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Study on the Corrosion Resistance and Wear Resistance of Micro-Arc Oxidation Coatings on the Clad Plate of Aluminum and Magnesium Alloy

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Abstract: Aluminium plate was cladded to magnesium alloy plate by using the explosive welding. The bonding morphology and composition of the explosive cladding plate was inspected by SEM and EDS. There is a wave bonding at the interface between aluminum plate and magnesium alloy plate. Then ceramic coatings were directly prepared on the surface of aluminum and magnesium alloy by micro-arc oxidation (MAO) in the same solution and at the same time. The microstructure and composition of MAO coatings were studies by SEM and EDS. The corrosion and wear resistance of MAO coatings on the two sides of the clad plate were investigated by salt spray tests and friction-wear test. The results show that the MAO coating on the Al surface consists of Al, O and Si elements, while MAO coating on the Mg surface consists of Mg, O and Si elements. The corrosion resistance of MAO coating on the Al surface was better than that on Mg surface of the explosive clad plate. The MAO coatings both on the Al surface and on the Mg surface can obviously improve the wear resistance of substrate.

Introduction

Magnesium alloy is a lightweight and environmentally structural material. It is 20－25% lighter than aluminum alloy. However, the wear resistance and thermal stability of magnesium alloy is relatively poor, Magnesium alloy also cannot form a dense oxide film through spontaneous passivation like aluminum alloy [1]. If aluminum alloy is wrapped around magnesium alloy, it can improve the surface properties of magnesium alloy, such as wear resistance and corrosion resistance because the surface protection of aluminum alloy is more mature and perfected [2-4].

Explosive welding is a solid-state process in which controlled explosion forces to join two or more materials together under high pressures [5-7]. Using explosive cladding, the two lightweight, non-ferrous metals can be solidly combined, so that in use the advantages of both metals are displayed. Its application should be prevalent in aerospace, automotive, electronics and other industries.

MAO treatment was investigated recently on the surfaces of the same non-ferrous alloy, such as Ti, Al and Mg, etc, but any reports about the MAO treatment of the clad plate have not been seen. In this work, protective coatings were prepared on the surface of magnesium side and aluminum side of the explosive clad plate by MAO treatment in the same solution. It was investigated that the corrosion and wear resistance of the MAO coatings on the magnesium and aluminum clad plate.

Experimental details

The chemical composition of the aluminum plate and magnesium alloy plate are given in Table 1. Aluminum was used as flyer plate and magnesium alloy was used as parent plate. Aluminum plate and magnesium alloy plate was designed with dimension of 100×250×3 mm and 100×250×5 mm respectively. The detonation velocity of the explosive material was 2800–3000 ms^{-1}.

All samples were polished to 0.5μm finish. The bonding interface examinations of welded samples were carried out using S-3400 scanning electronic microscope (SEM) with energy dispersive spectrometry (EDS).

Table1 The chemical composition of aluminum and magnesium alloy (wt.%)

Elements	Cu	Fe	Ni	Si	Mn	Zn	Ti	Al	Mg
Aluminum(flyer plate)	0.05	0.35	—	0.25	0.03	0.05	0.03	balance	0.03
Magnesium(base plate)	0.002	0.002	0.0001	0.017	0.47	0.8	—	3.1	balance

MAO coatings were prepared in 15 g/L Na_2SiO_4 and 1 g/L KOH solution under constant current density of 10A/cm^2 for 0.5-1 h. The salt spray test (5% NaCl solution) was used for corrosion resistant tests. After corrosion for 48 h, the samples' morphologies were inspected using digital camera.

The friction and wear behavior was carried out by a cutting disk tribometer, a load of 5N and rotation speed of 100r/min was chosen. After 30 min, the weight loss of the samples was tested by an electronic balance with a resolution of 0.00001g.

Results and discussion

The structure and composition of explosive clad plate

The clad plate of aluminum and magnesium alloy has been achieved by explosive welding technique. As shown in Fig. 1, the interface has interlocked bonding between the aluminum plate and magnesium alloy plate, and the interface is outlined by the characteristic sharp transition (Fig. 1a). This type interface bonding endows the aluminium and magnesium alooy with enough cohesion strength. As shown in Fig.1b, a 10μm band was observed between the interface of aluminum and magnesium, which maybe local melted zone. EDS analysis taken in this band (the lines in Fig.1b) indicates that this band consists of Al and Mg. The melted zone between the interface in the present work may be attributed to high kinetic energy in the jet which produced the heat and caused melting.

