**Nevşehir Bilim ve Teknoloji Dergisi**

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# The Effect of Cerium and Twins Fraction on Corrosion Resistance of AZ31-1Ca Sheet Alloys

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**Abstract**

In this study, in the range of 0.2% to 1.0% Ce elements were added to AZ31-1Ca alloys produced by low pressure die casting method. Hot rolling process was applied to these produced alloys at 400 °C with 1,5 m/min rolling speed at 15% deformation rate per pass. The corrosion resistance of samples extracted from sheets that have included different twins fraction after various Ce adding were investigated at 3.5% NaCl solution for 72 hours according to ASTM G31 of Standard Practice for Laboratory Immersion Corrosion Testing of Metals. The effect of secondary phases, grain size and twins on immersion corrosion resistance of investigated alloys was studied systemically on the base of microstructure analysis.

**Keywords:** AZ31, Ca, Ce, Hot rolling, immersion corrosion.

## AZ31-1Ca Saç Alaşımların Korozyon Direncine Seryum ve İkizlenme Fraksiyonun Etkisi

**Öz**

Bu çalışmada, %0,2 ile %1 arasında Ce elementi AZ31-1Ca alaşımına ilave edilmiş ve alçak basınçlı kokil kalıba döküm yöntemiyle alaşımlar üretilmiştir. Üretilen alaşımlara 400 °C'de ve 1,5 m/dk hadde hızında %15 olacak şekilde paso başına kesit daralması yapılarak sıcak haddeleme uygulanmıştır. ASTM G31 standardına göre saç malzemelerden çıkartılan malzemeler üzerinde 72 saat boyunca daldırma korozyon testi yapılmıştır. Ce ilaveli alaşımların korozyon direncine ikincil fazların, ortalama tane boyutunun ve ikizlenme fraksiyonun etkisi mikroyapısal karakterizasyon bulgularıyla desteklenerek incelenmiştir.

**Anahtar Kelimeler:** AZ31, Ca, Ce,Sıcak haddeleme, Daldırma korozyon.

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## 1. Introduction

Mg alloys have many advantages such as low density, high specific strength and excellent damping capability for structural applications of the automotive and space industry. However, the using of Mg alloys was limited by their poor corrosion properties especially that is more correct sheet alloys including many deformation mechanisms such as twinning, shear bands and particle stimulated crystallization (PSN) during the rolling process due to corrosion resistance can be changed with based on microstructure properties [1-4]. Moreover, the corrosive environment behavior of AZ31 Mg alloys is known as poorly due to their lower aluminum content [4]. However, Ca and Ce were utilized to enhance the corrosive properties of Mg alloys containing new secondary phases in the matrix or on grain boundaries [5]. Further, the microstructure of rolled Mg alloys forms during the rolling process according to rolling speed, strain rate and deformation rate per pass. Some studies about rolling speed on microstructure show that the twins more occupy than dynamically recrystallized grains at low rolling speeds [6-7]. The twins that can make a role to provide higher mechanical properties of Mg alloys providing grain boundary strength [1]. However, the double effect of Ca and Ce on twins fraction and formation of secondary phases during rolling at low rolling speeds is still unclear. This study is aimed to research microstructure and corrosion resistance of Ca and Ce added AZ31 that hot-rolled at 1,5 m/min speed at 400°C.

## 2. Material and Method

The melting was accomplished in an electric resistance furnace which protected by argon during all process. %99,99 Mg, %99,9 Al and %99,9 Zn metals and Mg-Ca, Mg-Ce and Mg-Mn masters were dissolved at 775°C. The liquids were inserted into the stainless steel cavity which was heated to 350°C in 2-3 atm protecting against the atmosphere by CO2+1vol% SF6 gas. X-ray fluorescence (XRF- Machine: Rigaku ZSX Primus II) was used to determine the content and the results were tabulated in Table 1. The homogenization was operated at 400°C for 24 hours. The billets (12x36x60 mm) were preheated at 450°C for 30 min before rolling and were heated for 5 min between all passes. The rollers were neither heated nor lubricated. The rolling speed was used as 1,5m/min.

