Research on Microstructures and Mechanical Properties of Mg-Gd-Y-Sr-Zr Alloy

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Abstract. The microstructures and mechanical properties of Mg-Gd-Y-Sr-Zr alloy was investigated by means of optical microscopy, scanning electron microscopy (SEM), X-ray diffraction (XRD) and tensile tests. The as-cast alloy contains a microstructure consisting of α-Mg matrix, Mg_5Gd phase, $Mg_{24}Y_5$ phase and $Mg_{17}Sr_2$. As the temperature increases, the tensile strength of the alloy decreases. However, the elongation increases with increasing the temperature.

Introduction

At present, magnesium alloys are the lightest structural alloys commercially available and have great potential for applications in automobile industry, 3C (Computer, Communication, Consumer Electronic) and electron industry [1,2]. However, the creep properties of magnesium alloys are limited by their low melting point which can vary depending on the alloying content[3,4]. Thus, developing a new kind of magnesium alloys with high mechanical performance is a significant issue [5,6].

Rokhlin [7] and He Shangming [8] have developed Mg–Gd–Y–Zr alloys which show higher strength at both room and elevated temperature and better creep resistance than WE54 and QE22. And they also have investigated the relationship between mechanical properties and microstructures of these high gadolinium-containing magnesium alloys. It was reported that the addition of Ca, Sr and rare earth(RE) elements is effective to improve the performance of magnesium alloy[9]. Due to the above-mentioned reasons, the present investigation aims to study the microstructures and mechanical properties of Mg-Gd-Y-Sr-Zr alloy.

Experimental Procedures

Mg-30Gd (wt.%), Mg-25Y (wt.%), Mg-20Sr (wt.%) and Mg-25Zr (wt.%) master alloys were made first by melting high purity Mg (N99.95%), Gd (N99.9%) and Y (N99.9%) in a vacuum medium- frequency induction furnace under an argon atmosphere. Then, the Mg–5Gd–3Y–2Sr-0.5Zr alloy ingots were prepared from high purity Mg (99.95%), the Mg-30Gd (wt.%), Mg-25Y (wt.%), Mg-20Sr (wt.%)and Mg-25Zr (wt.%) master alloys in a medium- frequency induction furnace with a graphite(99.99%) crucible under a mixed atmosphere of CO_2 and SF6 with the ratio of 100:1. The chemical composition of the experimental alloys is listed Table 1.

Table 1. Chemical composition of alloys (mass fraction, %)

Alloy	Gd	Y	Sr	Zr	Mg
Mg-Gd-Y-Sr-Zr	5.0	3.0	2.0	0.5	Bal.

Before the melting started, all the materials and the permanent metallic mold should be dried at 200°C for 1-2 hours. Firstly, he high purity Mg were heated to melt. When the temperature rose to

720-740°C, the Mg-30Gd (wt.%), Mg-25Y (wt.%) and Mg-20Sr (wt.%) were added into the molten metal. After all the alloy melted ,Mg-25Zr (wt.%) master alloys were putted into. Then, the melt was held at 740°C for 5min to obtain a uniform alloy, which was stirred at the same time. Finally, when the temperature was reduced to 710-720°C, the melt was slowly poured into the permanent metallic mold which was preheated to 200~250°C.

After casting , the solution treatment and aging were respectively at 510C×6h and 225C×12h. Tensile tests were performed by using a SHIMADZU AG-I 250kN precision universal material test machine at room temperature (RT) ,200C, 250 C and 300C respectively. For the elevated temperature tensile specimens, they were held for 5 minutes at their corresponding temperatures. And at least three bars were used for each test. All the specimens were etched in a 4 vol.% natal. The microstructures were observed using optical microscopy (OM), D8ADVANCE type X-ray diffraction analysis (XRD) and JSM 5610LV scanning electron microscopy (SEM), separately.

