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SOME ASPECTS OF ANTIFRICTION COATINGS APPLICATION EFFICIENCY BY MEANS OF FINISHING NONABRASIVE ANTIFRICTION TREATMENT

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The article analyzes the effectiveness of anti-friction coatings obtained by finishing anti-friction non-abrasive treatment (FANT), including processing in metal-clad technological media, in order to improve the performance of machine parts. The analysis of the application of coating technologies FANT on materials operating at elevated temperature and at high pressure, as well as with high values of energy fluxes in the environment, was carried out. The results of the application of various compositions of cladding elements and FANT technologies for various engineering products are presented. The results of studies of the use of FANT technologies developed with the participation of the authors confirm their high efficiency for improving the wear resistance of artillery gun barrel materials. Decrease in wear ranging from two to three times compare to regular technology. Field testing of anti-friction anti-wear coatings, carried out by specialists of the FSE SRI «Geodesia», confirmed the prospects of this direction for increasing the survivability of artillery barrels..

Key words: coatings; additives; break-in; wear; resource; machine parts

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Introduction. The technology of finishing antifriction non-abrasive treatment (FANT) is based on the effect of metal transfer during friction and is closely connected with the discovery of the phenomenon of «selective transfer» by Soviet scientists D.N.Garkunov and I.V.Kragelsky. Among the coatings obtained by the FANT technologies, the method of brass plating for processing parts of the cylinder-piston group of internal combustion engines (ICE) and diesel engines has become widespread. According to the results of numerous tests, it has been determined that the life of the internal combustion engine increases to 30 % while reducing fuel consumption by 3-5 %. An increase in the wear resistance of the interacting materials of parts by 2-4 times has been established. For the formation of anti-friction coatings [5, 10, 11, 13-16], the optimal surface roughness before applying them should be 0.06-0.60 microns. When brass is applied to the surface of a steel part, a layer 2-3 μm thick is formed, and during copper plating and bronzing a thickness of 1-2 μm is formed [11, 13, 15, 16]. To create a continuous even layer of cladding metal on the surface of the steel part, the friction process should occur with ubiquitous, uniform seizure of the surfaces of the workpiece and the tool and transfer is carried out not by individual large particles, but by a continuous layer with good adhesion.

The formation of an anti-friction coating on the surface of steel also occurs when friction is processed with a tool from various materials (felt, rubber, etc.) in the presence of a technological metal-plating medium containing surface-active substances (SAS) and a metal salt. For example, the composition of the technological environment may include the following components, % by weight: glucose – 1-5; copper chloride (I) – 2-5; silicon oxide – up to 4; glycerin – the rest [1]. The results of studies of coatings obtained with the use of this composition showed that when a friction pair is operated, coated steel (aluminum alloy AL30 in I-20A and HF12-16 oils on air and freon 12) at a specific load of 5 MPa reduces the wear rate of parts in 2-2.5 times. A decrease in the friction coefficient by 20 % and a reduction in the time of running-in of sample surfaces by 2 times were noted.

Discussion. The coating on steel and cast iron was carried out [2] using an elastic tool made of polyurethane impregnated with a composition containing copper salts of inorganic acids. The composition developed by the authors for the manufacture of tools contains: wood flour, polyethylene glycol, copper salt and polyurethane. Coating using this technology is carried out at a sliding speed of the part and tool up to 2.5 m/s and pressing force up to 1.5 MPa. To intensify the process, parts are machined in a coolant-lubricating process medium. Tribological tests of samples of steel 45 with this coating with a specific load of 2.0 MPa in I20A oil showed that the coating provides an increase in the wear resistance of the surface of materials up to 2 times.

