Magnesium Technology 2012
Edited by: Suveen N. Mathaudhu, Wim H. Sillekens, Neale R. Neelameggham, and Norbert Hort
TMS (The Minerals, Metals & Materials Society), 2012

Effects of Ca on Microstructure and Mechanical Properties of ZA62 Alloys

YOU Jun-hua[1], ZHANG Wei-gang[1], QIU Ke-qiang[1], REN Ying-lei[1]
[1](School of Materials Science and Engineering, Shenyang University of Technology, No.111, Shenliao West Road, Economic & Technological Development Zone; Shenyang, Liaoning 110870, P.R.CHINA)

Key words: Magnesium alloy, Ca element, Microstructure, Mechanical Properties

Abstract

Effects of Ca element on microstructure and mechanical properties of ZA62 alloys were investigated by using zeiss microscope, scanning electron microscope equipped with an energy dispersive spectrometer, X-ray diffractometer, and electronic universal testing machine. The results show that Ca can significantly refine microstructure and cause the precipitation of Mg_2Ca and Al_2Ca phases on grain boundary of ZA62 alloys. The addition of Ca can improve the tensile properties of alloys at room temperature. When the content of Ca is 2%, good properties are obtained, the tensile strength and yield strength of Mg-6Zn-2Al-2Ca alloy reaches 240.79MPa and 82.78MPa respectively.

1 Introduction

As one green metal structure material, magnesium alloys will substitute steel, iron, aluminum and plastic due to their low density, high specific strength, high specific stiffness, high modulus of elasticity, good cut processing performance and good EMI performance[1-3]. ZA alloys are promising high temperature creep alloys due to their low cost and good casting performance. However, ZA alloys will enter the hot cracking zone, form serious thermal cracking and shrinkage with increasing the content of Ca element[4]. When aluminum content is lower than 8%, the tensile strength increases while the yield strength decreases with increasing content of Ca. When aluminum content is higher than 8%, the results are contrary. At the same time, the microstructure and mechanical properties of ZA alloys can be affected by the hard and brittle Mg_2Ca phase and Al_2Ca phase.

In this study, taking the change of aluminum / zinc into account, researchers have designed Mg-6Zn-2Al-xCa series alloys, studied the effects of Ca on microstructure and mechanical properties of ZA62 alloys.

2 Experimental

The Mg-6Zn-2Al, Mg-6Zn-2Al-1Ca, Mg-6Zn-2Al-2Ca and Mg-6Zn-2Al-3Ca alloys used in this study were prepared by Mg(99.99%), Zn(99.99%), Al (99.99%), and Ca added in the form of Mg-20%Ca (mass fraction) master alloy. The experimental alloys were melted in pit furnace and protected by the gaseous mixture of nitrogen and sulfur hexafluoride. The specimens whose size was 40mm×2mm×4mm were fabricated from the casting for tensile properties test.

The microstructure, fracture pattern and element composition of alloys were examined by Zeiss microscope and SN3400 type scanning electron microscope (SEM) equipped with an energy dispersive spectrometer (EDS). The phase composition of alloys were analyzed by XRD-7000 type X-ray diffractometer (XRD). The tensile properties of alloys at room temperature were tested by WDW-100 type electronic universal testing machine. The tensile strength and yield strength were obtained based on the average value of three tests.

3 Results and discussion

3.1 Effect of Ca on as-cast alloys microstructure

Figure.1 shows the microstructure of as-cast Mg-6Zn-2Al-xCa series alloys. Seen from the Fig.1(a) to Fig.1(d), grain boundary precipitates transform from discontinuous precipitation into continuous precipitation gradually and grain refines significantly with the increasing of Ca content. The as-cast Mg-6Zn-2Al alloy is mainly composed of α-Mg and MgZn phases according to the XRD analysis in Fig.2. Most of the divorced eutectic MgZn phases exist in the grain boundary and a small amount of MgZn phase exist in the grain interior[5]. Sheet and rod-shaped phases formed in grain boundary except divorced eutectic phase with the increasing of Ca content. The content of Sheet and rod-shaped phases increased with Ca increasing.

