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Increasing the Wear Resistance of Restored Car Parts by Using Electrospark Coatings

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Abstract

The work scientifically substantiates the application of effective technology for the restoration of worn car parts by applying new electrospark coatings based on electroerosion nanomaterials. The developed technology is characterized by technological flexibility, cheapness, simplicity, does not require the use of expensive and scarce materials and equipment, and also meets the requirements of environmental safety. The proposed technology can be used to restore a wide range of parts for cars, tractors and other machines. Experimentally established dependences of the effect of the properties of electroerosive materials on the properties of electrospark coatings of restored car parts. It is shown that the content of nano-sized particles in the electrode material contributes to the improvement of the physical and mechanical properties of electrospark coatings. The dependences of the influence of the properties of electrospark coatings on the resource of restored car parts were experimentally established. It is shown that the resource of the shafts of turbocompressors restored according to the recommended technology is higher than the resource of new shafts by an average of 1.5 times. Experimentally established rational modes of applying wear-resistant coatings to worn shafts of turbocompressors, which provide the necessary complex of physical and mechanical properties of the coating and the given resource of the shafts as a whole (rotation frequency of the part, min - 1 - 50; electrode feed, mm/min - 0.4 ... 0.5). The characteristics of wear resistance of electrospark coatings of turbocompressor shafts, obtained using electroerosion nanomaterials, were studied. It is shown that the average value of the coefficient of friction of the electrospark coating was 0.146 instead of 0.486 without coating, which is 3.3 times lower. According to the results of production tests, it was found that the duration of operation of the turbocharger, with the restored method of electrospark treatment with a nanostructured electrode shaft, increased by 2.1 times compared to a new industrially manufactured shaft. Thus, when abrasive material containing a fraction of 0.1...0.4 mm was introduced, the operating time of the turbocompressor with a restored shaft was 12.8 hours, and the operating time of the turbocompressor with a new shaft without wear of the nominal size was 8.1 hours.

Key words: wear resistance, electrospark coatings, restoration, car parts, nanomaterials

Introduction

Restoration of worn parts of cars ensures saving of metal, fuel, energy and labor resources, as well as rational use of natural resources and protection of the environment. To restore the functionality of worn car parts, 5...8 times less technological operations are required compared to the manufacture of new parts.

Ensuring the necessary nomenclature of spare parts in the warehouses of motor transport enterprises requires large-scale development of the car repair infrastructure and scientifically based methods of organizing and managing the processes of restoring worn car parts. Solving this important scientific and national economic task leads to the objective need to have scientific principles for the organization of effective car repair production, which determined the choice of topic, the relevance of scientific research taking into account its theoretical and practical significance, the formulation of the goal, scientific novelty and tasks of the thesis.

A car is a complex technical system, the elements of which have different characteristics of resistance to loss of operational condition. They are influenced by both internal structural factors, which depend on the purpose and properties of the element, and a set of external factors defined as the operating conditions of the car.

A modern car consists of 15...20 thousand parts, of which 7...9 thousand lose their original properties during operation, and about 3...4 thousand parts have a service life shorter than that of the car as a whole. All this causes the greatest idle time of cars, resource costs of operation [1].

Literature review

A literature review showed that more than 70% of worn parts of automotive equipment could rationally be reused after restoration. This significantly reduces the resource costs of motor vehicle enterprises, and in addition, it is economically justified for repair production. The cost of restoring parts in most cases does not exceed 25-30% of their cost, and with the qualified appointment of the restoration technology, 100% resource is achieved. The different service life of car parts is due to various reasons. The main ones are: performed functional purposes, a diverse range of loads, different types of friction in connected parts and different materials from which they are made, precision and quality of processing in connected parts.

Automotive parts of the "shaft" type make up a large part of the nomenclature of parts that can be restored. In most cases, it is these details that limit the life of machine components and assemblies. The coefficient of their recovery during the overhaul of machines is 0.25 ... 0.95. The length of the restored shafts is 100...4000 mm, but more than 90% of these parts have a length of slightly more than 1000 mm. The diameters of the shafts are equal to 12...210 mm, but the diameter of 98% of the shafts does not exceed 60 mm. The average weight is about 3 kg.

