Mechanical properties of composite coatings of chromium and nanodiamonds on aluminum

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Abstract. Aluminum offers engineers weight saving advantages in their product design. However, aluminum has poor wear and friction properties. In addition, the surface oxide layer of this chemically active metal, which gives it the corrosion resistance, makes it a very difficult metal to plate [1]. Specific pre-treatment must be applied to remove the oxide layer from the aluminum surface. The nanodiamond particles additionally facilitates the process of chromium deposition. The object of this study is to evaluate the impact of nanodiamonds on the mechanical properties of the chromium coating plated on

1 Introduction

The aluminum has a lot of advantages in the design of engineering products because of its low weight. On the other hand it is relatively soft metal which means poor wear resistance and friction coefficient. New applications are possible when the light weight of aluminum is combined with the durability of the hard chrome.

The most widely commercially used now-a-days process for preparing an aluminum surface for plating is the zinc immersion process [2]. In this process a thin and adherent film of metallic zinc or alloy of zinc replaces the aluminum oxide film. The zinc provides a surface which is more readily plated with other metals than the aluminum. Not all metals, however, may then be simply deposited directly on the zinc surface.

The electrochemical chromium coatings have a wide practical application. They increase the hardness and the wear resistance of the matrix material and possess increased corrosion resistance. The modification of the chromium galvanic coatings with nanodiamond particles (ND) additionally increases these chemical and mechanical properties.

The main goal of this study is to investigate the influence of the ND on the readiness of chromium to be plated on the aluminum surface, the thickness and the continuity of the coating, the microhardness and wear resistance of the composite material comprised of electrolytic chromium coatings with nanodiamond particles and aluminum matrix material.

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2 Experimental

The research conducted in this study is directed to evaluate the mechanical properties of composite chromium coating modified with nanodiamond particles on samples of aluminum alloy (dural AC 2017). The chromium was deposited on the surface of the aluminum items by electrolytic process with the traditional acidic electrolyte containing CrO_3 - 220 g/l and H_2SO_4 - 2.2 g/l. The parameters of the electrolytic process were: current density – 45 A/dm^2; duration of the process – 45 min and temperature of the electrolyte – 50^{o}C. The diamond nanoparticles were added to the electrolyte as an aqueous suspension. Their concentration was 5, 10 and 25 g/l. The nanodiamond particles were produced by detonation synthesis [3].

The thickness of the coatings was determined by light microscopy. The microhardness tests were carried out according to Vickers standard at minimum 10 points. The applied load was 10 g. The dry friction wear resistance was studied by the pin-on-plate test unit (fig. 1). During the test a rectangular 15 x 5 x 10 mm wear sample (1) was mounted in a sample holder (4) equipped with a hemispherical insert (3) ensuring proper contact between the test sample and a steel ring (2), heat treated to 55 HRC, which was rotated at a constant speed of 136 rpm. The wear surface of the sample was perpendicular to the loading direction. Double lever system was used to force the sample towards the ring at 157 N ± 1% and 307N.

The loss of sample mass was measured after a sliding distance of 500m.

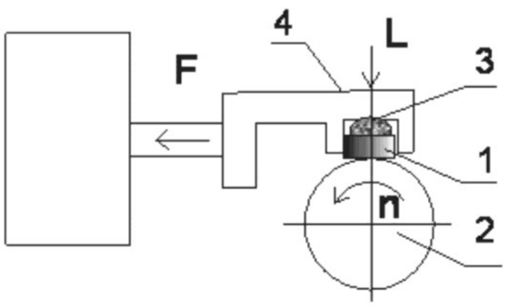

Fig. 1. Schematic view of a block-on-ring test unit

3 Results and discussion

Figures 2, 3 and 4 show the scanning electron image of coatings obtained from electrolytes with different concentrations of diamond nanoparticles.

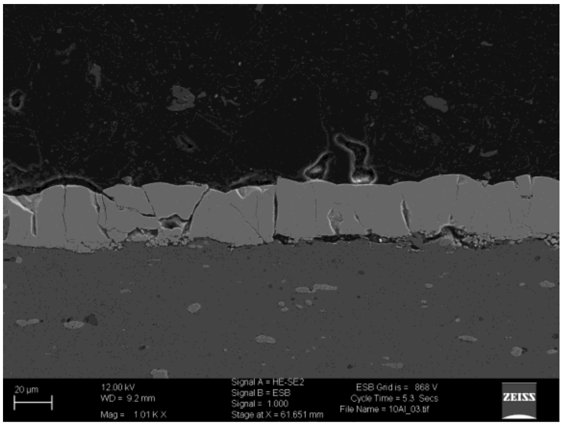

Fig. 2. SEM image of composite coating on aluminum, concentration of nanodiamonds – 5 g/l

