Properties of coatings formed by plasma electrolytic oxidation on plastically deformed aluminum alloy AO3-7

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Abstract. The article presents the research results of the influence of electrolyte composition and plasma electrolyte oxidation (PEO) modes on microhardness and wear resistance of coating formed on a bush of the gear type pump HIII-Y, which is reconditioned by plastic deformation.

1. Introduction.
At the present time one of the aggregates that acquired wide usage of the gear type pump HIII-Y. It is intended for mineral oil delivery in the hydraulic systems of tractors, loaders, agricultural, municipal, road-building machines and other machinery. Bushes of the gear type pumps HIII-Y are referred to the elements subjected to the maximum wear. Antifriction aluminum alloy AO3-7 is used for their manufacturing. Basic wear of these elements influencing on the pump volume decrease of type HIII-Y, takes place on the internal cylindrical and end surfaces, connected with gears, which reaches 0.3 mm.

In repair manufacture for reconditioning of different purpose elements as well as elements manufactured from aluminum alloy plastic deformation is used. Plasma electrolyte oxidation (PEO) is an advanced method of hardening of the articles made from aluminum alloys. The usage of oxide and ceramic coatings for hardening of aluminum alloy elements hardening reconditioned with plastic deformation allows increasing their wear resistance considerably and hence, durability, which is a prospective line of repair manufacture development in modern conditions. Beyond that such combined method of repair, it is possible to use to eliminate manufacturing defect.

2. Materials and research methods
The samples were produced by cutting new and bushes of the gear type pumps HIII-32Y-2, reconditioned by plastic deformation (pressing). For shaping the sample surface into the right geometric form and obtaining the required micro roughness they were subjected to the mechanical treatment. Since, to increase wear resistance, the surfaces of the prepared samples were subjected to hardening by plasma electrolyte oxidation (PEO). Coating formation was done on the experimental installation including power supply unit, electrolytic bath with the element fastening system and cooling water jacket. The tests were carried out in the electrolyte containing distilled water with addition of potassium hydroxide...
KOH ГОСТ 9285-78 with analytic grade qualification (PFA) and sodium water glass Na₂SiO₃ GOST 130078-81, completely ρ=1,47x10³ kg/m³ and module m=3,0. This electrolyte is widely used in repair manufacture for hardening wide nomenclature of elements of aluminum alloys, operating in various conditions [1].

Microhardness of coatings formed by plasma electrolyte oxidation (PEO) method was measured with computerized microhardness tester KMT-1 on sections over formed coating thickness depending on electrolyte composition and modes of plasma electrolyte oxidation (PEO). Load on the diamond point in the shape of tetrahedral pyramid with apical angular 136°±20° was 1,96 N. Error at control print measurement was not more than 0,3 μm.

Relative wear resistance of the sample coatings was tested with frictional testing machine MTY-01. The testing method is based on relative motion of testing sample and counter sample, pressed to each other with specified force in lubricating material technical oil-20). During test the friction moment with graphic display of its variation on the screen and variation of the test samples weight change are recorded. The contact scheme is the following: end surfaces of rotating counter samples and immobile sample. Tests for wear have been carried out for 50 h, at contact pressure 0,5 MPa and sliding speed 1,0 m/s.

3. Results and discussion.
Microhardness of the coatings formed by plasma electrolyte oxidation (PEO), depends on the number of hard high temperature phases of aluminum oxides α - Al₂O₃ and γ - Al₂O₃ in them and is one of their main features. Increase of the potassium hydroxide content (KOH) in the electrolyte more than 3 g/l results in decrease of microhardness of the hardened layer (Fig. 1). This is due to the following: the presence of alkali excess in the electrolyte leads to change in composition and structure of the colloidal micelles, which are original particles for coating formation [1]. Increase of the Na₂SiO₃ content in the electrolyte results in decrease of coating hardness (Fig. 1). This is because in its coatings structure the phases of mullite 3Al₂O₃x2SiO₂ and silicon oxide SiO₂ start prevailing, which is in keeping with the other authors investigations [1 – 4].