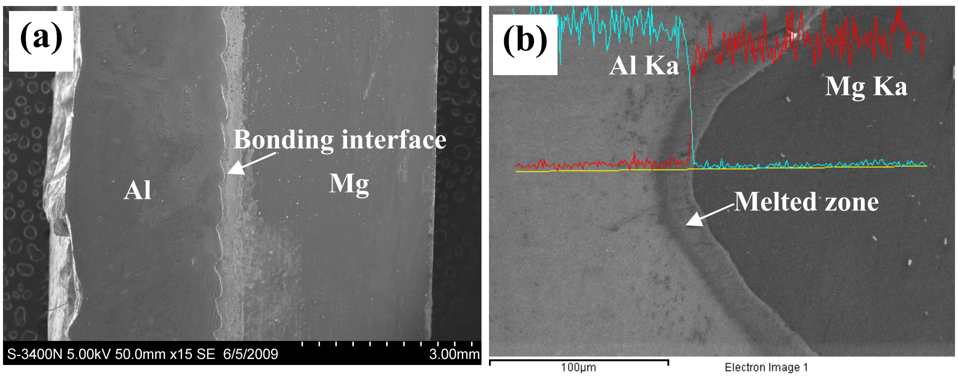

Fig.1 Morphologies of the interface of magnesium and aluminum along the bonding line
(a) Low magnitude morphology of interlocked interface of explosively clad plate
(b) Profiles of Al and Mg along the straight line

MAO treatment for clad plate

Fig. 2 shows the cross-section morphologies of the MAO coating on two side of the clad plate treated in the same electrolyte for the same time. As seen in Fig. 2a, the coating on the magnesium alloy surface exhibits a typical porous structure with some micro cracks. The coating on the aluminum surface is thicker and more compact than that on the magnesium alloy, which containing a porous inner layer and a dense outer layer (shown in Fig. 2b). The lower PB ratio is the main reason for the high porosity of MAO coating on the magnesium surface [10], which indicates that the coating on the aluminum surface of the clad plate should be more effective to improve the corrosion and wear resistance than that of the coating on magnesium alloy surface.

Fig. 3 shows EDS pattern of the MAO coatings on the surfaces of magnesium alloy and aluminum. The result of Fig. 3(a) reveals that the coating of magnesium alloy mainly consists of O, Mg, Si, with the atomic concentration of 54.11%,15% and 7.3%, respectively, which indicates the coating maybe compose of silicate of magnesium and magnesium oxide. From Fig. 3(b), it can be seen the composition of the coating on the aluminum surface is mainly O, Al, Si elements. The coating maybe compose of silicate of aluminum and aluminum oxide

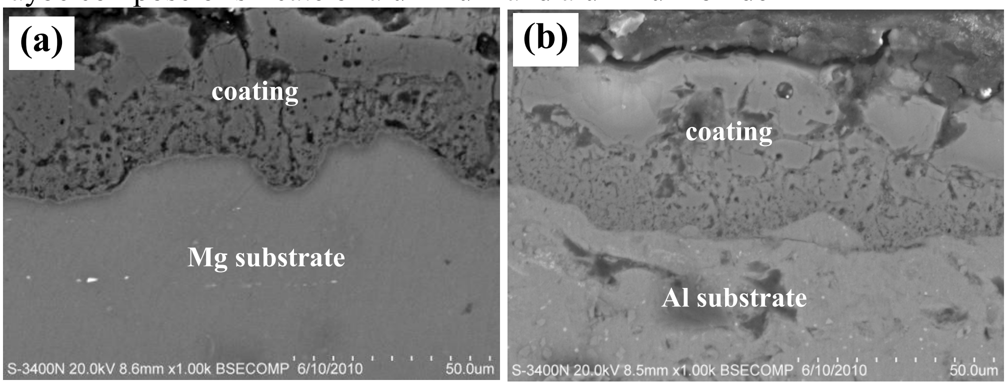

Fig. 2. Cross section morphology of MAO coating on (a) magnesium substrate and (b) aluminum substrate

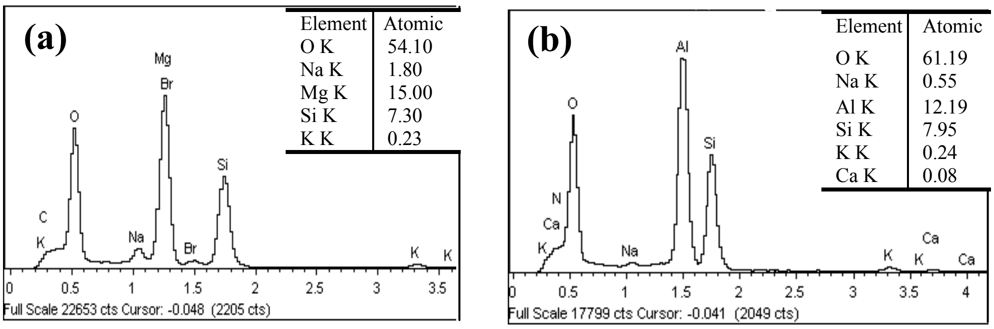

Fig.3 EDS spectra and composition of MAO coating (a) of magnesium alloy and (b) of aluminum.

