Effect of Micro-arc Oxidation Time on Corrosion Resistance of Magnesium Alloys

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Abstract. This experiment investigates the effect of time on the quality of the film during the micro-arc oxidation of magnesium alloys. The micro-arc oxidation surface morphology, the thickness of the film layer, and the influence on the corrosion resistance of the magnesium alloy were studied at different times. The experiment found that when the micro-arc oxidation time is controlled at 9 minutes, the surface quality of the film layer is the best, and the improvement of the corrosion resistance is more obvious.

1. Introduction

With the increasing requirements of the Chinese automotive industry for energy saving and emission reduction and the popularity of 3C products, magnesium alloys have a wide range of application prospects due to their high specific strength, good heat dissipation, and good shock absorption. Unfortunately, magnesium alloys have many undesirable properties, such as due to their inherently high chemical reactivity and significantly reduced abrasion and poor corrosion resistance. In particular, for outdoor applications of magnesium, its sensitivity to corrosion eventually leads to severe pitting. The easiest way to protect magnesium and its alloys is to provide a coating on top of the metal substrate. Such as anodizing, ion implantation, laser surface treatment, chemical conversion, electroplating, electroless plating, thermal spraying, chemical vapor deposition (CVD) and so on. The MAO process is popular as a coating technology that protects Mg alloys. MAO coating technology uses environmentally friendly alkaline electrolytic media and proves the excellent bonding of the coating to the substrate. Therefore, it is very important to produce a micro-arc oxide film with excellent corrosion resistance in the least time. This article will discuss the time parameters and study the effect of the time of micro-arc oxidation on the morphology and corrosion resistance of the coating.

2. Experimental

AZ31B is an experimental substrate material for plating deposition. A 20 mm × 20 mm × 3 mm sample was cut out on a magnesium alloy plate for MAO treatment. The samples were sonicated in absolute ethanol and then dried with a hairdryer. The MAO coating was prepared under a constant voltage power supply. The composition of the plating solution is shown in Table 1. The working frequency is 500Hz, and the processing time is set to 3 minutes, 9 minutes, and 15 minutes. Phase composition detection by X-ray diffraction (XRD, D / MAX-2500). The surface morphology of the film layer was observed with a scanning electron microscope (SEM; VEGA3 TESCAN), and its composition was analyzed by an
energy spectrometer (EDS; INCA Oxford). Gamry was used for electrochemical measurements. A 3.5 wt% NaCl solution was used as a test solution. The sample and platinum electrodes were used as working and counter electrodes, respectively. The reference electrode is used as a saturated calomel electrode (SCE).

Table 1. The main compositions and process parameters of the MAO electrolyte.

| Composition            | Concentration (g/L) | Process parameters          |
|------------------------|---------------------|----------------------------|
| NaAlO₂                 | 8 g/L               | Appropriate electrical parameters |
| Na₂C₆H₅O₇·2H₂O         | 3 g/L               | Mechanical stirring         |
| NaOH                   | 1 g/L               |                            |

3. Results and discussion

3.1. Effect of micro-arc oxidation treatment time on film thickness
Set the time range of the micro-arc oxidation process to be between 3-15 minutes. Micro-arc oxidation was performed at different times. The eddy current thickness gauge was used to measure the thickness of the film cross section of the magnesium alloy under different micro-arc oxidation times. After measuring a large number of data and averaging the thickness values of the magnesium alloy under different micro-arc oxidation treatment times, the results are shown in Table 2. The data in the table shows that the micro-arc oxide film gradually becomes thicker with time. However, the growth rate of the film under different time periods is different. It increases by about 10 μm from 3 minutes to 9 minutes, and only increases by about 5 μm from 9 minutes to 15 minutes. With the increase of the thickness of the film layer, the corrosion resistance improves, and the next step is to explore the change of the corrosion resistance by combining the surface morphology of the film layer and the electrochemical.

Table 2. Thickness of coatings in different times.

| Time(min) | 3  | 9  | 15 |
|-----------|----|----|----|
| Thickness (μm) | 10.1 | 19.7 | 23.4 |

3.2. Effect of different micro-arc oxidation times on the surface morphology of the film
Figure 1 shows the surface morphology of the MAO coatings formed at different times, and their respective partial enlarged pictures. With increasing treatment time, although the diameter of the pores increased, the porosity of the coating decreased. As time goes on, the surface of the coating becomes rougher and thicker. At higher currents, due to the thermal stress generated by rapid solidification during processing, cracks will occur on the surface of the coating, and the corrosive medium will erode the substrate through the cracks.
3.3. Effect of different micro-arc oxidation times on electrochemical corrosion results

The potential kinetic polarization curve obtained for the MAO coating is shown in FIG. 2. MAO coatings exhibit different behavior in the anode region, reflecting the characteristic behavior of the coating. It can be seen that the pitting potential increases first and then decreases with increasing treatment time. The corrosion current density decreases first and then increases with the micro-arc oxidation time. The high density of pores allows more electrolyte to pass through the porous layer and erode the barrier layer, which results in poor corrosion resistance. The thickness of the coating also affects corrosion resistance. The higher the thickness of the oxide coating, the better the corrosion resistance. However, as time increases, the thickness increases but many cracks appear, and the corrosive medium will erode the substrate through the cracks, which causes the corrosion resistance of the micro-arc oxide film layer to decrease for a long time.

Figure 1. Surface morphologies of coatings in different times.
4. Conclusion
(1) Magnesium alloy micro-arc oxidation gradually decreases with increasing thickness.
   (2) The surface porosity of the micro-arc oxide film decreases with time, but cracks begin to appear on the surface with time.
   (3) By combining the electrochemical results with the film thickness and the morphology of the surface film, it is concluded that the corrosion resistance is the best at 9 min.

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