Microstructures and Mechanical Properties of Cast Mg-Zn-Y-Zr Mg Alloys

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Abstract: The as-cast microstructure and mechanical properties of Mg-xZn-yY-0.5Zr (ZWK) alloy were studied, and the effects of Zn and Y elements were analyzed. The results showed that the equilibrium phase of the as-cast alloy is mainly composed of α-Mg matrix and network eutectic phase, and its specific composition is mainly affected by the Zn/Y atomic ratio. For ZW105K, ZW205K, and ZW305K alloys, the equilibrium phase gradually evolves from W-Mg3Zn3Y2 phase to W phase + I phase (I-Mg3Zn6Y), I phase with the increase of Zn/Y atomic ratio (i.e. 2.69, 5.25, 11.89). For ZW202K, ZW205K, ZW215K Alloy, the equilibrium phase gradually evolved from I-Mg3Zn6Y phase to W phase + I phase, W phase with the decrease of Zn/Y atomic ratio (i.e. 10.87, 5.25, 1.71). With the increased of Zn or Y content, the number of eutectic phases gradually increased, the strength (YS, UTS) gradually increased, but the plasticity (EL) gradually decreased. Based on the comprehensive analysis, ZW205K alloy shows the best comprehensive mechanical properties among the two groups of alloys. The YS, UTS and EL was 88.3±0.2 MPa, 187.1±3.7 MPa and 14.1±2.1 %, respectively.

Keywords: Mg alloy; Mg-Zn-Y; microstructures; Mechanical properties

1 Introduction

As one kind of lightweight green structural material, Mg alloy shows great application prospect due to low density, high specific strength and good damping performance. Among many Mg alloys, the medium-high strength Mg-Zn-Y-Zr (ZWK) alloy has attracted widespread attention [1]. However, at present, most ZWK series alloys employ high contents of Zn and Y elements. The high content of rare earth Y greatly increases the alloy cost, which becomes a key bottleneck for engineering applications. Thus, the development of low-alloyed ZWK alloys has become the latest research focus.

In this paper, the microstructures and mechanical properties of low-alloyed ZWK alloys were investigated. The relationships among compositions, microstructures and properties were revealed. The mechanisms for strengthening and toughening was clarified. This paper will help promote the applications of Mg alloys.

2 Experimental procedure

Mg-*x*Zn-0.5Y-0.5Zr (nominal *x*=1.0, 2.0, 3.0wt.%, i.e. ZW105K, ZW205K, and ZW305K) and Mg-2.0Zn-*y*Y-0.5Zr (nominal *y*=0.2, 0.5, 1.5wt.%, i.e. ZW202K, ZW205K, ZW215K) alloys were prepared with traditional metal mold gravity casting. The raw materials for melting are pure Mg (99.wt.%), pure Zn, master alloy of Mg-25wt.%Y and Mg-30 wt.%Zr, which were melt in crucible resistance furnace (SG2-3-10). During the whole process of melting and casting, the protective mixed gas 1vol.%SF_6 + 99 vol.%CO_2 was used. After melting pure Mg and pure Zn at 660~700°C, the Mg-25Y master alloy was added at and melt at 700~720°. Then, the grain refiner Mg-30Zr master alloy was added and melt at 730°C. 1.5 wt.% JDMJ flux was used for melt purification. After 15min settling, melt was poured into a metallic mold preheated at 200°C. The real compositions were determined by ICP-AES.

Phase identifications were conducted with a D8 Advance X-ray diffractometer (XRD). Microstructure specimens were prepared through standard metallographic procedures including grounding, polishing and etching (solution: 4.2 g picric acid, 10 ml acetic acid, 80 ml ethyl alcohol and 10 ml water). Microstructure was observed with optical microscopy (OM, Leica DMi8) and scanning electron microscope (SEM, Nova NanoSEM 450) equipped with energy-dispersive spectrum (EDS).

Tensile specimens (Fig. 2) were prepared with electric-spark wire-cutting. Tensile tests were conducted on Zwick/Roell-20KN material test machine with test speed 0.5 mm/min. For each alloy, 7 parallel specimens were tested, and the average values and standard deviations for yield strength (YS, MPa), ultimate tensile strength (UTS, MPa) and elongation (EL. %) were calculated.

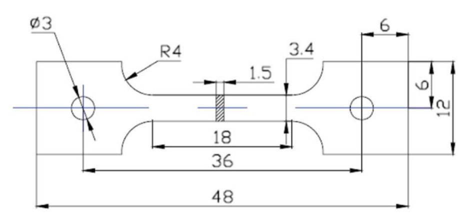

Figure 1. Dimension of tensile test sample ([1]).

