ELECTROCHEMICAL CORROSION BEHAVIOR OF MG-5Al-1Ti-xZn ALLOYS

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Abstract: In this study, the effect of addition of Zn element on the electrochemical corrosion resistance of Mg5Al1Ti magnesium alloy produced by conventional casting method was investigated. Master alloy Zn addition is 2% and 4%. The corrosion test was carried out in a 30gr NaCl / l + 10ml HCl / l solution with potentiodynamic polarization measurement methods. Potentiostatic polarization corrosion experiments were performed using a computer controlled Gamry model PC4/300mA potentiostat / galvanostat with DC105 corrosion analysis software. Scanning Electron Microscope, stereo microscope and X-ray diffraction analysis were used for microcharacterization. Corrosion current density and corrosion potential values were measured from the potentiodynamic polarization curves of the investigated alloys. The Mg5Al1Ti master alloy containing 4% Zn element exhibited the lowest current density at 1.55mA/cm^2.

Keywords: Mg5Al1TiAlloys, ZnAddition, Casting, CorrosionResistance.

I. INTRODUCTION

Mg is the lightest metal material used today as a construction material. Four inches of steel density and two in three of aluminum density. Because of its high specific strength and rigidity, good casting and machinability properties, good damping capacity, good armor properties against electromagnetic effects and effective heat dissipation, magnesium alloys are the top among the candidate materials in many engineering applications such as microelectronics, telecommunication, space and automobile industry [1-4]. Despite the positive properties of Mg and Mg alloys, the place in engineering applications is limited to low corrosion resistance. The development of mechanical and corrosion characteristics of these alloys is possible by adding alloying elements through an appropriate casting procedure [5]. The main alloying elements added to Mg-based alloys are Al, Zn, Ca, Sr, Sb, Si and Mn [6-8].

Aluminum and zinc are the main alloying elements that participate in magnesium. Alloying of magnesium with aluminum generally increases corrosion resistance. Aluminum and zinc alloying elements initially increase the oxidation rate of the alloy, and this oxide layer plays a role in preventing the corrosion from progressing. In addition, aluminum and zinc are used to give magnesium an adequate strength [7]. On the other hand titanium is a light and strong metal with low density. The most famous chemical property of titanium is the great resistance it shows against corrosion. Elemental resistance, which is almost as platinum-resistant, is capable of counteracting exposure to chlorine gas and common salt solutions [3,4,9-13].

In this study, As an alternative to the AS41 alloy, the effect of 2% and 4% Zn on the electrochemical corrosion resistance of the Mg5Al1Ti master alloy was investigated.

II. DETAILS EXPERIMENTAL

The investigated alloys were melted in an atmospheric controlled 1200 ºC capacity electric resistance furnace and produced by conventional casting method Commercially pure (99,8%) Mg and Al10Ti master alloy were used as starting materials to prepare the Mg5Al1Ti matrix alloys. After that 2% and 4% Zn was added to the matrix alloy remelting at 800 ºC. The chemical compositions of the produced alloys were measured by wave-length dispersion X-ray fluorescence (XRF-Rigaku ZSX Primus II) and listed in **Table 1.**

Table 1. Chemical compositions of the alloys.

Alloy Code	Alloying Elements			
	Al	Ti	Zn	Mg
Mg5Al1Ti	4,6	1,1	-	Rest
Mg5Al1Ti-2Zn	4,6	1,0	1,9	Rest
Mg5Al1Ti-4Zn	4,8	1,0	3,9	Rest

Microstructure images were taken by a Carl Zeiss Ultra Plus field emission scanning electron microscope (SEM) equipped. The alloys were ground, polished and etched with a mixture of 6 g picric acid, 5 ml acetic acid, 10 ml distilled water and 100 ml ethanol. The constituent phase analyses were carried out by means of Rigaku Ultima IV X-ray diffractometer (XRD) using a Cu target with a scanning angle from 10 ° to 90 ° and a scanning speed of 3 °/min.

Potentiostatic polarization corrosion experiments were performed using a computer controlled Gamry

model PC4 / 300mA potentiostat / galvanostat with DC105 Corrosion Analysis software. The corrosion experiments were carried out in a 300 ml beaker of 30 gr NaCl/L and 10 ml HCl/L solution cell at room temperature and the investigated alloys with a fixed surface area of 0,785 cm2 as the working electrode, a 6 mm diameter carbon electrode serving as the counter electrode and a saturated calomel electrode (SCE) as the reference electrode were placed in the test cell. During the experiments, the potentiodynamic polarization curves were plotted from the cathodic to the anodic direction with a potential scan at a scan amplitude of 1 mV/s from -1.00 V to 1.00 V. Corrosion potential (E_{corr}) and corrosion current density (i_{corr}) were calculated from the tafel curves using the corrosion software. All experiments were repeated three times until the polarization curves were verified to make the results more reliable.

After the potentiostatic polarization corrosion experiments, the thinning of the corroded specimens in mm thicknesses of the specimens and the progress of the further corrosion in the specimen were determined with a Nikon Shuttlepix P-400R Model stereo microscope.