**Table 1.** Chemical Composition of Materials

| Alloys | Al | Zn | Mn | Ca | Ce | Mg |
|---|---|---|---|---|---|---|
| AZ31-%1Ca | 2.69 | 0.92 | 0.14 | 0.80 | | Bal. |
| AZ31-%1Ca-0,2%Ce | 3 | 1.08 | 0.16 | 1.18 | 0.18 | Bal. |
| AZ31-%1Ca-0,5%Ce | 2.99 | 0.90 | 0.24 | 0.96 | 0.43 | Bal. |
| AZ31-%1Ca-1,0%Ce | 2.82 | 1.11 | 0.35 | 1.02 | 1.05 | Bal. |

The metallography was accomplished as reported our previous study [8]. The average grain size was measured by using the standard linear-intercept method for LOM images. 3.5% NaCl solution was used to immersion corrosion at 25°C. 180 g / lt-1 $CrO_3$ solution was utilized to cleaning after corrosion as following:1 minute in ultrasonic cleaning machine and dried by ethanol before mass loss measure. Morphology of the alloys was examined by SEM after the immersion corrosion test.

## 3. Results

The LOM images of investigated alloys were shown at Fig. 1. In addition, the average grain size of alloys was illustrated in Fig.4. As seen in Fig.1, grains are almost similar when the amount of Ce in the range of 0.2% to 0.5% although, the more Ce than %0.5 increased the size of grains (See Fig.4).

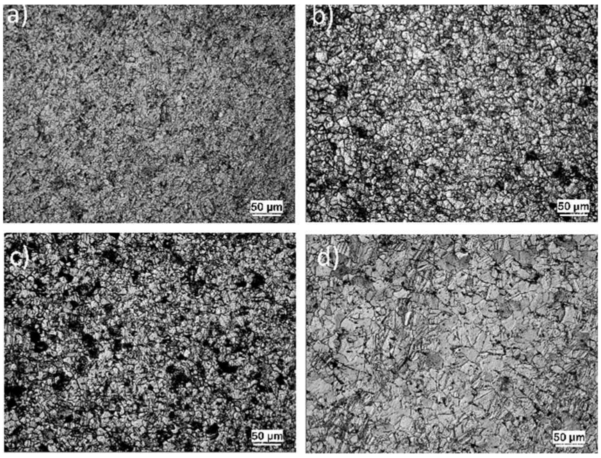


**Figure.1**. LOM images of sample a) AZ31-1Ca, b) AZ31-1Ca-0.2Ce, c) AZ31-1Ca-0.5Ce and d) AZ31-1Ca-1.0Ce

The SEM images of investigated alloys were shown in Fig.2. The secondary phase distribution was similar for all samples as seen in Fig.2. The same type of them are inside of grains and the others on the grain boundaries. However, the size of the secondary phases was different. AZ31-1Ca alloy includes finer secondary phases which mostly distributed separately on the grain boundaries partially inside of grains. However, when the 0.2%Ce is added to AZ31-1Ca alloy, the secondary phases clearly are becoming larger and the majority of them located on grain boundaries. Moreover, as the amount of Ce is 0.5%, the same secondary phases formed finer and placed inside of grains. On the other hand, many of the secondary phases dissolved in the matrix when the amount of Ce is 1.0%.

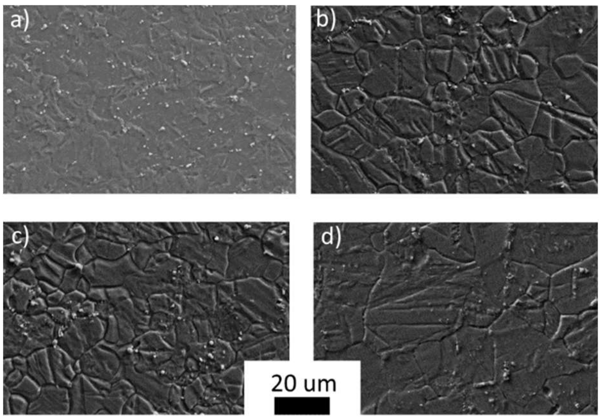


**Figure.2** SEM images of sample a) AZ31-1Ca, b) AZ31-1Ca-0.2Ce, c) AZ31-1Ca-0.5Ce and d) AZ31-1Ca-1.0Ce.

As presented ~~this~~ Fig.3 twins more occurred when the amount of Ce is 0.2%, however the more Ce addition limited the twins formation on microstructure. Further, twins fraction is obtained by addition of 1.0%Ce as a minimum amount (See Fig. 3).

