WEAR AND CORROSION RESISTANCE OF Ni-P COATING ON AA7075 ALUMINUM ALLOY

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Abstract:

This study was initiated to compare the wear and corrosion performances of an AA7075 quality aluminum alloy after electroless Ni-P process. The characterization of the coating was made by microscopic examinations, thickness, surface roughness and hardness measurements. Wear and corrosion performances of the uncoated and coated samples were investigated by using a reciprocating wear tester and a Potentiodynamic Polarization Scanning (PDS) technique, respectively. Formation of Ni–P layer on AA7075 aluminum alloy accompanied not only by remarkable increase in the surface hardness, but also caused significant improvement in wear and corrosion resistances.

Keywords: COATING, CORROSION, ELECTROLESS, WEAR.

1. Introduction

Aluminum and its alloys belong to the most important lightweight engineering materials [1]. Nowadays, lot of research work was done on aluminum and its alloys because of their exclusive properties such as high strength to weight ratios, high thermal conductivity and good corrosion protection [2, 3]. However, several drawbacks restrict the application of unprotected aluminum alloys, especially their low hardness and limited wear resistance. To improve the practical usage of aluminum alloys, many researchers have attempted to develop high wear-resistance strategies [4, 5]. Among different surface techniques, electroless deposition appeared as an attractive surface modification technique generating a micro-scale amorphous Ni–P layer to enhance wear and corrosion resistance of aluminum and its alloys [6, 7]. In order to assess the wear and corrosion behavior of this coating, the wear and corrosion experiments were carried out, and the results were compared with those of the 7075 aluminum alloy substrate.

2. Methods and Procedures

AA7075 disc-shaped samples with 25 mm diameter and 5 mm thickness were used as the substrate for the preparation of electroless NiP coating. This grade was chosen because it is very popular in aeronautics. The aluminum attracts easily with oxygen, hence the fine layer is allow to form on the surface. Therefore, it is difficult to coat the aluminum substrates covered with a very thin and impervious oxide film, so suitable surface preparation (mechanical grinding and polishing, alkaline cleaning with acetone and methanol, acid pickling and pretreatment) is required [8]. The commercial Ni–P electroless solution (DURNI-COAT DNC 520-9) containing 5 g/L nickel, 40 g/L NaH_2PO_2 and suitable amounts of additive and stabilizer were used. The stirring rate of plating bath was about 250 r/min, using a magnetic stirrer and a polytetrafluoroethylene (PTFE) coated magnet with 2 cm length and 5 mm in diameter. The deposition was carried out in a 100 ml thermostated double wall beaker at 90 °C and pH 4.6 for 1 h to achieve a thickness of 13 μm.

Cross-sectional morphology of the electroless Ni–P coated sample was characterized by using an Optical Microscopy (OM). Mechanical properties of the uncoated and coated samples were examined by microhardness measurements and dry sliding wear tests. Microhardness tests were conducted on polished samples from cross section of the coating with a Vickers indenter under a load of 10 g for a dwell time of 10 s. Three microhardness measurements were obtained for each sample, and the average value was recorded. Dry sliding wear tests of the uncoated and coated samples were performed on a reciprocating wear tester operating in ball-on-disc configuration at room temperature. In this configuration, an Al_2O_3 ball with a diameter of 10 mm was sliding forward and backward against the coatings with a sliding speed of 1.7 cm s^{-1}. Normal load of the test, sliding amplitude (wear track length) of the reciprocating motion and overall sliding distance were 2 N, 10 mm and 50 m, respectively. During the wear tests, the temperature and the relative humidity were maintained as 20±5 °C and 40±5 %, respectively. The friction coefficient force was continuously recorded during the tests. Width and depth of the wear tracks were measured by a surface profilometer (Surftest SJ 400) to calculate wear performance of the samples. Following the wear tests, wear tracks were examined by an OM.

The electrochemical corrosion tests were performed utilizing a typical three electrode potentiodynamic polarization test unit in the corroding media of aerated solution of 3.5 wt. % NaCl at room temperature. Before potentiodynamic polarization measurements, an initial delay of 45 min. was employed in order to measure the open circuit potential between working and reference electrodes. Potentiodynamic polarization curves were generated by sweeping the potential from cathodic to anodic direction at a scan rate of 1 mVs^{-1}, starting from – 0.25 up to + 0.25 V. Corrosion potentials (E_{corr}) and corrosion current densities (i_{corr}) were calculated using a Tafel type fit in the software. Finally, the surface images of the corroded samples were examined using an OM.