III. RESULTS AND DISCUSSION

3.1. Microstructural Analysis

The results of SEM micrographs and XRD analysis of the alloys produced by casting method are given in **Fig.1** and **Fig.2**, respectively. As seen in the SEM micrographs the microstructure was comprised of mainly intermetallic phases arranged predominantly along grain boundaries in primary α-Mg matrix. The results of XRD analysis presented that the formation of $Mg_{17}Al_{12}$ phases in primary α-Mg matrix occurred with addition of 5%Al element. MgZn phase was formed with addition of Zn in the matrix up to 4%. Primary α-Mg, $Mg_{17}Al_{12}$ and MgZn phases are shown on the SEM micrographs as numbers 1, 2 and 4, respectively [14]. While region of number 3 was eutectic phases, Ti was soluted in the solid phase of the primary α-Mg and $Mg_{17}Al_{12}$ phases, as reported in Ref [7].

3.2. Corrosion Properties

The potentiodynamic polarization curves in the 30gr NaCl/l + 10ml HCl/l solution of the investigated alloys are given in Figure 3a. Corrosion current density (i_{corr}) and corrosion potential (E_{corr}) values from the curves given in Figure 3a have been measured and presented in Figure 3b. The addition of 4 % Zn element to the Mg5Al1Ti matrix alloy resulted in a significant drop in corrosion current density (i_{corr}) from 4.33 mA/cm2 to 1.55mA/cm2. The average corrosion potential (E_{corr}) is -1.60 V for all the examined alloys [14].

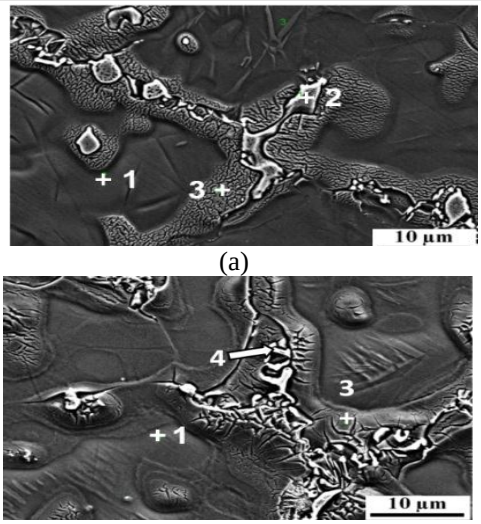


Fig.1. SEM micrographs of the a) Mg5Al1Ti and b) Mg5Al1Ti-4Zn alloys.

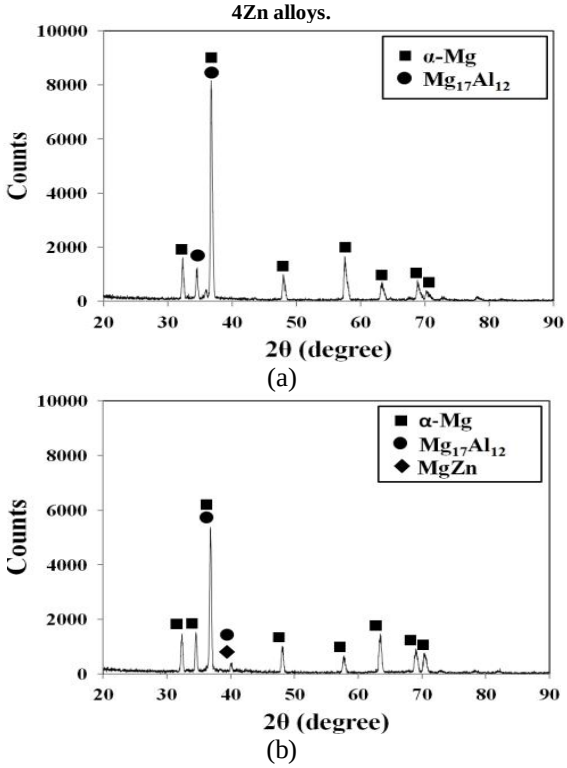
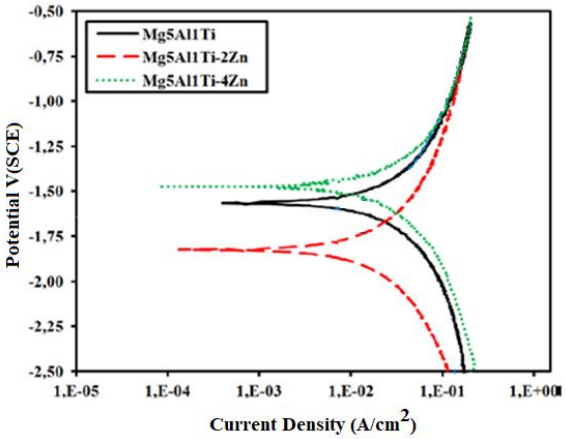
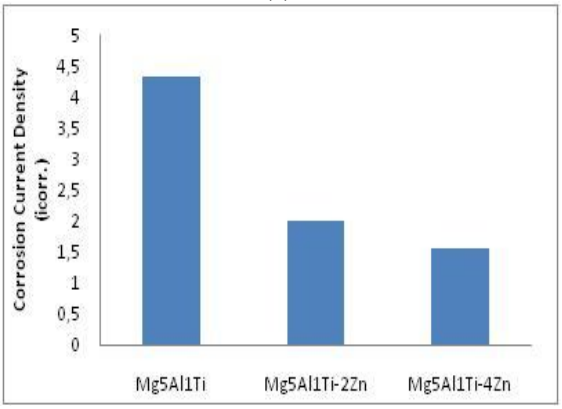


Fig. 2. XRD patterns of the (a) Mg5Al1Ti and (b) Mg5Al1Ti-4Zn alloys.