In parts of the "shaft" type, defects most often appear on the landing surfaces under the bearings and threaded surfaces. Surfaces under bearings are restored when worn more than 0.017...0.060 mm; surfaces of fixed joints (places for hubs with key grooves, etc.) due to additional parts - if worn more than 0.04...0.13 mm; surfaces of movable joints - when worn more than 0.4...1.3 mm; for sealing - more than 0.15 ... 0.20 mm. Key grooves are restored when worn with a width of more than 0.065...0.095 mm; slotted surfaces - when worn more than 0.2...0.5 mm [2].

With the entire set of renewable shaft surfaces 46% wear to 0.3 mm; 27% – from 0.3 to 0.6 mm; 19% - from 0.6 to 1.2 mm and 8% - more than 1.2 mm (Fig. 1).

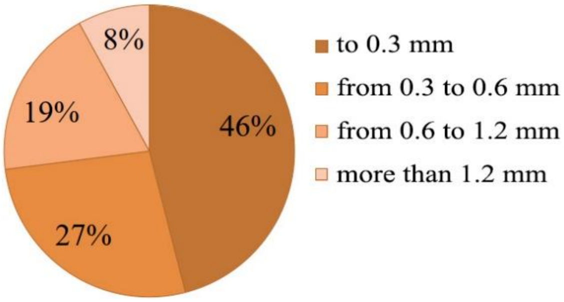


Fig. 1. Analysis of defects of parts of the "shaft" type according to the degree of wear

The main requirement that must be fulfilled during the restoration of shafts is to ensure the size and roughness of the restored surfaces, their hardness, the integrity of the coating, the strength of the adhesion of the applied layers to the base metal, as well as the symmetry, alignment, radial and end runout of the treated surfaces, parallelism of the lateral surfaces of the spline teeth and keyway grooves of the shaft axis.

Shafts of automobile machinery are made mainly of medium-carbon and low-alloy steels. They are subjected to surface hardening with high frequency currents, cementation followed by hardening, normalization.

After analyzing literary sources [1-4], it is customary to divide the defects of "shaft" type car parts into three groups: mechanical damage, chemical-thermal damage, and wear of "shaft" type car parts.

Mechanical damage to parts of the "shaft" type occurs as a result of damage to its surface with cracks, risks and burrs, as well as possible bending of the shaft, its breakage or twisting.

In a number of cases, risks and indentations are formed on the surfaces of parts of the "shaft" type, especially often this happens in shaft - sliding bearing combinations, as a result of contamination of the lubricant or the abrasive effect of particles of foreign origin.

Micron-sized cracks may form on the surface of shaft-type parts due to the influence of excessive local loads, impacts from the ignition of the working mixture or other types, as well as overloading of the shaft. The appearance of this defect occurs in the most loaded places of "shaft" type parts - at the border of the bearing surface. This defect is especially common in crankshafts and camshafts of the internal combustion engine of cars. Shafts made of cast iron are most prone to cracks. In addition to cracks arising as a result of impact forces, fatigue cracks appear in the most stressed places of shaft-type parts as a result of long-term exposure to alternating loads. In some cases, cracks may appear as a result of thermal action. Also, mostly for shafts of small diameter (up to 1 mm), bending and deformation of parts as a result of shock loads is characteristic. Such a defect appears, for example, in the turbocharger rotor shaft. As a result of fatigue of the metal, its breakdowns and breakdowns are observed during strong impacts of collapses, which often occur on cast parts. In a number of cases, due to the influence of a large torque associated with overcoming temporary significant resistances during operation, "shaft" type parts are prone to twisting [5].

Purpose

The purpose of the article is to improve, on the basis of scientific research, the technology of restoration and surface strengthening of worn car parts through the use of electrospark coatings based on electroerosion nanomaterials that provide a given resource.

Research methodology

The electroerosion dispersion (EED) method was chosen to obtain electrode material for electrospark alloying (ESA). An installation for obtaining nanodispersed powders from conductive materials was used as equipment, which includes a voltage regulator, a pulse generator, and a reactor (Fig. 2) [8].

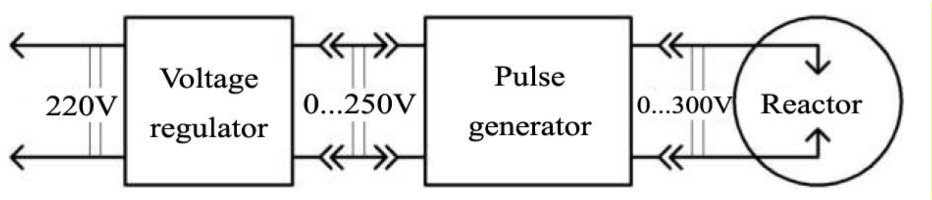


Fig. 2. Structural diagram of the EED installation

The voltage regulator regulates and sets the desired variable voltage in front of the pulse generator. In this installation, a single-phase voltage regulator PHO-260-10 TU 16.-817.298-70 is used, which allows you to adjust the output voltage of 0...260 V, and the current up to 45 A and the maximum power of 12 kW.