The investigations of current density influence on the formed coatings microhardness have not been done, because in the papers some authors [1 – 3] noted that with the current density increase microhardness increases too. However, current density increase at plasma electrolyte oxidation (PEO) exceeding 30 A/dm² results in its transition into arc mode, which results in deterioriation and subsequent coating damage. In this regard, we selected current density of 25 A/dm², since at that value coatings are formed with maximum speed and minimum duration. Figure 2 presents the area with maximum values of microhardness in the coating is located at the distance of 20 – 30 μm from metal base in zone of sample actual size. The rest area, in the order of 80% from total thickness, possesses microhardness values of about 12 GPa. It is connected with the number of phases α and γ - Al₂O₃ and their distribution over the thickness of the hardened layer, which determine high microhardness of coatings [1 – 4].

For practical usage of the coatings formed by plasma electrolyte oxidation (PEO), the investigation of their tribo-technical features are of maximum interest. The most complete notion about them can be obtained on the ground of data on their wear test results. The carried out tests on wear [5 – 12] of the samples from plastically deformed alloy AO3-7 with plasma electrolyte oxidation (PEO) hardening and without hardening, allow quantifying their wear resistance.

After 50 hours of tests, we discovered the following. Regardless of the fact that in the tested friction pairs with the samples hardened plasma electrolyte oxidation (PEO) we recorded slight increase of counter samples wear (11 – 16%). Wear of in whole sliding joint with the samples hardened by plasma electrolyte oxidation (PEO) from plastically deformed aluminum alloy AO3-7 is in 3,0 times less, in comparison with standard pairs, where the samples unhardened by plasma electrolyte oxidation (PEO) were used (Fig. 3).
Figure 1. Influence of the content of Na₂SiO₃ (1) and KOH (2) in electrolyte on coating microhardness. Modes of plasma electrolyte oxidation (PEO): Dᵣ=25 А/dm²; Т=2 h; tₑᵣ=20°C

Figure 2. Change of microhardness through coating thickness. Modes of plasma electrolyte oxidation (PEO) and electrolyte composition: Dᵣ=25 А/dm²; Т=2 h; tₑᵣ=20°C; Cₑᵣ=3 g/l; CNa₂SiO₃=14 g/l

The carried out comparative tests for wear of the coatings formed by the plasma electrolyte oxidation (PEO) method on plastically deformed aluminum alloy AO3-7 at different modes and electrolyte composition, proved that increase of the KOH content and Na₂SiO₃ in the electrolyte above 3 and 14 g/l, correspondingly, results in decrease of wear resistance of the hardened layer. However, from another point of view, at their content below the specified values, coatings possess higher microhardness, which leads to critical wear of the counter samples. Current density increase at plasma electrolyte oxidation (PEO) up to 25 A/dm² provides increase of wear resistance of the hardened layer. At high values, coating wear resistance practically does not vary, only excessive consumption of electric energy takes place. Coating formation at current density below 25 A/dm² provides minimum wear of the counter samples, but hereby coating wear resistance drops.
Figure 3. Wear after 50 hours of tests: 1, 1’ – the sample (alloy AO3-7) with coating and without it, correspondingly; 2, 2’ – the counter sample (steel 18XIT), operating together with the sample with coating and without it, correspondingly; 3, 3’ – wear of sliding joint with coating and without it, correspondingly.

4. Conclusion.

Varying the component content in electrolyte and current density, microhardness of coatings formed by the plasma electrolyte oxidation (PEO) method on the plastically deformed alloy AO3-7, can be changed in a wide interval. This gives the opportunity to use them for the surface hardening of the elements from aluminum alloys that are used in different conditions.

Optimal modes of plasma electrolyte oxidation (PEO) and the electrolyte composition, at which we achieve the minimum wear resistance of the tested sliding joints, are the following: Dт=25 A/dm²; T=2 h; CКОН=3 g/l; CNa₂SiO₃=14 g/l; tсл=20°C. The results of this investigation can be recommended for manufacturing application for hardening of the bushes of gear type pumps III-Y and other elements from aluminum alloy AO3-7, which are reconditioned by plastic deformation.

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