

Effect of minor Gd on the corrosion behavior of AZ81 alloy

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Keywords: Gd; Magnesium Alloy; Microstructure; Corrosion behavior

Abstract. The corrosion behaviors of AZ81 magnesium alloy with minor Gd addition have been researched in this paper. The results show that with the minor addition of 0.5-1% Gd, the microstructure of AZ81 magnesium alloy is obviously refined, and the spotted, high-melting point phase Al-Gd intermetallic compounds is found in AZ81 magnesium alloy. The corrosion behaviors of AZ81 alloy decreases obviously with the increase of Gd addition. When the content of Gd is 1%, AZ81 magnesium alloy exhibits the lowest corrosion rate. The corrosion rates of AZ81+Gd magnesium alloy in 3.5% NaCl solution are always higher than those in 0.5% NaCl solution.

Introduction

Magnesium alloys have been widely used in the fields of automobile manufacturing, aerospace industries and electronic industry, because of their advantages of low density, high specific strength and good recycling potential. Corrosion is another key concern which restricts the wide spread applications of Mg alloys as a structural materials. AZ81 exhibits excellent corrosion resistance due to the high percentage of Al in the Mg-Al series alloy. When the alloy modification takes place to improve its high temperature performance, microstructure changes are inevitable. These additions may introduce various thermally stable intermetallics in the microstructure. Since the corrosion behaviors of AZ81 magnesium alloy is highly sensitive to microstructure, these intermetallics definitely play an important role in the properties [1-5].

On the other hand, poor corrosion resistance of magnesium alloys is a main reason of limiting their further applications. Among the Mg alloys, Mg-Al alloy is the commercially used magnesium alloy for automotive application. In the as-cast AZ series alloys, the addition of rare earth (RE) elements is believed to be a beneficial method to improve their corrosion resistance. Attempts have been made to change the microstructure of Mg-Al alloys by introducing thermally stable intermetallics through addition of special alloying elements and thereby improving its corrosion performance [6-10]. In this work, the influence of minor RE elements Gd additions on the corrosion behaviors of AZ81 Magnesium alloy is studied immersion in 0.5 and 3.5% NaCl solutions.

Experimental

Pure metallic Mg, Al, Zn and Mg-22 wt.% Gd master alloy are used as raw materials in this work. The researched alloy is designed as AZ81-xGd where x was the content of RE elements Gd, and $x=0.5$ and 1 respectively. These AZ81 alloys are prepared in an induction melting furnace with an Al_2O_3 crucible under the gas protection of mixed atmosphere of CO_2 and SF_6 . The mold is metallic materials. The as-cast AZ samples are machined and heated for solution treatment at 415 °C for 14 h with the protection of MgO powder, and then quenched in hot water. Artificial aging treatments are completed at 225 °C for 12 h.

Specimens for immersion corrosion tests are cut into coupons, 4-5 mm in thickness and 14-15 mm in diameter, ground with 400 grit water proof abrasive paper and 1200 grit metallographic papers, washed in distilled water, degreased with acetone and immediately immersed in 0.5 wt% and 3.5% NaCl solution. The immersion tests time is 8 hours at 25±2 °C with no stirring. The corrosion products are removed by immersion in the distilled water at room temperature for 15 min,

and the materials loss is determined by electronic balance. The corrosion rate can be calculated by the following formula:

$$CR = 365 \times 24 \times 1000 (G_0 - G) / (\rho S t) \quad (1)$$

where CR is the corrosion rate (mm/a), G_0 is the weight of metallic samples before immersion corrosion test (g), G is the weight of metallic samples after immersion corrosion test (g), ρ is the density of AZ81 magnesium alloy (1.8 g/cm^3), S is the area of metallic samples (mm^2), and t is the immersion time of corrosion test and 8h in this experiments. Scanning electron microscopy (SEM) and Olympus optical (OM) are used to characterize the morphologies of corrosion morphologies after immersion corrosion test.