A pulse generator (PG) is a device that converts industrial frequency alternating current and generates pulses of a given amplitude, duration and follow-up frequency. GI requirements: high efficiency, maintain the established dispersion mode in the EED process, i.e. stability in work [4-6].

The reactor is a container filled with distilled water as a working fluid and dispersing material loaded into it - scrap high-speed steel of the P6M5 brand. A desiccator 2–240 GOST 25336-82 was used as a reactor vessel. From the pulse generator, electrodes of the same brand as the dispersing object are immersed in the container. Installation parameters: voltage, pulse frequency and capacity of discharge capacitors are selected experimentally based on the dispersion material.

The powder obtained from high-speed steel of the P6M5 grade by the EED method was studied on the equipment discussed below.

To determine the coefficient of friction and the intensity of wear of the surface of the sample with an electrospark coating applied to it and the counterbody, the automated friction machine "Tribometer" of the company "CSM Instruments" (made in Switzerland) was chosen. The used device (Fig. 3) is connected to the computer for control.

Fig. 3. Automated friction machine "Tribometer"

The tests are carried out according to the standard "ball-disc" scheme, which allows the use of the Hertz Model, and comply with the international standards ASTM G99-959 DIN50324, that is, they can serve to evaluate the wear resistance of the sample and the counterbody.

The surface roughness of the samples was examined using the "SURTRONIC 25" profilometer (Fig. 4). It has a multifunction RS-232 port, with which data can be transferred to a computer for further analysis using the optional advanced data processing software with the advanced analysis program "Talyprofile" or to a printer for printing.

Fig. 4. Profilometer "SURTRONIC 25"

The program allows you to calculate parameters, set calculation modes in full accordance with international standards. Special functions allow you to obtain a vertical/horizontal display of the profile, artificially cut the profile, thereby simulating wear of the surface, enlarge individual sections for a more detailed examination, obtain an inverted profile, exclude from the calculation "unwanted" sections of the profile, remove the shape, and also calculate separately waviness and roughness.

The electroerosion dispersion method is based on the melting of metal particles from the surface by a pulse of electric discharge. If a voltage (distance) is applied between the electrodes immersed in a liquid dielectric, when they approach (increase in voltage), the dielectric breaks down - an electric discharge occurs, and a plasma with a high temperature is formed.

Since the time used in this method of processing electric pulses does not exceed 0.01 s, the released heat does not have time to spread deep into the material (metal waste), and even a small amount of energy is enough to heat, melt and vaporize a small amount of metal. In addition, the pressure developed by the plasma particles when they hit the electrode contributes to the emission (erosion) of not only molten, but also simply heated matter. Since electrical breakdown, as a rule, occurs along the shortest path, the most closely spaced parts of the electrodes are destroyed first. When approaching one electrode of a given shape (tool) to another (workpiece), the surface of the latter will take the shape of the surface of the first. The productivity of the process and the quality of the resulting surface are mostly determined by the parameters of the electric pulses (their duration, tracking frequency, pulse energy) [7].

Research results

In order to identify the distribution of elements on the surface of the electroerosion powder, X-ray spectral microanalysis was performed with the help of the scanning electron microscope "QUANTA 600 FEG" and the X-ray radiation analyzer of the company "EDAX" integrated into it and the following results were obtained (Fig. 5).

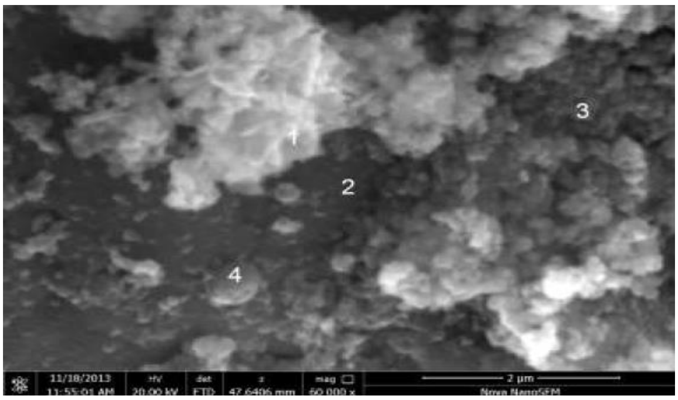


Fig. 5. Points of X-ray spectral microanalysis of powder

In the Table 1 shows the results of X-ray spectral microanalysis of powders.