3. Results and Discussions

The cross-section morphology of the Ni-P coating detected by OM is illustrated in Fig. 1. Micrograph of the coating deposited on top of the aluminium alloy revealed that the coating has a good adhesion to the substrate and there is no discontinuity at the coating/substrate interface. Additionally, profilometry measurements indicated that the Ni-P coating has a roughness value Ra = 0.17 ± 0.01μm.

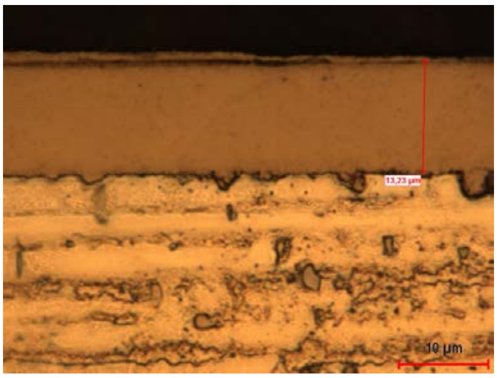


***Fig. 1** Cross-section micrograph of Ni-P coating.*

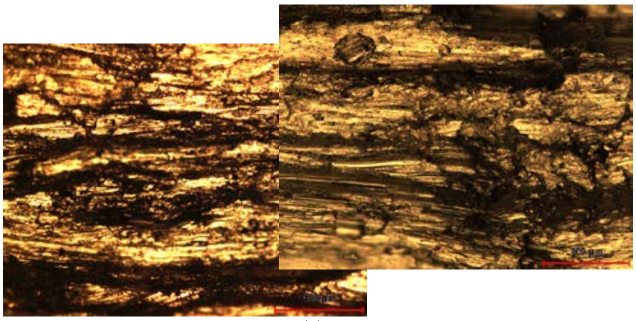
The microhardness value of the Ni-P coating is 204 $HV_{0.01}$, while the microhardness of the uncoated sample is about 35 $HV_{0.01}$. Thus, the electroless Ni-P coating caused to about a 5.8 fold increase in the hardness.

The results of wear tests for uncoated and coated samples are given in Table 1. It is seen that the Ni-P coating has lower friction coefficient and lower wear rate than those of uncoated sample. Comparing with uncoated sample, the Ni-P coating possesses both better friction-reducing ability and better wear resistance. By taking into account the wear rates, it is quantified that wear resistance of the Ni-P coating is ~11 times higher than that of the uncoated sample.

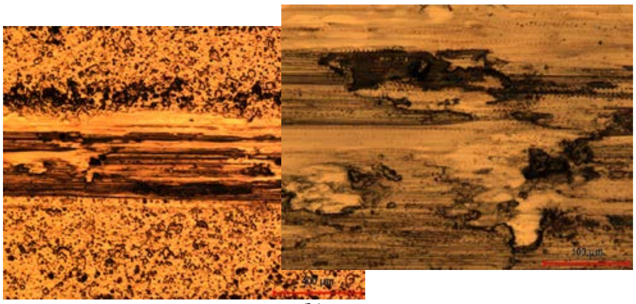
Table 1: *Friction coefficients and wear rates of uncoated and coated samples.*

Sample	Friction coefficient	Wear rate x10^{-4} ($m^3 \cdot N^{-1} \cdot m^{-1}$)
Uncoated Sample	0.5–0.75	111.5
Ni−P coating	0.44	9.89

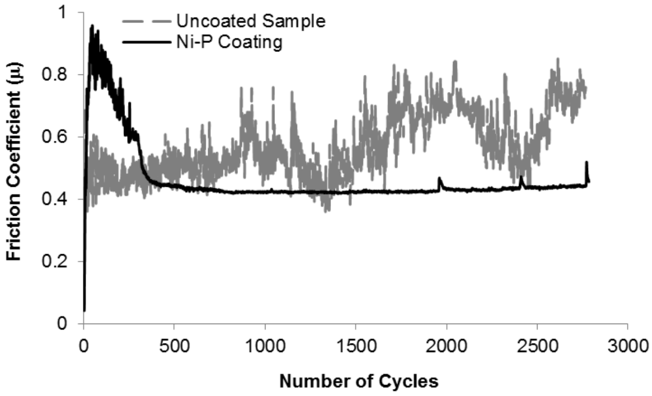
The images of the wear tracks on the uncoated and coated samples along with the friction curves presented in Fig. 2 confirm the above findings. The images show the intensification of damage and roughness in the wear track, which is considerably lower for the Ni-P coating than for the uncoated sample (Fig. 2 a, b). Friction coefficients for the uncoated and coated samples used in the above experiments are shown in Fig. 2 c. The friction coefficient obtained for the Ni-P coating stabilizes after 30 number of cycle and shows a steady value of 0.44, whereas the friction coefficient for the uncoated sample shows a variable regime and a higher value (0.5–0.75).