Results

The microstructure of as-cast AZ81 magnesium alloy with minor Gd addition is shown in Fig. 1. It can be shown that microstructure of as-cast AZ81 magnesium alloy consists of α -Mg solid solution containing Al, Zn elements, and a lot of β - $\text{Mg}_{17}\text{Al}_{12}$ phase eutectic. This eutectic is divorced in matrix. Lamellar kind of precipitation can be found in the vicinity of much $\text{Mg}_{17}\text{Al}_{12}$ phases, which may be occur from supersaturated eutectic α -Mg solid solution decomposing into lamellar $\text{Mg}_{17}\text{Al}_{12}$ phases.

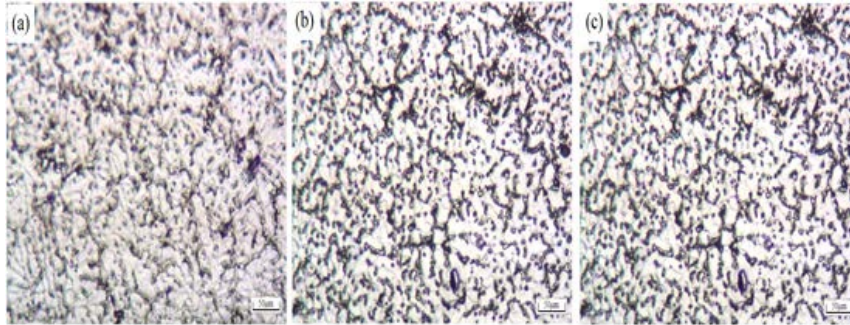


Fig.1 The microstructure of as-cast AZ81 magnesium alloy with Gd addition
(a) AZ81; (b) AZ81+0.5%Gd; (C) AZ81+1%Gd

The microstructure of AZ81 magnesium alloy after solution and aging treatments with minor Gd addition is shown in Fig. 2. It can be seen that the $\text{Mg}_{17}\text{Al}_{12}$ phases in AZ81 magnesium alloy after solution and aging treatment are distributed in the grain interior and at the grain boundaries and have granular and rod-like morphologies (see Fig. 2a). With the addition of 0.5-1% Gd, the microstructure of AZ81 magnesium alloy is remarkably refined, and the spotted, high-melting point phase Al-Gd intermetallic compounds is found in the alloy. A small amount of $\text{Mg}_{17}\text{Al}_{12}$ phase remains in AZ81+0.5% Gd alloy (see Fig. 2b). With the increase in Gd content, a large number of blocky Al-Gd intermetallic compounds are formed and tended to segregation (Fig. 2c). The possibility of forming metallic compounds should be predicted by the electronegativity difference between two elements and the solidification reaction kinetics. The larger the electronegativity differences between two alloy elements, the stronger the higher possibility of forming metallic compounds. The electronegativity difference between Al and Gd is higher than that between Al and Mg. This indicates that Al-Gd compounds can be formed more easily than $\text{Mg}_{17}\text{Al}_{12}$ compounds, and so $\text{Mg}_{17}\text{Al}_{12}$ phases decrease with the addition of Gd. Blocky Al-Gd compounds formed in the microstructure.

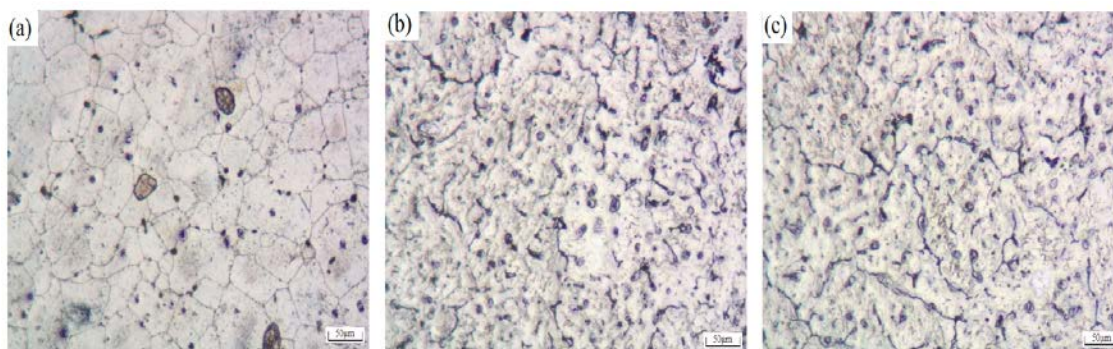


Fig.2 The microstructure of aging AZ81 magnesium alloy with Gd addition
(a) AZ81; (b) AZ81+0.5%Gd; (C) AZ81+1%Gd