Table 1

Results of X-ray spectral microanalysis of P6M5 high-speed steel powder

Element	C	O	Al	Mo	V	Cr	Fe	W
Weight, %	7,145	9,5	0,15	1,95	0,64	1,9	73,37	5,17

Thus, X-ray spectral microanalysis made it possible to determine the elemental composition of micro-objects of powder particles obtained by electroerosion dispersion of high-speed steel waste based on the characteristic X-ray radiation excited in them.

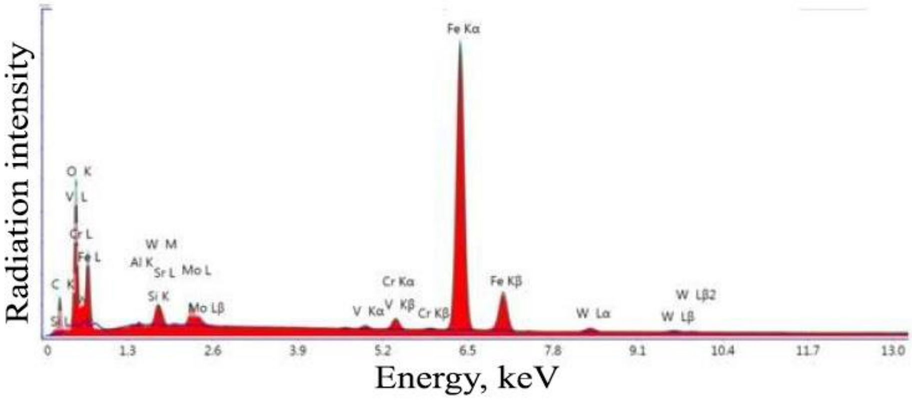


Fig. 6. X-ray spectral microanalysis of P6M5 powder at point 1

According to the results of the presented generalized data, it was established that the main elements in the powder obtained by the method of electroerosion dispersion of tool high-speed steel of the P6M5 brand (GOST 19265-73) in distilled water are: oxygen, iron, carbon, molybdenum and tungsten [8, 9].

It was established that when using stainless steel AISI 420 as a control (ball), after multiple passes over the tested surface of the experimental samples (substrates made of 30XHSA steel), the following occurs on the corresponding friction path:

- 100 m - intensive wear of the counterbody;
- 200 m – intensive wear of the counterbody;
- 500 m - intensive wear of the counterbody.

The results of tribological tests of samples using different friction paths are presented in Fig. 7, a-c.

The results of tribological tests of the friction surface of samples made of steel 30 HDSA, as well as electrospark coatings from BRS, indicate a high coefficient of friction of the latter. It was also noted that a jump occurs during tests of tribological samples from BRS. In this case, this is due to high roughness (Ra = 2.14 μm) and wear is characterized by smoothing of hard protrusions on the surface of the sample (Fig. 7, a-c) [10-12].