For the application of composite coatings that reduce friction energy losses, the authors developed [3] metal-cladding process emvironment, which additionally contains organofluorine compounds, as well as copper chloride, glucose, silicon oxide and glycerin. The role of reducing agent in this composition is performed by glucose. Silicon oxide increases the viscosity of the medium and reduces the consumption of components. The surface of the workpiece is activated by the abrasive action of silicon oxide and the presence of aldehyde groups in glucose. According to the authors, in the process of processing, fluorine-containing radicals bind to copper and form a complex coating that provides good anti-friction properties. The assumption made by the authors [3] is confirmed by X-ray spectral analysis data. Due to the hydrophobic interaction of hydrocarbon and fluorocarbon chains, a certain amount of lubricating medium is retained on the friction surface of parts, which ensures friction with low energy costs on the principle of a diffusion-vacancy mechanism. Tribological tests of samples from steel 45 showed a reduction in the friction coefficient of materials with such a coating by 1.9 times compared with the coating obtained without organofluorine components, while simultaneously increasing the wear resistance of the coating by 3 times and reducing the period of running-in to 1.4 times.

In [17] is was proposed a composition for coating, which includes copper carbonate, hydrochloric acid, glycerin and organofluorine compound. The mechanism for the formation of a composite coating is similar to that given. The presence of hydrochloric acid necessitates the use of this composition for the coating of steel with a high content of alloying elements. The results of laboratory tests of this coating showed a decrease in friction losses by up to 1.8 times, an increase in wear resistance by up to 2 times and a reduction in the time of burn-in of the surfaces of parts up to 2.5 times.

The authors of [17] also recommended the composition of the metal-cladding composition of glycerin, copper tetrafluoroborate, trisodium citrate sodium, potassium dichromate, orthophosphoric acid, and water. The use of orthophosphoric acid, according to the authors, allows to intensify the process of formation of the coating on alloyed steels and to ensure the improvement of its anticorrosive properties. Tribological tests of steel samples with this coating showed a reduction in friction coefficient by 1.5 times and wear rate by 2 times. This composition is recommended [17] for use for coating steel, cast iron and aluminum parts.

In [4], a method of forming antifriction coatings was proposed during the running-in of parts of assemblies in standard lubricants containing metal-cladding additives. The results of bench tests of units of refrigeration units, run-in using this technology, confirm its effectiveness. Studies of the structure of materials after running proved the formation of a coating on the surfaces of parts. The use of this technology is recommended for non-separable or already assembled assemblies and it is advisable in cases where it is impossible to process each part separately (for example, for rolling bearings). After running in, the knots should be washed and the remnants of the metal-plating medium removed from the cavities of the body and from the surfaces of the parts.

To implement the running-in technology, a composition containing copper carbonate, hydrochloric acid and glycerin was developed. The use of this composition has also been tested for the formation of coatings on the parts of the gearboxes of machines, gearboxes of various equipment and in rolling bearings. Processing time at idle is 1-5 minutes depending on the applied materials of parts. The use of technology has reduced the period of technological operation of running in refrigeration units at the enterprise by up to 1.5 times. At the same time, there was a decrease in complaints from consumers for unit failures, which are due to scuffing and seizure of parts and an increase in the service life of units up to 2 times.

If it is impossible to completely remove the working environment from the friction unit, the following composition has been developed [12], % by mass: inorganic acid – 0.001-0.2; mono-

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hydric alcohol is 0.1-2.0; metal additive – 0.5-5.0; oil – the rest. According to the data of [12], the use of this composition has reduced the time for running the gearbox of a screw-cutting lathe by 3 times and increased its service life by 30-40 %.

Coating technologies with the use of metal-plated process media have been tested [8, 9] on household appliances (kitchen processor), on the basic mechanisms of the shuttle machine sewing machines, on the blade tool of the sliding-cutting machines for leather-shoe and textile materials (wear reduction by 1.8-2.5 times), on the cutting edge of knives of shelling and chip machines, etc.

The team of authors of the Institute of Mechanical Engineering. A.A.Blagonravov, Russian University of Tourism and Service, SRI «Geodesia», Moscow Agro-Engineering University. V.P.Goryachkina conducted studies of the engines of GAZ-24, ZIL-130 and KAMAZ-740 machines, including laboratory, bench and operational tests of samples and parts of a cylinder-piston group, processed by various FANT technologies. According to the test results, the following conclusions were made:

• wear rate of crankshaft – liner pair, processed by FANT is 1.5-7 times lower compared with the results of untreated parts when operating in specific pressure intervals 10-25 MPa;

• FANT allows to reduce the time of running-in of parts materials up to 40 %, to reduce the total running-in wear by 50-60 %, and the coefficient of friction by 12-20 %;

• FANT reduces the integral wear rate by 40 % and significantly increases the resistance of materials of parts to scuffs.

