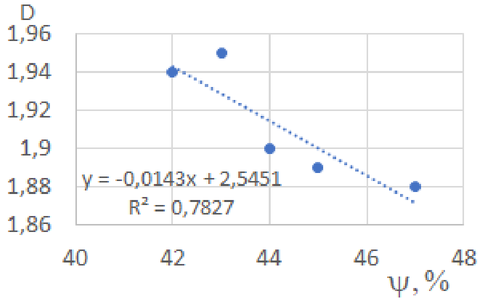


Fig. 7. Correlation between the fractal dimension of the D peak surface and the relative narrowing for tangential samples

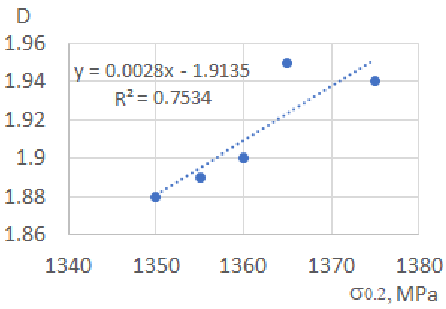


Fig. 8. Correlation between the fractal dimension of the body surface D and the yield strength s$_{0.2}$ for axial samples

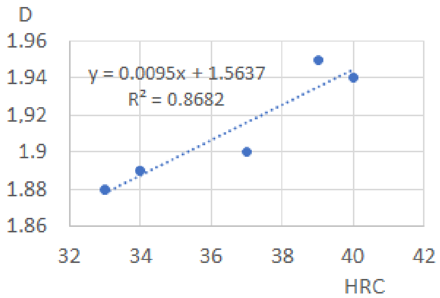


Fig. 9. The relationship between the fractal dimension of the surface of peak D and its HRC hardness in the tangential direction

Conclusions

1. A method of comparative evaluation of the effectiveness of strengthening technologies to increase the durability of hydraulic hammer parts has been created and tested, which is based on testing parts after various strengthening options and provides action during the loading process of pressures and gas-dynamic characteristics that simulate the relevant parameters of operational loads.

2. Tests of parts strengthened by the researched methods showed that, compared to the initial version, a significant increase in wear resistance is achieved:

- in the controlled cross-section of the fight and peaks during strengthening by detonation-gas surfacing, while the crack resistance of the material increases by 1.3-2.4 times compared to the initial state.

3. Mathematical models were obtained, which makes it possible to make an operational forecast of the mechanical properties of hydraulic hammer parts strengthened by detonation spraying based on the analysis of their fractal structure within the error limits of up to 6%.

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