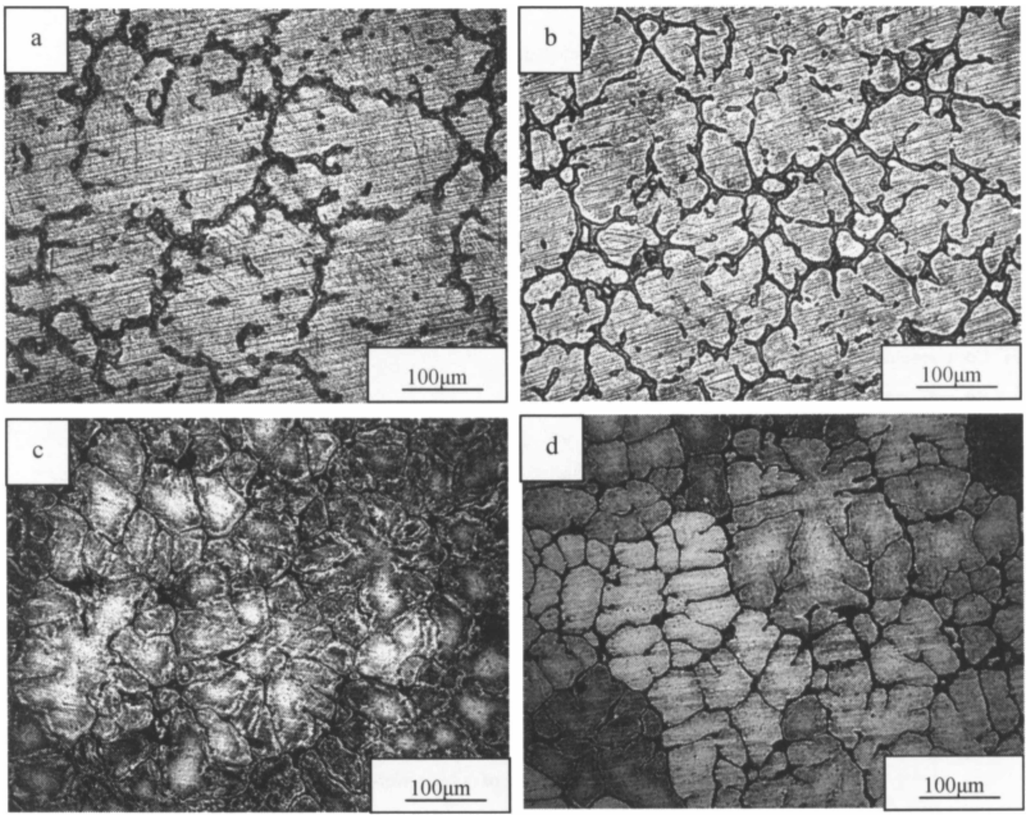

Figure.1 Optical microstructures of as-cast Mg-6Zn-2Al-xCa alloys

a) Mg-6Zn-2Al b) Mg-6Zn-2Al-1Ca c) Mg-6Zn-2Al-2Ca d) Mg-6Zn-2Al-3Ca

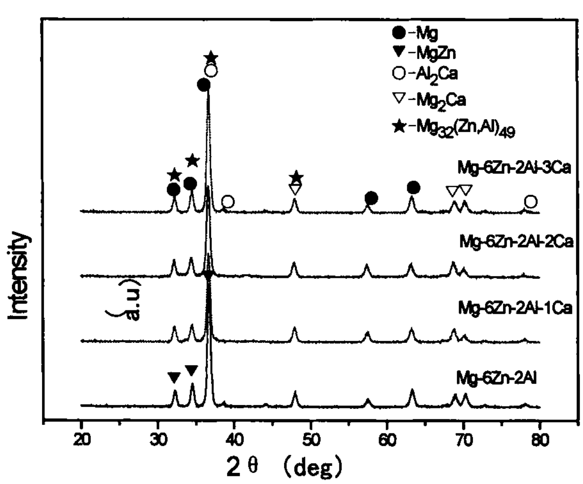

Figure.2 X-ray diffraction patterns of Mg-6Zn-2Al-xCa alloys

Figure.2 shows the phase composition of Mg-6Zn-2Al-xCa series alloys. Seen from the diffraction patterns of Fig.2, Mg-6Zn-2Al alloy is composed of α-Mg phase , MgZn phase and a small amount of $Mg_{32}(Zn, Al)_{49}$ phase. With the addition of Ca element, the MgZn phase disappears, Mg_2Ca phase and Al_2Ca phase precipitates. There all exists α-Mg phase and $Mg_{32}(Zn, Al)_{49}$ phase but no MgZn phase in Mg-6Zn-2Al-1Ca, Mg-6Zn-2Al-2Ca and Mg-6Zn-2Al-3Ca alloys.