Bench tests of the ZIL-130 engine with FANT crankshaft necks showed that the method is effective at variable loads and reduced oil pressure, i.e. under conditions of technological and operational engine running-in.

The results of the operational tests of KAMAZ-740 engines showed that the wear rate of liners subjected to FANT with a vehicle mileage of 55 thousand km is more than 5 times lower than that of untreated engine liners, and with a vehicle mileage of more than 90 thousand km lower than 2.3 times.

Field tests and bench tests of the FANT technology, performed on special-purpose diesel equipment, showed a decrease in the wear rate of parts by a factor of 1.4-2. Bench tests of the fuel-regulating equipment of aircraft engines showed a decrease in the wear of the surfaces of the most loaded parts of the units treated with FANT in metal cladding environments, up to 4.5 times. Positive results are shown on laboratory and bench tests of plunger pumps as part of hydraulic units [8, 9].

During the testing of metal-cladding compositions, an increase in the service life of a submersible centrifugal pump (ECNM type) designed to work under difficult conditions was established when pumping formation oil from oil wells having a temperature of 140 °C and containing 99 % of associated water and solid abrasive particles with a mass concentration of 0,01 %.

Repair enterprises of railways [5], repair plants of the Rempultmash system and enterprises operating straightening-tamping and straightening machines (VPR and VPRS) are provided with the working medium RSTM-1 and the additive concentrate PZTM-1, which are introduced into the liquid and solid lubricants materials to improve their anti-wear and anti-friction characteristics. The results of the production tests of the tamping unit of the CDF machines showed an improvement in the parameters of its operation, and the wear resistance of wear parts was increased by 30 %.

Testing of coating technology with the use of metal cladding environments to increase the survivability of artillery barrels and small arms are described in [6, 7]. It is noted [6] that there are compositions of metal-cladding compositions capable, under certain conditions of interaction of materials, to ensure the flow of processes of «self-organization in a thermodynamically favorable direction». The effect of passivation of friction surfaces occurs due to the introduction of additives into the lubricant: organic compounds (fluoroplast, fatty acids, etc.); metals (Co, Ni, Cu, Zn, etc.); catalysts (Pt, Pd, fullerides, etc.); Nb, Ta, Zr, etc. ceramics; metals dissolved in the organic compound, fillers (compounds in powder form) that form an anti-friction coating or surface layer with improved anti-friction properties.

The studies conducted at CDRB SHW showed that for small arms it is effective to use the multifunctional composition «Zhivoy Metal» (MFC «ZM»), developed at the Research Institute of Special Technologies. The composition is a complex of specifically treated compositions of catalysts, ceramics and organic structures. The composition of the MFC «ZM» includes special and organometallic systems and minerals, which gives the MFC the ability to form heterogeneous (metal – ceramics – organic compounds) protective coatings that have high resistance to embrittlement under mechanical and thermal effects. The catalytic systems in the MFC reduce the diffusion of hydrogen into the surface layers of materials, do not allow to reduce the strength of the surface layer during diffusion of the dispersion-strengthening elements from the surface layers to deeper ones.

Approbation of the method [6] on the models of sport-hunting and sniper weapons showed that the coating obtained is not inferior in terms of wear resistance to chromium coating and surpasses it in performance, internal and external ballistics. The use of MFC «ZM» allowed to increase the survivability of the trunks of a 12.7-millimeter sniper rifle by a factor of 2-2.5 when firing monoblock and shell bullets.

Primary testing of metal-cladding compositions with the aim of increasing the survivability of structures was carried out at the ground tests of the gun MT-12 (FSE SRI «Geodesia», 2001). Before firing, a metal-clad antifriction antiwear composition of 58 cm^3 was applied to the cleaned and degreased surface of the bore no. 1189. Earlier, 64 shots from BPS were fired from this barrel. Before each round, a thin layer of the composition of the original metal-clad composition was applied to the leading belts of the shells.