After the potentiodynamic polarization experiment, the topographic surfaces of the investigated alloys were observed in Figure 4 with the stereo microscope. A corrosion progression occured into the sample surfaces as deep cylindirical cup (Figure 4). Depth of the cylindirical corrosion failure throughout the thickness of the samples was measured in mm by means of the stereo microscope with a 3D image analysis software program after potentiodynamic polarization experiments conducted for 75 minutes in the corrosion solution. These measured values were translated in mm/min and mm/year to determine the rate of corrosion progression. Corrosion rate values in mm/min and mm/yr obtained are given in Figure 5.

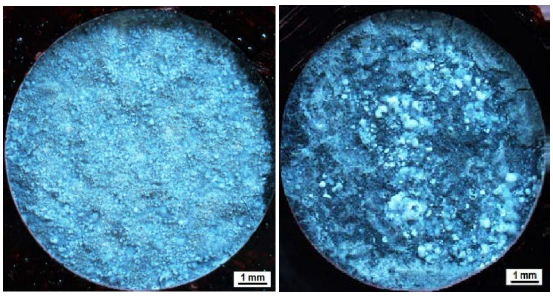


(a)



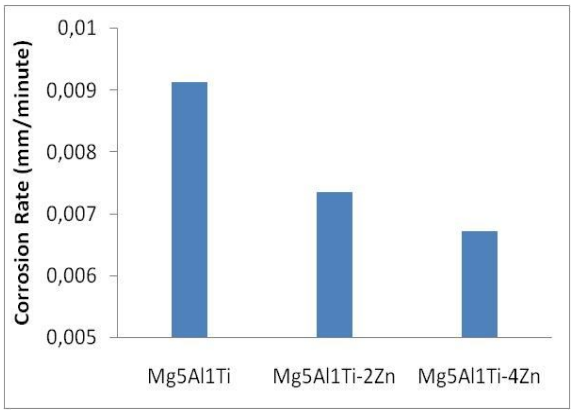
(b)

Fig. 3. (a) The dynamic polarization curves and (b) Corrosion current density of the studied alloys.

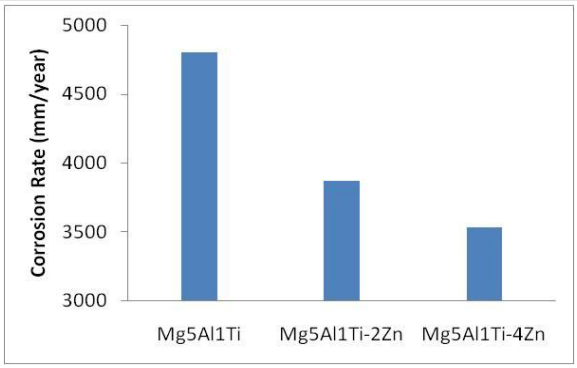


(a) (b)

Fig. 4. Topographic images on the corroded surfaces of the (a) Mg5Al1Ti and (b) Mg3Al1Ti-4Zn after the potentiodynamic polarization experiments.



(a)



(b)

Fig. 5. Corrosion progression rates calculated in (a) mm/min and (b) mm/year after Potentiodynamic Polarization corrosion experiments in 30gr/NaCl+10ml/HCl solution.

The results of the corrosion rate (Figure 5) are consistent with the icorr values obtained as a result of the Potantiodynamic Polarization experiments. The higher the corrosion rate of the Mg5Al1Si master alloy at 4800 mm/year the lower the corrosion progression rate of the Mg5Al1Ti-4Zn alloy at 3532 mm/year. The post-corrosion stereo microscope images shown in Figure 4 reveal that the mostly dark gray and nebulous or lesser white areas on the surface of the Mg5Al1Ti alloys containing 4% Zn element lead to the corrosion resistance [14,15].

CONCLUSIONS

Effect The primary conclusions that can be derived from the present studycan be drawn:

1. Compared with the Mg5Al1Ti matrix the microstructures by small amount of Zn additions showed differences. MgZn phase was present in α Mg matrix by the addition of 4% Zn.
2. Mg5Al1Ti master alloy has the highest current density with 4.33 mA/cm^2, Mg5Al1Ti master alloy containing 4% Zn element exhibits the lowest current density with 1.55 mA/cm^2.
3. Mg5Al1Ti-4Zn alloy has theleastcorrosionprogression rate at 3532 mm / year.

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