The SEM images of the Mg-6Zn-2Al and Mg-6Zn-2Al-2Ca alloys are shown in Figure.3. It can be seen from Fig.3(a) that the intergranular phases are semi-continuous bone-like structure. EDS analysis indicates that the intergranular phases are mainly composed of Mg and Zn elements, at the same, there exist a small amount of Al element. XRD analysis shows that the intergranular phases are MgZn phase containing a small amount of Al. When 2% Ca is added, Mg_2Ca and Al_2Ca emerge in matrix. The intergranular lamellar eutectics phase is composed of Mg_2Ca. The lamellar Al_2Ca phase mainly exist in the grain boundary, as is shown in Fig.3(b). The content of Al_2Ca phase and Mg_2Ca phase increases significantly with the increasing of Ca content, and the grain of α-Mg matrix decreases gradually in experimental alloys.

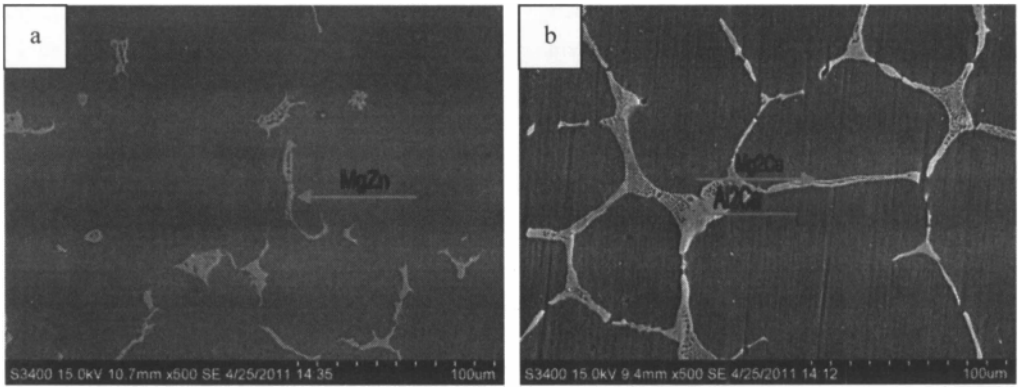

Figure.3 SEM images of ZA62 and ZA62-2Ca alloys

a) Mg-6Zn-2Al b) Mg-6Zn-2Al-2Ca

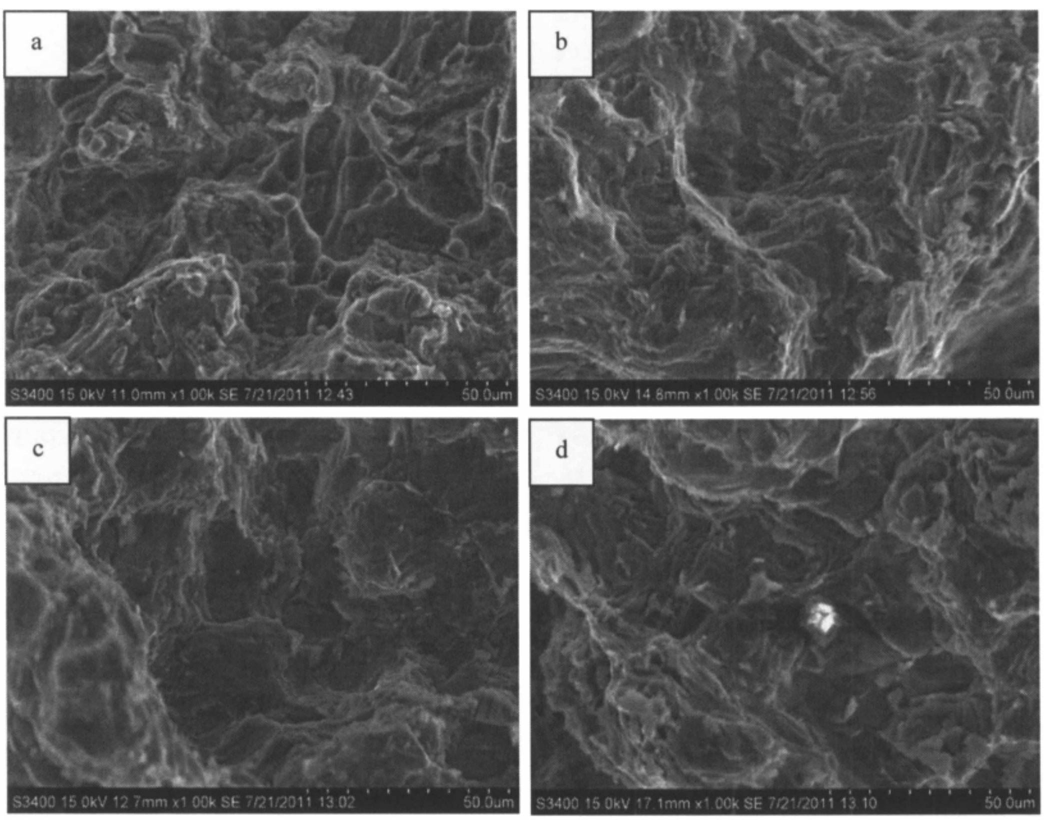

Fig.4 SEM tensile fractographs of as-cast Mg-6Zn-2Al-xCa alloys at room temperature