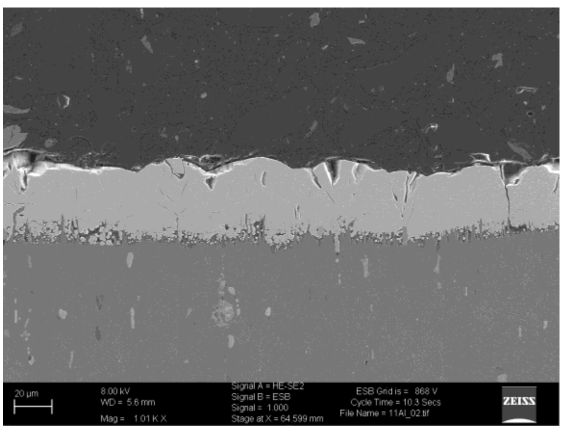

Fig. 3. SEM image of composite coating on aluminum, concentration of nanodiamonds – 10 g/l

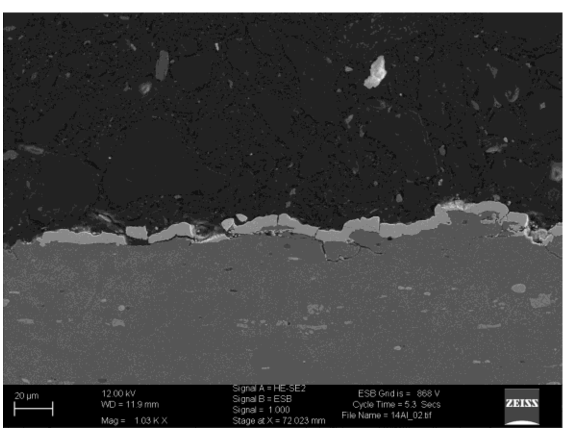

Fig. 4. SEM image of composite coating on aluminum, concentration of nanodiamonds – 25 g/l

It was found out that the yield of chromium on steel and the thickness of the coating is increased with the increase of the concentration of the diamond nanoparticles [2]. It is not the same with the chromium coating on aluminum and especially on this alloy. It is clearly seen from the figures that the best coating is achieved from electrolyte with concentration of nanodiamonds 10 g/l (fig.2). The same tendency is observed when testing the mechanical properties of the coating. The microhardness is the biggest at concentration of nanodiamonds 10 g/l (fig. 5). It goes from 260 kg/mm^2 (5 g/l) to 283 kg/mm^2 (10 g/l) and falls down to 230 kg/mm^2 (25 g/l). The matrix under the coating is also with increased microhardness (140 – 200 kg/mm^2) compared to 90 – 100 kg/mm^2 for the uncoated aluminum alloy.

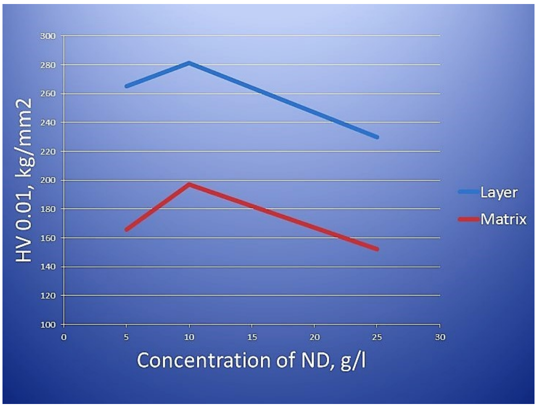

Fig. 5. Microhardness of the composite coating and the aluminum matrix at different concentrations of nanodiamonds

The wear resistance and the friction coefficient of the composite coating have similar behavior as the thickness of the coating at different concentrations of nanodiamonds (fig. 6 and 7). The best results are obtained at concentration of nanodiamonds in the electrolyte 10 g/l.