3 Result and discussion

Microstructure

Figure 2 shows the XRD patterns of as-cast Mg-Zn-Y-Zr alloys. It can be seen that only the α-Mg matrix phase can be observed. According to [2, 3], the W-$Mg_3Zn_3Y_2$ and I-Mg_3Zn_6Y phases can be presented in Mg-Zn-Y alloys. However, they were not detected with XRD in this study due to a lower content of Zn and Y elements.

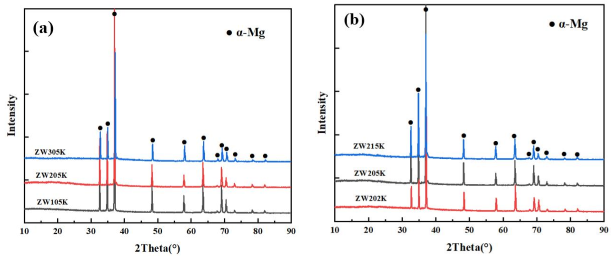

Figure 2. XRD patterns of as-cast Mg-Zn-Y-Zr alloys: (a) Mg-*x*Zn-0.5Y-0.5Zr, (b) Mg-2.0Zn-*y*Y-0.5Zr.

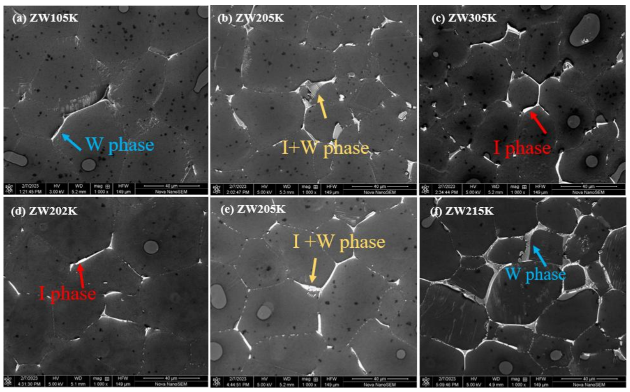

Figure 3. SEM of alloys: (a) ZW105K, (b) ZW205K, (c) ZW305K, (d) ZW202K, (e) ZW205K, (f) ZW215K.

Figure 3 shows the SEM of Mg-Zn-Y-Zr alloys, where EDS of some micro-areas were also analyzed. Firstly, the microstructures of Mg-*x*Zn-0.5Y-0.5Zr alloys were analyzed. It can be seen that the secondary phases in ZW105K alloy are mainly W-$Mg_3Zn_3Y_2$. With the increase in Zn content to 2%, I-Mg_3Zn_6Y phase also presents in ZW205K alloy. When the Zn content increases to 3%, W-phase disappears while the secondary phase is only I-phase. Secondly, the microstructures of Mg-2.0Zn-*y*Y-0.5Zr alloys were also analyzed, the secondary phase in ZW202K, ZW205K, ZW215K alloys is believed to be I, I+W and W phase, respectively. In addition, it has been reported that, when the long-period stacking order (LPSO) phase can present in Mg-Zn-Y-Zr alloy [2, 3]. But in Figure 3, LPSO phase was not observed, which is mainly because of its small amount.

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Mechanical properties

Figure 4 shows the mechanical properties. The strength gradually increases with increasing the Zn or Y content. The elongation gradually decreases with an increase in Zn content, but does not change linearly with an increase in Y content, whose reason will be analyzed later. The ZW215K alloy shows the highest UTS (193.1±7.9 MPa) and YS (103.7±1.5 MPa). The ZW205K alloy shows the highest elongation (14.1±2.1%). If the strength and elongation are considered together, the ZW205K alloy shows the best comprehensive mechanical properties.

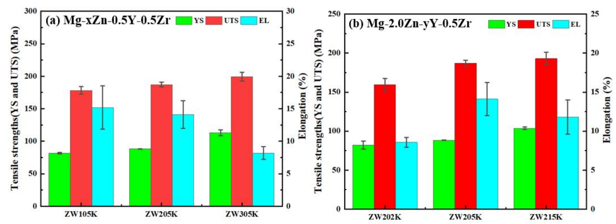

Figure 4. Mechanical properties of Mg-Zn-Y-Zr alloys: (a) Mg-xZn-0.5Y-0.5Zr, (b) Mg-2.0Zn-yY-0.5Zr.

4 Conclusion

The phase constitutions are greatly influenced by the content of Zn or Y content, where the phases can be I, I+W or W. If the strength and elongation are considered in compromise, the ZW205K alloy shows the best comprehensive mechanical properties.

References

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