Increasing the wear resistance of autotractor equipment parts

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Abstract. Maintaining the performance of power units of automobile and tractor equipment for a long time is a very urgent task today. In this regard, work is being carried out to develop and master the technology for applying advanced coatings to increase surface hardness. However, the development of coatings that increase wear resistance is inextricably linked with research aimed at studying the properties of the coatings themselves, as well as their impact on the performance of the products themselves. To ensure long-term and trouble-free operation of units with friction pairs, not only advanced coatings are used, but also methods for applying special microrelief, protective materials and lubricants. Many scientific schools are working on solving the problem of increasing resources. Each approach involves testing and calculations. This paper shows the effect of ceramic coating on the service life of the crankshaft of a KamAZ vehicle engine. This paper examines the possibility of using a ceramic coating as a means of protecting the crankshaft journals from wear. Data from studies on increasing the service life of friction pairs are presented. Dependencies that characterize the wear rate are presented. A fragment of a method for calculating crankshaft deformations caused by residual stresses is proposed.

1 Introduction

The operation of automobile and tractor equipment is inextricably linked with the occurrence of wear and tear of rubbing parts and components of the transmission, engine and other systems. Increasing wear resistance is a very urgent task, which allows reducing the costs of maintenance, repair and operation of equipment.

Currently, there are promising ways to increase the wear resistance of a surface. These include:

- Method of carbide-arc hardening (CVSA) using a carbon electrode and multicomponent pastes [1-3];

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- Method of ultrasonic hardening [4-6];
- Laser hardening [7, 8];
- Plasma spraying [9-11].

The use of the listed methods of hardening has its own specific applicability. In friction units subject to high temperature loads, plasma spraying, ceramic coatings and laser hardening have been effectively used. Parts that are not subject to intense heating can be strengthened by surface-plastic deformation methods, such as ultrasonic methods and vibration rolling.

The purpose of this work was to determine the effective use of methods for strengthening the friction surfaces of automotive parts.

2 Results of the research and discussion

According to Autostat, the average operating life of freight vehicles is 17 years; most often, major repairs are performed on the power unit [12]. To increase the service life of the vehicle, the crank mechanism (CCM) was modernized, namely, the application of a ceramic coating to the rubbing parts. The studies were carried out on a KamAZ car engine; the coating application locations are shown in Figure 1.

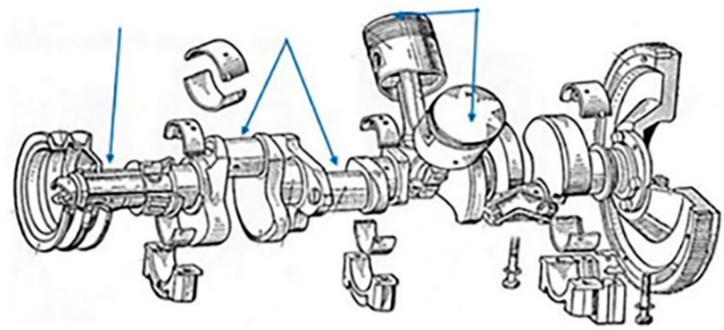

Fig. 1. Places for applying ceramic coating to elements of the crank mechanism.

This process is carried out using high-temperature plasma (2400 °C), which melts ceramic particles, forming uniform coatings on the parts.

The crankshaft is the basis of the internal combustion engine. It is used to convert the rotational motion of the engine crankshaft into the linear motion of a piston.

Main parts of the crankshaft that are subject to wear:

- Crankshaft;
- Connecting rod bushings and bearings;
- Piston rings;
- Cylinder liners.

For the standard manufacture of some parts of the KamAZ crank mechanism, aluminum alloy and wear-resistant cast iron are used. To increase the service life, it is necessary to apply ceramic coating to the main elements of the CVM; this will increase not only wear resistance, but also the chemical resistance and heat resistance of the elements. The coating allows you to reduce the coefficient of friction of surfaces, which will improve the performance of the internal combustion engine. Ceramic coating is also applied to the cylinder block (BC) and cylinder head (cylinder head) of an internal combustion engine with a gas-diesel power system to protect it from external environmental influences. This treatment increases the heat resistance of surfaces and reduces thermal conductivity, which reduces the load on the lubrication and cooling system of the machine.

The most widely used oxide ceramics are based on aluminum oxide, zirconium, magnesium, as well as solid solutions and compounds (binary and ternary systems): Al_2O_3–ZrO_2, ZrO_2–Y_2O_3, ZrO_2–MgO, Al_2O_3–MgO, ZrO_2–CaO, ZrO_2– CeO_2; ZrO_2–Al_2O_3–Y_2O_3, Al_2O_3–MgO–ZrO_2, etc. The most promising oxides are: chromium, titanium, beryllium, rare earth metals, etc. Research conducted earlier [13] showed high tribological properties at high temperatures in vacuum and air chromium oxide (Cr_2O_3) in the form of coatings applied by vacuum electron plasma methods (Table 1).