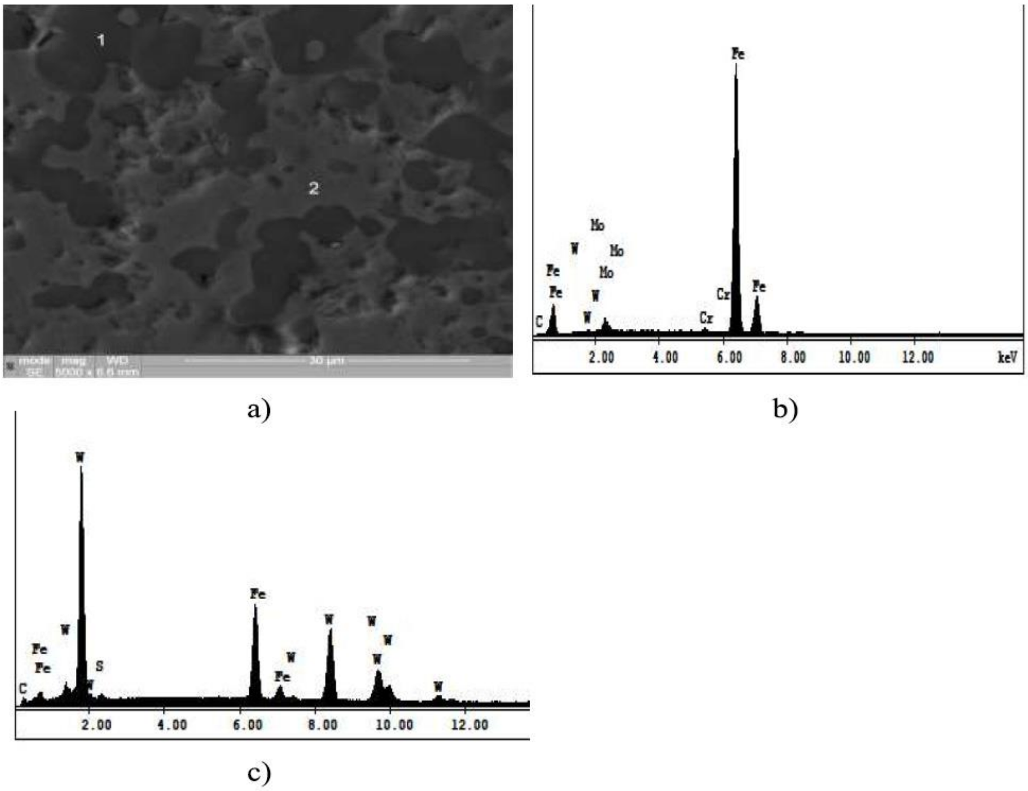
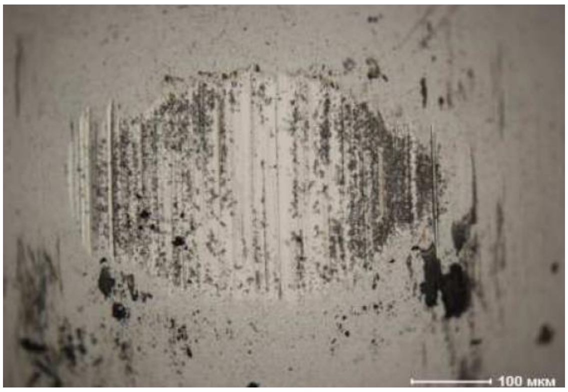


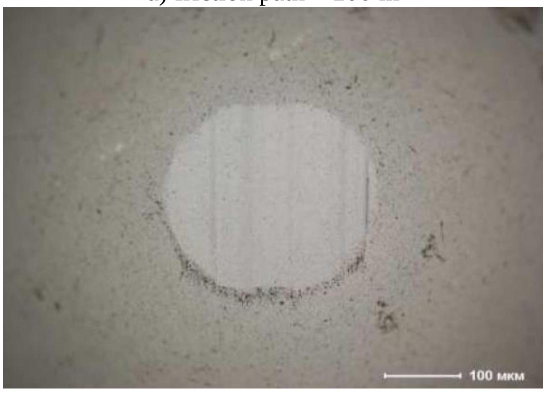
Fig. 7. The results of tribological tests of samples with different friction paths:
a - 100 m; b - 200 m; c - 500 m

The optical image of the wear spot of the counterbody (ball) after passes over the investigated surface of the experimental samples (electrospark coatings from BRS and substrate from 30KhGSA steel) is presented in Fig. 8, a-d.

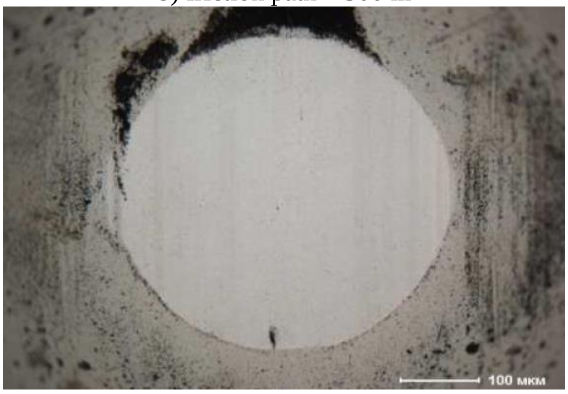
a) friction path – 100 m



b) friction path – 500 m



c) friction path – 100 m



d) friction path – 500 m

Fig. 8. Optical image of the wear spot of the counterbody (ball) after passes over the investigated surface of the experimental samples: electrospark coatings from BRS (a, b); substrates made of steel 30KHHSA (c, d)

The optical image of the wear spot showed that when using stainless steel AISI 420 steel as a control (ball) [13], after multiple passes over the tested surface of the experimental samples (electrospark coatings with BRS), the following occurs on the corresponding friction path:

- 100 m - adhesion of sample wear products to the counterbody;
- 200 m - adhesion of sample wear products to the counterbody;
- 500 m - partial wear of the counterbody and sticking of wear products of the sample on the counterbody.

