NANOSTRUCTURED COMPOSITE COATINGS FOR THE PROTECTION AND RESTORATION OF PRECISION FRICTION PAIR PARTS

НАНОСТРУКТУРИРОВАННЫЕ КОМПОЗИТНЫЕ ПОКРЫТИЯ ДЛЯ ЗАЩИТЫ И ВОССТАНОВЛЕНИЯ ДЕТАЛЕЙ ПРЕЦИЗИОННЫХ ПАР ТРЕНИЯ

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Abstract: *The paper deals with the creation of fundamentally new functional multicomponent coatings applying the technologies of ion-plasmous sputtering. Developed a restoration technique for the precision pairs of hydro fuel equipment. The obtained coatings are peculiar because of their enhanced wear resistance, low coefficient of friction, and good adhesion with basic material.*
KEYWORDS: *PRECISION FRICTION PAIR PARTS, MULTICOMPONENT COATINGS, ION-PLASMOUS SPUTTERING*

1. Introduction

Reliability of diesel and gas turbine power plants and water power devices of different functionality to a considerable degree depends on failure-free operation of friction pairs having the functions of sensitive elements of automatic control units, distributors of hydraulic tracking drives, and other critical units. The majority of failures including hydraulic unit failure occur due to the malfunction of control units and distributors as well as plunger, piston, and vane pairs of pumps and hydraulic motors.

Movable couplings of different construction and purpose with the parts having radial or plane coupling surfaces created with high accuracy and degree of surface smoothness are attributed to precision pairs (PP).

The type of damageability of PP elements considerably depends on the type of pair, loading conditions, purity, and the properties of operating fluid, which may contain some abrasive particles as well as reactive reagents (water, sulphur, phosphorus, chlorine etc.). The spectrum of wear types is very wide – from systematic abrasive cutting that worsens adjustment characteristics to local and avalanche seizure, and jamming, which result in aggregate operation failures.

At present, in the process of fuel hydraulic aggregate repair, the majority of PP is replaced by new ones because of the loss of the performance characteristics. This circumstance leads to a considerable growth in expenses for equipment repair, because, as a rule, it is necessary to replace the whole unit due to the malfunction of one subunit.

Thus the development of new enabling restoration techniques for worn-out PP part surfaces is a topical problem.

Wear of internal PP elements (valves, plungers, pistons, etc.) can be compensated by creating restoring coatings deposited by method of ion-plasma sputtering [1].

2. Experimental Equipment and Technique

Ion-plasma sputtering was implemented using a vacuum plant; its diagram is represented in Fig. 1. The basic element of the plant is a vacuum chamber for sputtering 9 with sources of material being sputtered 2 and a turntable where the parts being processed are fastened 5. The plant is supplied with a vacuum-pumping system, a working gas feed system, a cooling system, and a power-supply system.

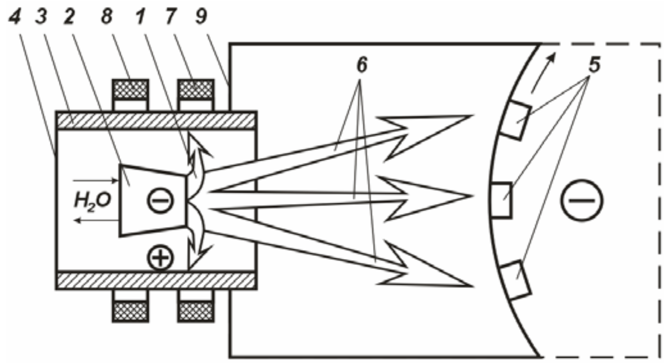

Fig.1. Diagram of vacuum ion-plasma sputtering plant: 1 – plasma, 2 – cathode (arc evaporator), 3 – circular anode, 4 – gun, 5 – parts being processed, 6 – material being sputtered, 7 - focusing magnetic coil, 8 – stabilizing magnetic coil, 9 – vacuum chamber

In order to sputter fine metals and their alloys argon is fed to the chamber to obtain, for instance, nitrides, carbides – reaction gas (nitrogen, methane, etc.). Thus, in argon environment with titanium evaporator, pure titanium in the form of atoms and liquid drops of metal deposits on parts. When nitrogen is present in the chamber, there occurs a plasma chemical reaction, which results in the formation of titanium nitride compounds forming the coating.

The process of sputtering occurs under pressure in the chamber in the range from 10 -3 to 1.0 Pa at the temperature of the sputtered part surface from 300 to 700◦C.