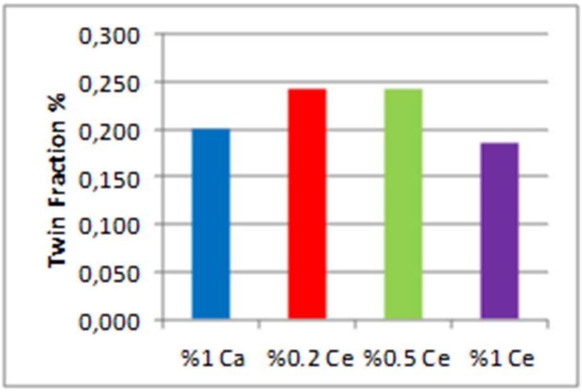


**Figure.3**. Twins Fraction of Samples

The average grain size of samples was presented in Fig.4. As seen in Fig.4, Ce addition does not make an important difference in size of grains when it is in the range of 0.2% to 0.5%. However, as Ce is 1.0%, the average size of grains is the biggest [9].

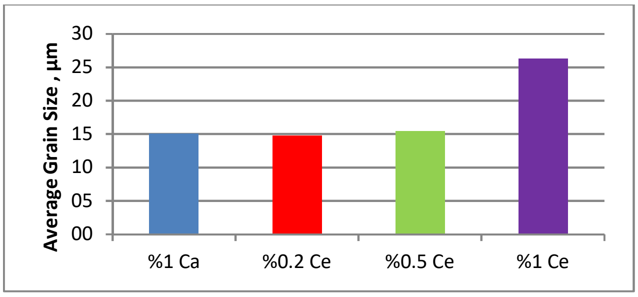


**Figure.4.** Average grain size of samples.

The immersion test results of the studied materials were shown in Fig. 5. As seen this Fig.5, the metal loss of AZ31-1Ca-1Ce alloy occurred excessively. However, the lowest metal loss was observed at AZ31-1Ca-0,5Ce alloy.

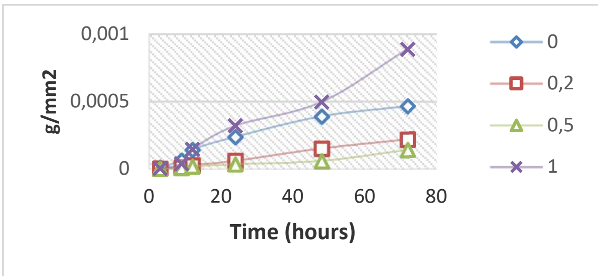


**Figure. 5**. Immersion corrosion test results of samples.

Fig. 6 illustrates the SEM images of 0.2%Ce and 0.5%Ce added alloys after immersion test in 3.5% NaCl solution for 72 hours. As seen this Fig.6, the corroded section of samples mostly occurred on matrix material. However, the secondary phases resist the corrosion and protect their stable condition. The main and important difference of secondary phases of 0.2%Ce and 0.5%Ce is the location and size of them. 0.2%Ce added alloy have bigger sized secondary phases and they are accumulated on grain boundaries. However, 0.5%Ce added alloy includes finer ones and they mostly distributed inside of grains [10].

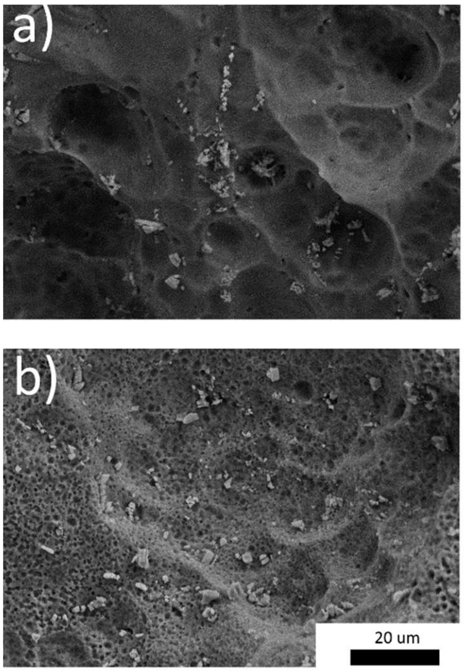


**Figure.6.** SEM images a) AZ31-1Ca-0.2Ce and b) AZ31-1Ca-0.5Ce after immersion corrosion test

## 4. Conclusions

The result of this study was sequenced as following;

1. The average grain size is more dominant to determine of corrosion resistance than twins fraction.
2. The distribution and size of secondary phases effect the corrosion resistance effectively where the larger and located on grain boundaries are desirable properties to obtain stronger corrosion resistance.

## 5. Acknowledgment

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