a) Mg-6Zn-2Al b) Mg-6Zn-2Al-1Ca c) Mg-6Zn-2Al-2Ca d) Mg-6Zn-2Al-3Ca

3.2 Effect of Ca on as-cast alloys tensile fractographs

The SEM tensile fractographs of as-cast Mg-6Zn-2Al alloys at room temperature are shown in Figure.4. It can be seen from Fig.4(a) that there exist numerous small size dimple in Mg-6Zn-2Al alloy due to coarse MgZn phases in grain boundary. The fractographs exhibit typical ductile dimple fracture pattern. Seen from Fig.4(b), Fig.4(c) and Fig.4(d), the SEM tensile fractographs of as-cast Mg-6Zn-2Al-xCa (x=1, 2, 3) alloys change greatly due to the increasing of Ca content. Fig.4(b) and Fig.4(c)show that there exist a small amount of large dimples in the process of fracture due to the formation of lamellar and rod-shaped Mg_2Ca and Al_2Ca phases, the tensile fracture of the alloys occurs along inter-granular boundary. Fig.4(d) shows that there no exist dimples in Mg-6Zn-2Al-3Ca alloy, the tensile fracture results from recombination action of quasi-cleavage and cleavage.

3.3 Effect of Ca on mechanical properties of alloys

Table 1 Tensile properties of as-cast Mg-6Zn-2Al-xCa alloys

合金名称	σ_b(MPa)	$\sigma_{0.2}$(MPa)	δ(Δx)
Mg-6Zn-2Al	199.21	68.08	2.30
Mg-6Zn-2Al-1Ca	225.73	67.16	0.69
Mg-6Zn-2Al-2Ca	240.79	82.78	0.59
Mg-6Zn-2Al-3Ca	213.04	0	0.28

The relationships between mechanical properties and Ca content are shown in table 1. Seen from the table 1, with the Ca content (mass fraction) increasing from 1% to 2%, the tensile strength increases from 225.73MPa to 240.79MPa and yield strength increases from 67.16MPa to 82.78MPa respectively. However, with the further increasing of Ca content, the tensile strength and yield strength of the alloys decrease rapidly. When the Ca content reaches 3%, the tensile strength of the alloy is 213.04MP and the yield strength of the alloy reduces to zero. The reason is that the excessive addition of Ca causes cleavage fracture and quasi-cleavage fracture in consistent with the fracture analysis. It can be seen from the table 1, the elongation percentage of Mg-6Zn-2Al-xCa alloys decrease significantly with the increasing of Ca content.

4 Conclusions

(1) The grain size of Mg-6Zn-2Al-xCa magnesium alloys is effectively reduced, the MgZn phase disappears, Mg_2Ca phase and Al_2Ca phase precipitates on the grain boundary as a result of the Ca addition.

(2) The addition of Ca can improve the tensile properties of alloys at room temperature. When the content of Ca is 2%, the tensile strength and yield strength of Mg-6Zn-2Al-2Ca alloy reaches 240.79MPa and 82.78MPa respectively, while the tensile strength and yield strength of Mg-6Zn-2Al-xCa alloys declines due to the precipitation of coarse Mg_2Ca and Al_2Ca phases on grain boundary with the further increasing of Ca content.

References

[1] SHI Ya-jing, LI Quan-an, REN Wen-liang, etal. Research and development of heat resistant magnesium alloy[J]. Light Alloy Fabrication Technology. 2009. 37(5):1-4

[2] Mihriban O, Pekguleryuz, Mike Dierks, etal. Creep resistant magnesium alloys for power-train applications [J]. Proceedings of Annual World MA 2001 Magnesium conference, 2001, 32(1) 37-45

[3] Munit A Z, Cotler C, Stem A, etal. Mechanical properties and microstructure of gas tungsten are welded magnesium AZ91D plates[J]. Materials Science and Engineering 2001, 302: 68-73

[4] Lou A A. Recent magnesium alloy development for elevated temperature application[J]. International Materials Reviews, 2004, 49(1): 13-30

[5] LIAO Kun, ZHANG Fu-quan, CHEN Ji-hua, etal. Effects of tin on microstructure and mechanical properties of ZA62 alloys[J]. Foundry Technology 2006, 27(4): 378-381