In order to extend the plant performance capabilities its modification was created – instead of one of the arc sources there was installed a planar magnetron sputtering device and added a special system of gas feed.

The advantage of the magnetron sputtering is the absence of a drop phase, the possibility of sputtering a wide spectrum of materials, high utilization of the material, "good" adjustment characteristics, high density and homogeneity even of thin coatings. However, the magnetron sputtering technique has some drawbacks too – poor efficiency when depositing some kinds of materials as well as low effect of ion bombardment. In this case, when sputtering the compounds, a separate feed of the working and reaction gas is also desirable.

The possibility of combining the arc and the magnetron sputtering methods, which appeared in connection with the plant modification, allowed to partially diminish the drawbacks of the both methods using their basic advantages at the same time. In particular such technique gave the opportunity to diminish the drop phase without any substantial decrease of the effect of ion bombardment. Moreover there was widened the spectrum and improved the quality of the materials being sputtered.

3. Subject of Research

A plunger precision pair of locomotive diesel high-pressure fuel pump with a nominal coupling diameter of 17 mm (Fig.2.) was chosen as a subject of research. PP consists of an internal element – a plunger and an external element – a barrel.

Fig.2. General view of a plunger precision pair (assembled)

The plunger (Fig.3.) has an initial hardness of 59…63HRC.

Fig.3. General view of the plunger

The researched PP operates in very severe environment. Safe radial clearance of PP coupling does not exceed 2 micrometers. As a rule due to heavy wear the PP plunger is beyond repair.

4. Basic Research Results

For the creation of the restoring wear-resistant coating the coatings on the basis of Ti – Al - N (titanium-aluminium-nitrogen) was researched as the basic ones (Fig.4).

Fig.4. Microphotography of the obtained composite coating (x550)

In the process of sputtering Ti was used as the first evaporator, Al – as the second evaporator, also Al – as a magnetron cathode material. Constant sputtering parameters:

- current of the first evaporator - 40A,
- current of the second evaporator - 70A,
- reference voltage on the parts being sputtered - 60 V,
- argon pressure in the sputtering chamber - 1,5·10-3 mm Hg,
- nitrogen pressure in the sputtering chamber 2·10-3 mm Hg,
- time of sputtering - 20 min.,
- current of the focusing coils of evaporators - 0,3A,
- current of the stabilizing coils evaporators - 0,7A,
- voltage across magnetron- 300 V.

Magnetron current changing in the range from 0 to 10A was chosen as a variable parameter. The results of microhardness research depending on current change across magnetron and, subsequently, the quantity of aluminium in the coating are presented in Fig.5.

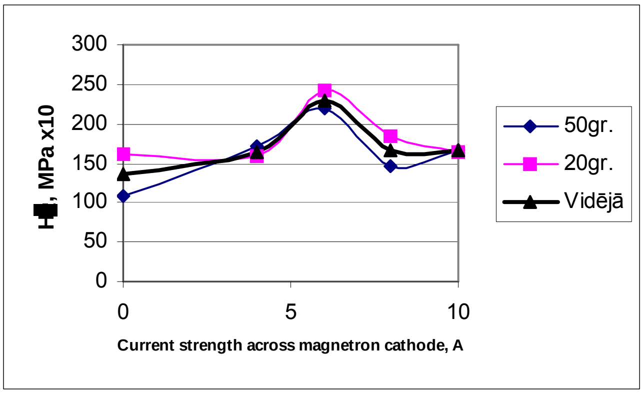

Fig.5. Behaviour of plunger operating surface microhardness depending on current change across magnetron

In what follows, a sputtering mode with 6A current strength across magnetron ensuring the achievement of maximum microhardness of 2200 Hμ was taken as a basic one.

The technique of plunger operating surface restoration by means of ion-plasma sputtering includes the following basic stages:

1. Making the measurements of the part subject to restoration
2. Stabilization thermal tempering
3. Removal of oxidized surface layer
4. Determination of the required size of surface layer being sputtered
5. Ion-plasma sputtering of the first size restoring layer, which ensures good adhesion to the base and levelling of interlayer stresses
6. Ion-plasma sputtering of the second (external) layer with enhanced wear resistance on the basis of titanium and aluminium nitrides
7. After sputtering processing of the part
8. Plunger pair lapping
9. Making control measurements of the restored part

5. Conclusion

As a result of the conducted research there was:

- developed a restoration technique for the precision pairs of hydro fuel equipment;
- optimized the modes when sputtering the coating by magnetron current.

The obtained coatings are peculiar because of their enhanced wear resistance, low coefficient of friction, and good adhesion with basic material.

6. References

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