Field testing of a protective coating applied with metal-clad anti-wear compounds was carried out by firing armor-piercing sabots in the amount of 20 shots on each test day. In total 100 cannons are produced from the cannon. After the shooting of each group of shots (20 pcs.), The gun was kept for 24 hours at room temperature, then the bore was measured by a mechanical star every 50 mm, and in cross-sections adjacent to the charging chamber (930; 1050; 1260; 1380; 1500 mm), the measurement was performed by a wear control device.

Additionally, a series of tests of 44 shots from a worn barrel after 200 shots was made. When analyzing the results from consideration, shots with ordinary shells were excluded, since according to measurements, after carrying out a series of 34 shots with such shells, no significant wear was found both before and after the firing. Wear in cross-sections 1260; 1380 and 1500 mm was 2.6; 2.2 and 2.0 mm respectively.

In addition, the results of measurements before 44 shots with sabot projectiles were not taken into account, as they hadn't fired from the barrel for 7.5 years, as a result of which the barrel was covered with a corrosion film that was not completely removed even with thorough cleaning: instead, the results of intermediate measurements after 22 shots with sabotage shells and measurements after 44 shots with a PKS device during the day.

According to the test results, it was determined that the wear is very large in the initial part, but drops sharply as it approaches the muzzle, and the wear at the muzzle becomes noticeable only after all the firing. The rate of wear in the last 44 shots conducted by anti-wear technology, drops sharply compared with the wear on the previous 137 shots conducted by standard technology. On average, the wear rate drops 3 times – from 1.8 to 0.6 mm per shot. Decrease in wear ranging from two to three times in comparison with regular technology.

Another series of ground tests of the protective coating was performed using a tank gun (SRI «Geodesia»). The wear resistance of the protective coating applied to the surface of the barrel bore was carried out by firing armor-piercing sabots in the amount of 35 shots.

Before work, the surface of the bore was cleaned using a barrel cleaning mechanism from the mobile complex and degreased with gasoline. Then, the magnitude was measured and the character of wear of the barrel bore was determined with a PINT device (a device for measuring the pipe straightness) with an instrumental error of 0.01 mm.

After the initial measurements, the antiwear composition was applied to the surface of the bore by reciprocating movements of the wiper (120 cycles). Then, two groups of 7 shots were fired in the group and one group of 14 shots, one group of 7 shots («Product 3BM42»), on the leading belts of which another composition was applied before shooting. After the shooting of each group, the barrel was cleaned, wiped dry, then the barrel bore was measured with the PINT device..

In the course of all firing, the initial velocity and technical dispersion of projectiles at a distance of 100 m were recorded. To assess the barrel wear resistance, experimental results were obtained based on shot firing on the results of firing single-piece «Product 3BM42» from four barrels at the Geodesy Research Institute without the use of anti-wear technology.

The averaged dependences showed that, within 120 shots, the dependence of wear on the number of shots is linear, since the deviations of the average values of wear on all graphs from the straight line are insignificant compared to the deviations from the trunk to the trunk. From the data obtained it was determined that in the process of applying the «wear-free» technology to the surface of the bore of a protective coating, the wear resistance increases 2.2 times.

When using, instead of linear dependencies, the average experimental ones in the range from 0.5 to 1.0 mm, the wear resistance coefficient increases to 3-3.5 (in a 1000 mm cross section, the specific wear in this area is not 0.015 mm, but 0.022 mm, respectively, the wear resistance coefficient increases to 3.2). Thus, field testing of antifriction anti-wear coatings, carried out by specialists of the FSE SRI "Geodesia", showed the promise of this direction for increasing the survivability of artillery barrels. Systematic research involves the review and evaluation of the experience gained in this and related areas.

Conclusion. An analysis of the reviewed papers leads to the following conclusion. To increase the durability of artillery barrels there is a great scientific and technical potential in the field of antifriction anti-wear coatings. This resource can be actively used to ensure the modernization of the ground test system of artillery barrels. In this regard, the corresponding theoretical and methodological bases for model verification and validation of test results are currently being developed.

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