Corrosion behavior of the clad plate

Fig. 4 shows the corrosion morphologies of uncoated and coated magnesium alloy and aluminum after exposure for 48 h in salt spray test. Uncoated Mg is seriously corroded as shown in Fig. 4(a), followed by uncoated Al serious corrosion (4(c)).The main corrosion form is localized corrosion for them. Comparing the four photos in Figure 4, it can be found the corrosion resistance of coated Mg or coated Al is obviously better than that of uncoated Mg or uncoated Al, which indicates the two coatings both have protective effect. However, coated Al has better corrosion resistance than coated Mg. The same conclusions can also be drawn from Figure 5. Coated Mg have the lower Tafel slope

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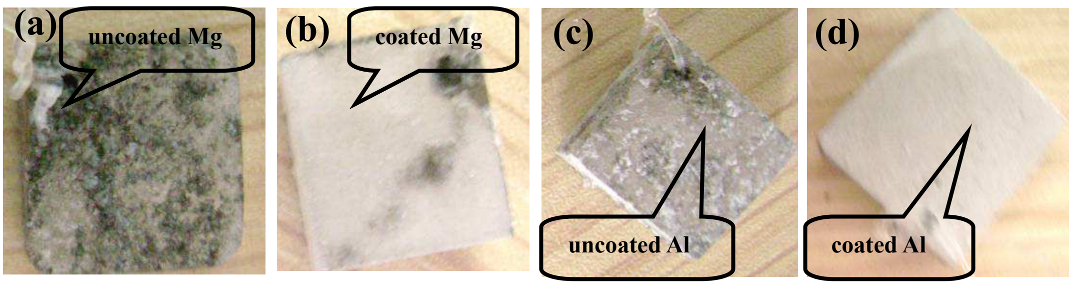

Fig. 4 Surface corrosion morphologies of the clad plate observed by digital camera
(a) and (b) uncoated and coated Mg. (c) and (d) uncoated and coated Al

(line (a) in Fig. 5) because the active dissolution of the magnesium substrate was prevented by the MAO coatings in 5% NaCl solution. The Tafel slope of coated Al (line (b) in Fig. 5) is slightly increased than that of the coated Mg side because the transfer of Cl− is held up for the higher corrosion resistance of the denser MAO coatings on aluminum. As mentioned previously, there are many irregular micro pores and cracks on the MAO coatings of the Mg side (as shown in Fig. 2(a)).So Cl −would be rapidly transferred through the porous layer and reached the substrate, causing localized corrosion.

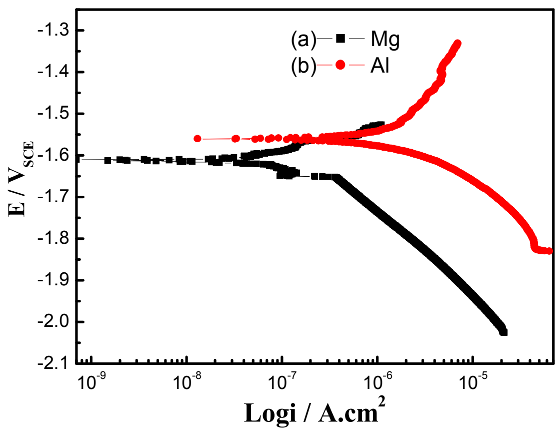

Fig. 5 Tafel polarization curves of MAO coatings on the Mg-Al clad plate in 5% NaCl solution

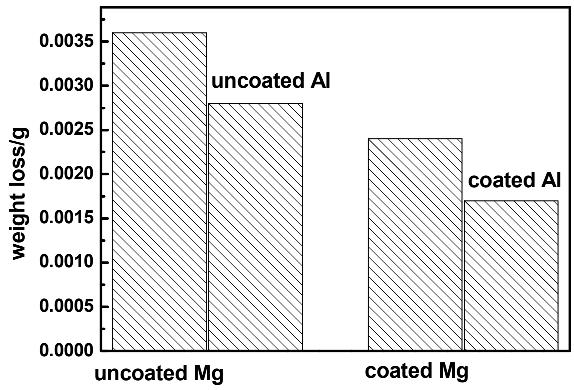

Fig. 6 Weight loss of the uncoated Mg or Al and coated Mg or Al of the clad plate

Wear resistance of the clad plate

The weight loss of uncoated and coated magnesium alloy and aluminum is shown in Fig. 6. The weight loss of uncoated Mg with 0.0036 g is the largest. For uncoated Al, the weight loss is about 0.0024 g. After MAO treatment, the wear resistance of the coated Al or coated Mg is both obviously enhanced. It was well known that the surface hardness of aluminium alloy could be increased evidently by the MAO treatment. The high hardness of the MAO coatings makes the weight loss of the coated magnesium or aluminium alloy decreased during friction test.

Summary

Aluminum plate can be cladded onto a magnesium alloy plate by the explosive welding technique. The interface had a wavy appearance and the melting zone can be seen in the interface between the cladded aluminum plate and magnesium alloy plate. MAO coatings can be produced on the surface of aluminum and magnesium alloy of the explosive clad plate in the same MAO treatment solution. MAO coatings on Mg surface are mainly composed of oxide and silicate of Mg, while MAO coatings on aluminum surface are composed of oxide and silicate of Al. The coatings on the surface of aluminum and magnesium alloy of the claded plate both have protective effect. Coated Al has better corrosion resistance than coated Mg, which is mainly due to their different composition and structure of the MAO coatings. The MAO coatings on the Mg-Al clad plate can improve the wear resistance of aluminum plate and magnesium alloy plate.

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