Table 1. Properties of refractory oxides.

Oxide	Crystal cell	Density, g/cm^3	Tmelt, °C
Al_2O_3	hexagonal	3.97	2050±10
MgO	cubic	3.60	2500±15
ZrO_2	monoclinic	5.60	2680±20
CeO_2	cubic	7.30	2725±20
Cr_2O_3	hexagonal	5.21	1990
SiO_2	cubic	2.32	1710
BeO	hexagonal	3.02	2530±30
ThO_2	cubic	9.02	3050

The applied coatings must ensure long-term operation of friction units. In addition to long-term operation, it is necessary to ensure high reliability of operation. To meet these requirements, the antifriction layer must have the following properties:

- high fatigue resistance, which is expressed in the ability of the material not to collapse under the influence of changing loads over the entire range of operating temperatures;
- high wear resistance, expressed in the ability of materials to resist wear under certain friction conditions;
- low friction coefficient;
- high corrosion resistance when exposed to lubricants;
- good workability;
- high technology and low cost;
- high resistance to scuffing;
- the ability of the material to reduce the impact of foreign solid particles;
- availability of applied materials;
- low toxicity of materials, which will provide the opportunity to organize "green" production technologies;
- lack of catalytic activity of the material towards oils.

Research has shown that the ceramic coating made it possible to reduce wear during the period of normal operation of the crankshaft parts (Figure 2). The running-in period has increased from 120 to 150 minutes, this is due to the fact that the hardness of the ceramic (HRC 70) is higher than the hardness of the base metal (HRC 50).

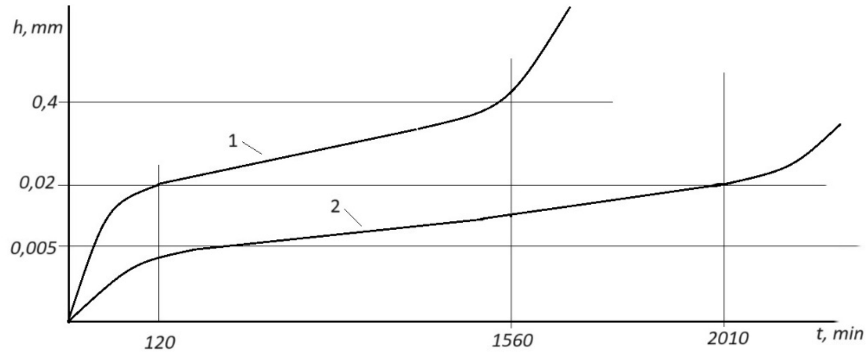

Fig. 2. Dependence of wear on the crankshaft surface on operating time: 1 – crankshaft without coating; 2 – crankshaft with ceramic coating.

As can be seen (Figure 2), a period from 150 to 1560 minutes characterizes the operation of the crankshaft in the presence of a ceramic coating. Further work takes place without coating because it is worn out and the shaft works as in the basic version.

Thus, it can be seen that the service life of the crankshaft increased by 28.8%.

Ceramic coatings on the rubbing surfaces of automotive parts have a positive effect on their performance and durability.

However, the coating process is associated with the formation of residual stresses in the surface layer. Residual stresses can lead to part deformations. Such deformations must be predicted at the stage of technological preparation of production, having only a drawing of the part.

In order to develop a methodology for determining possible deviations in size and shape, it is proposed to calculate them through bending moments caused by residual stresses relative to the middle surface [14]:

$$\sigma x = \frac{6Mx}{d^2}, \tag{1}$$

where σ_x is the value of residual stresses; d – shaft diameter [15];

M_x – bending moment equal to

$$Mx = -D\left(\frac{\partial^2 \omega}{\partial x^2} + \mu \frac{\partial^2 \omega}{\partial y^2}\right) \tag{2}$$

D is the cylindrical stiffness of the plate, ω is the desired shaft deflection.

Determining the optimal conditions for applying a ceramic coating requires research at the pre-production stage [16, 17].

3 Conclusion

Thus, ceramic coatings are a promising way to harden the surfaces of automotive parts. They ensure reliable functioning of the mechanisms. Ceramic materials have high heat resistance, chemical resistance, wear resistance and electrical insulating properties. This allows the use of ceramic materials in various units and components. They are especially effective in highly loaded friction units operating under high temperature and mechanical loads.

Thanks to the ceramic coating, components, assemblies and parts are protected from corrosion and their hardness increases. Depending on the application method and layer thickness and ceramic composition, surface wear can be reduced by 25-30%. Thus, the use of coatings makes it possible to increase the service life and overhaul mileage of automotive parts.

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