It was experimentally established that the roughness of samples with electrospark coating is Rz 13.2 μm (Ra 2.14 μm).

It was experimentally established that electrospark coatings obtained with electrode material from electroerosion powders of high-speed steel have a thickness from 19.07 microns to 31.42 microns.

Conclusions

1. The proposed technology can be used to restore a wide range of parts for cars, tractors and other machines.

2. Experimentally determined dependences of the influence of the properties of electroerosive materials on the properties of electrospark coatings of restored car parts. It is shown that the content of nano-sized particles in the electrode material contributes to the improvement of the physical and mechanical properties of electrospark coatings. In particular. the average value of the microhardness of the electrospark coating (4.36 HV), obtained by the electrode material from electroerosion powders of high-speed steel, is greater than the microhardness of the substrate (2.09 HV) by up to 2.1 times.

3. Experimentally determined dependences of the properties of electrospark coatings on the service life of restored car parts. It is shown that the resource of the shafts of turbocompressors restored according to the recommended technology is higher than the resource of new shafts by an average of 1.5 times.

4. Experimentally established rational modes of applying wear-resistant coatings to worn shafts of turbocompressors, which provide the necessary complex of physical and mechanical properties of the coating and the given resource of the shafts as a whole (rotation frequency of the part, min - 1 - 50; electrode feed, mm/min - 0.4 ... 0.5).

5. The characteristics of wear resistance of electrospark coatings of turbocompressor shafts obtained using electroerosion nanomaterials were studied. It is shown that the average value of the coefficient of friction (μ) in the electrospark coating was 0.146 instead of 0.486 without coating, which is 3.3 times lower.

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Марченко Д.Д., Матвєєва К.С. Підвищення зносостійкості відновлених деталей автомобілів шляхом застосування електроіскрових покриттів

У роботі науково обґрунтовано застосування ефективною технології для відновлення зношених деталей автомобілів шляхом застосування нових електроіскрових покриттів на основі електроерозійних наноматеріалів. Розроблена технологія відрізняється технологічної гнучкістю, дешевизною, простотою, не вимагає використання дорогих та дефіцитних матеріалів та обладнання, а також відповідає вимогам екологічної безпеки. Пропонована технологія може бути використана для відновлення широкої номенклатури деталей автомобілів, тракторів та інших машин. Експериментально встановлені залежності впливу властивостей електроерозійних матеріалів на властивості електроіскрових покриттів відновлених деталей автомобілів. Показано, що зміст нанорозмірних частинок в електродному матеріалі сприяє покращенню фізико-механічних властивостей електроіскрових покриттів. Експериментально встановлені залежності впливу властивостей електроіскрових покриттів на ресурс відновлених деталей автомобілів. Показано, що ресурс валів турбокомпресорів, відновлених за рекомендованою технологією вище ресурсу нових валів у середньому в 1,5 рази. Експериментально встановлені раціональні режими нанесення зносостійких покриттів на зношені вали турбокомпресорів, що забезпечують необхідний комплекс фізико-механічних властивостей покриттям та заданий ресурс валам в цілому (частота обертання деталі, хв - 1 - 50; подача електрода, мм/хв - 0,4 ... 0,5). Вивчено характеристики зносостійкості електроіскрових покриттів валів турбокомпресорів, отриманих з використанням електроерозійних наноматеріалів. Показано, що середня значення коефіцієнта тертя у електроіскрового покриття склало 0,146 замість 0,486 без покриття, що в 3,3 рази нижче. За результатам виробничих випробувань встановлено, що тривалість роботи турбокомпресора, з відновленим методом електроіскрової обробки наноструктурним електродом валом, у 2,1 рази збільшилася по порівнянні з новим промислово виготовленим валом. Так, при введенні абразивного матеріалу, що містить фракцію розміром 0,1….0.4 мм час роботи турбокомпресора з відновленим валом становило 12,8 годин, а час роботи турбокомпресора з новим валом без зносу номінального розміру становило 8,1 год.

Ключові слова: зносостійкість, електроіскрові покриття, відновлення, деталі автомобілів, наноматеріали.