Table 1 shows the corrosion rate of AZ81+Gd magnesium alloy at different NaCl solutions. It can be seen that AZ81 magnesium alloy shows serious corrosion in NaCl solution. And the corrosion rate of AZ81 alloy is 3.6 and 5.3 mm/a at 0.5% and 3.5% NaCl solution respectively. With the addition of Gd, the corrosion behavior of AZ81 alloy decreases obviously. When the content of Gd is 1%, AZ81 magnesium alloy shows the lowest corrosion rate. In addition, the corrosion rates in 3.5%NaCl solution are always higher than those in 0.5%NaCl solution. The corrosion resistance of magnesium alloy AZ81 can be improved by the addition of proper content of Gd.

Table 1 Corrosion rate of AZ81+Gd magnesium alloy at NaCl solutions. (mm/a)

Composition	AZ81	AZ81+0.5%Gd	AZ81+1%Gd
0.5%NaCl	3.6	2.9	2.4
3.5%NaCl	5.3	4.6	3.5

Fig 3 shows the morphology of AZ81+Gd magnesium alloy immersed in 0.5NaCl solution. It can be seen that many corrosion pits can be found in the corrosion surface after the separation of corrosion products for these AZ81+Gd magnesium alloy. And AZ81 magnesium alloy exhibits serious corrosion compared with AZ81+Gd magnesium alloy.

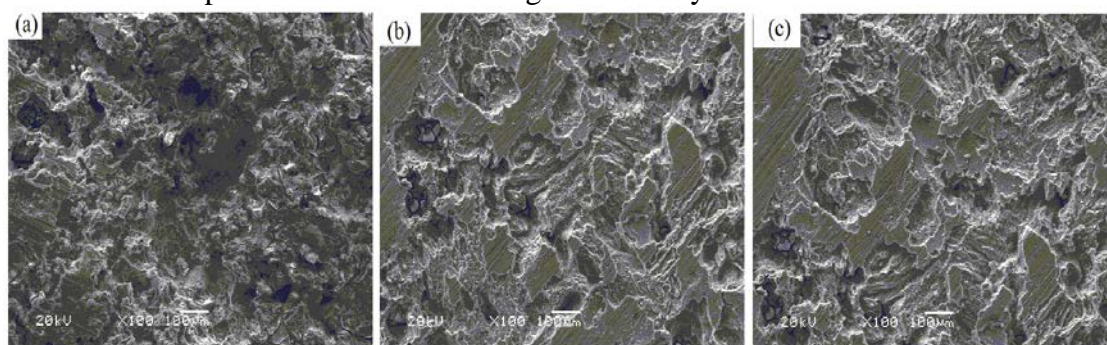


Fig.3 The morphology of AZ81+Gd magnesium alloy immersed in 0.5NaCl solution
(a) AZ81; (b) AZ81+0.5%Gd; (C) AZ81+1%Gd

Conclusions

- (1) With the addition of 0.5-1% Gd, the microstructure of AZ81 magnesium alloy is obviously refined, and the spotted, high-melting point phases Al-Gd intermetallic compounds are found in the alloy.
- (2) When the content of Gd is 1%, AZ81 magnesium alloy shows the lowest corrosion rate in this study. The corrosion rates of AZ81+Gd magnesium alloy in 3.5%NaCl solution are always higher than those in 0.5%NaCl solution.

Acknowledgements

The financial support of the National Natural Science Foundation of China (NSFC-Henan Joint Fund of Personnel Training, U1404501), the Innovative Research Team (in Science and Technology) in University of Henan Province (No. 2012IRTSTHN008), Basic and Frontier Technologies Research Plan of Henan Province (No. 092300410184) and Research Foundation of Henan University of Science and Technology (No. 2014QN013) is gratefully acknowledged.

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