(a)



(b)



(c)

Fig. 2 *Low and high magnification OM micrographs of wear tracks generated on the (a) uncoated, (b) coated samples and (c) friction coefficient curves recorded during wear tests.*

The Ni-P coating shows great positive shift in corrosion potential and evident decrease in corrosion current density in comparison with the uncoated sample (Fig. 3). The corrosion potential E_{corr} of the Ni-P coating is -767 mV and the corrosion current density i_{corr} is 23.5 x 10^{-6} A/cm^2. Meanwhile, the corrosion potential E_{corr} and corrosion current density i_{corr} of the uncoated sample are about -1050 mV and 47.9 x 10^{-6} A/cm^2, respectively. Besides, an improved anticorrosion efficiency (IE) of the Ni-P coating than the uncoated sample could be calculated by Eq 1 [9]:

$$IE\ (\%) = 100 \times (I_B - I_A)/I_B; \qquad \text{(Eq 1)}$$

where I_A and I_B are I_{corr} of the Ni-P coating and uncoated sample, respectively. According to Eq 1, an enhanced anticorrosion efficiency (IE %) of the Ni-P coating is 50.9 % compared with the uncoated sample. The high corrosion resistance of the Ni-P coating is because of its amorphous characteristics; the absence of the defects in crystalline alloys such as grain boundaries, dislocations, stacking faults and other surface defects [10].

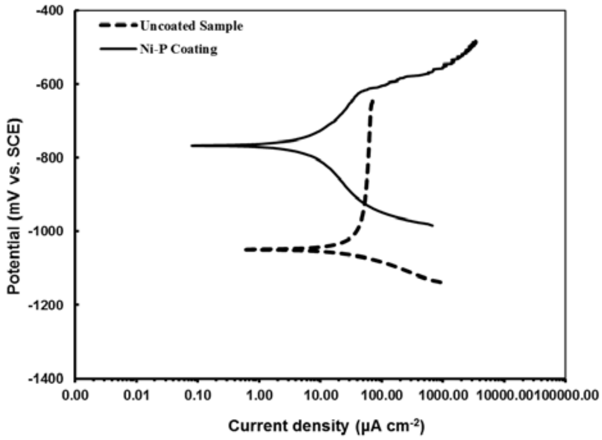
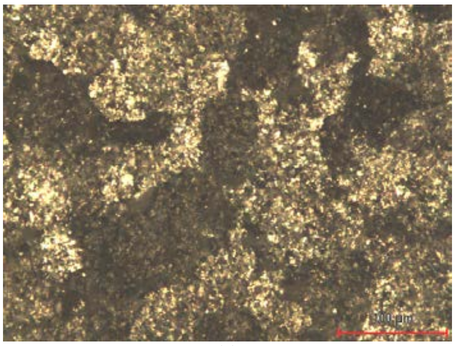
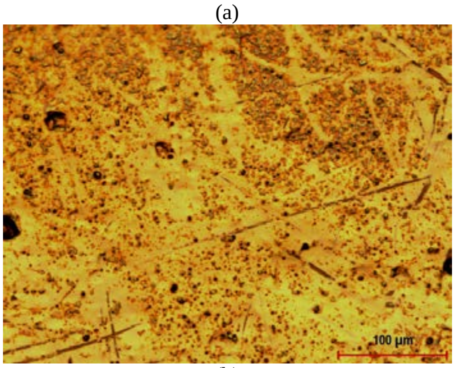


Fig. 3 *Polarization curves of the uncoated and coated samples.*

Figure 4 shows the OM images of the uncoated and coated samples after the corrosion tests. As shown in figure, the main failure mechanism for the uncoated sample was the pitting corrosion (Fig. 4 a). Many pits were seen on the uncoated sample, but the pits on the Ni-P coating did not formed (Fig 4 b).



(a)



(b)

Fig. 4 *Corrosion surfaces of the (a) uncoated and (b) coated samples.*

4. Conclusion

The behavior of the substrate coated with electroless Ni-P was compared to that of the uncoated AA7075 aluminum alloy. Analyzing the properties of the uncoated and coated samples applied to the tests, one can conclude that:

1. Ni-P coating on AA7075 alloy is prepared by electroless deposition. The cross-section view of the Ni-P coating reveals that the coating is uniform, crack free and adherent metallic coating.

2. The hardness, wear and corrosion resistances of the Ni-P coating generated by electroless deposition are remarkably higher than those of the uncoated sample.

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5. Literature

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