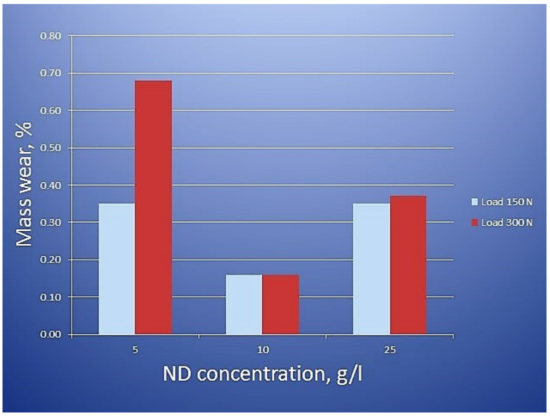

Fig. 6. Wear resistance of the composite coating expressed as mass wear at different concentrations of nanodiamonds

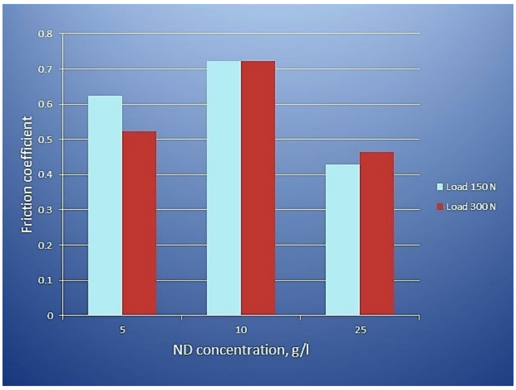

Fig. 7. Friction coefficient of the composite coating at different concentrations of nanodiamonds

The surface topography of the samples prepared at concentrations of nanodiamonds 5 and 10 g/l after the wear tests at sliding distance 500 m are shown in figures 8 and 9. The applied load is 150 N. Two types of wear mechanism can be seen, abrasive and corrosive wear. The dominate mechanism is corrosive wear. There are oxide regions on the surface after the tribological test.

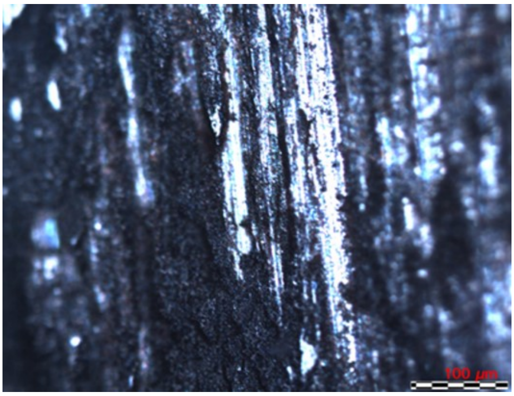

Fig. 8. Surface topography of sample with 5 g/l ND after the wear test. Applied load 150 N and sliding distance 500 m.

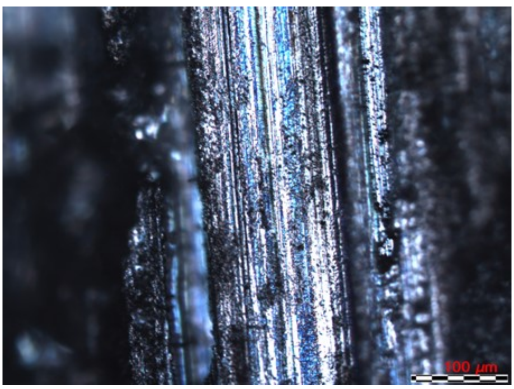

Fig. 9. Surface topography of sample with 10 g/l ND after the wear test. Applied load 150 N and sliding distance 500 m.

The typical wear mechanism of the sample with 25 g/l ND after the wear test at sliding distance 500m is abrasive wear, but there is small amount of adhesive wear (fig. 10).

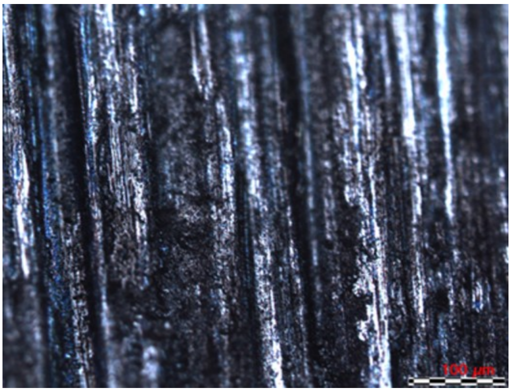

Fig. 10. Surface topography of sample with 25 g/l ND after the wear test. Applied load 150 N and sliding distance 500 m.

4 Conclusions

The presence of nanodiamond particles in the electrolyte facilitates the process of chromium deposition on aluminum items.

The chromium coating adheres very well on the substrate aluminum with thickness of about 20 μm.

The chromium coating increases the wear resistance and improves the friction of the aluminum products.

Two types of wear mechanism can be seen, abrasive and corrosive wear. The dominate mechanism is corrosive wear. There are oxide regions on the surface after the tribological test.

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