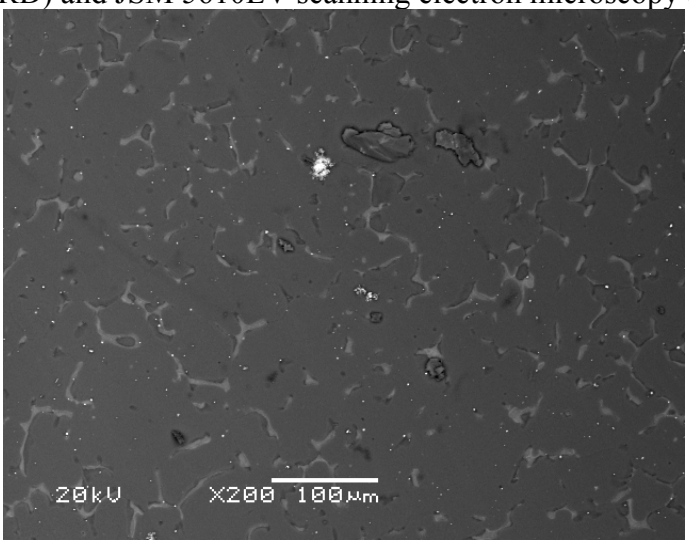

Fig. 1. SEM image of as-cast Mg–5Gd–3Y-2Sr–0.5Zr alloy

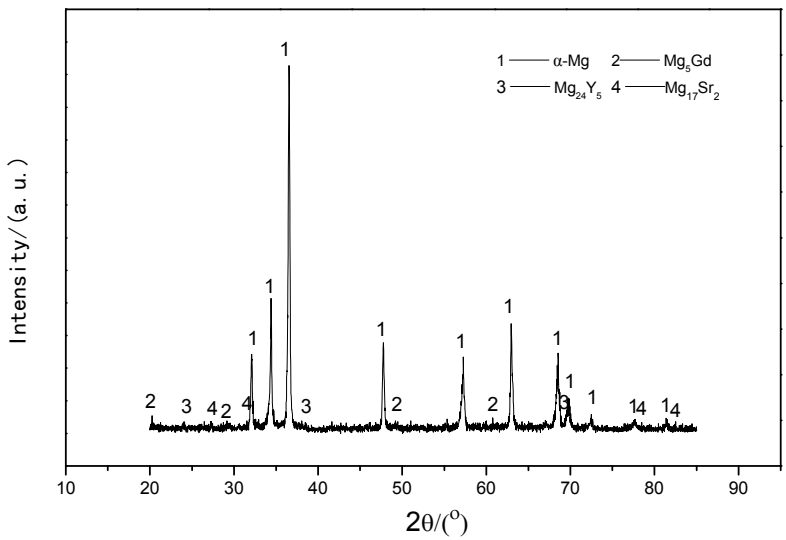

Fig. 2. XRD pattern of as-cast Mg–5Gd–3Y–2Sr-0.5Zr alloy

Results and Discussion

The SEM image of as-cast Mg–5Gd–3Y-2Sr–0.5Zr alloy is shown in Fig. 1. In the SEM image, it was observed that one phase solid solution with the white net-work of second phase which is mostly disposed between the dendrite branches of α-Mg solid solution, and there are many white petal-like Zr-rich regions were diffuse in the α-Mg matrix. The average grain size is very fine. Fig. 2 shows the phase compositions of the as-cast alloy by XRD analysis. It indicates that Mg–5Gd–3Y-2Sr–0.5Zr alloy mainly consists of α-Mg solid solution, Mg_5Gd, $Mg_{24}Y_5$ and $Mg_{17}Sr_2$ eutectic compounds.

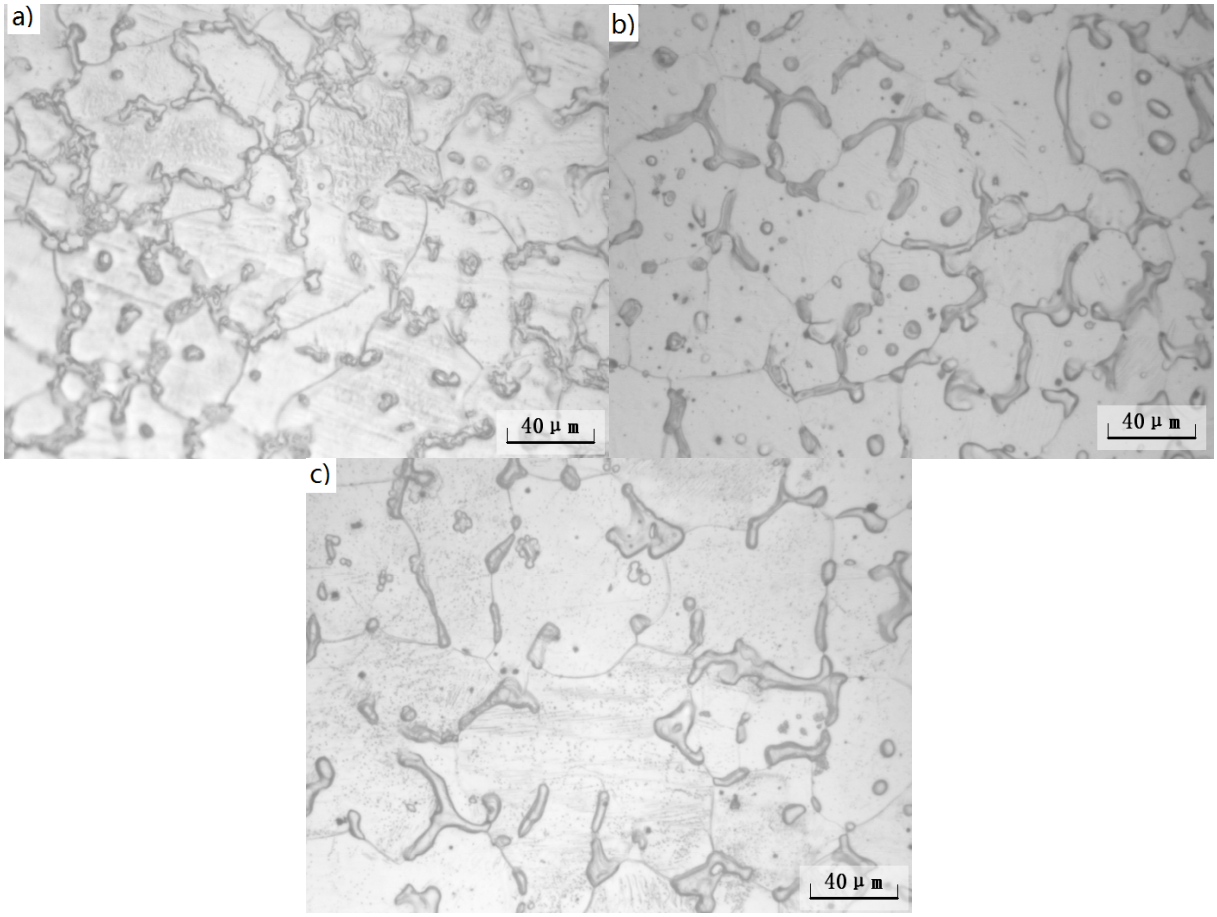

Fig. 3.The microstructures of Mg–5Gd–3Y–2Sr-0.5Zr alloy

a)as-cast b)solid solution c)aging treatment

The microstructure evolutions of Mg–5Gd–3Y–0.5Zr alloy with different treatment are list in Fig. 3. It was found that some of the precipitate dissolve into the matrix after solution treatment, but the most of the precipitate do not dissolve into the α-Mg matrix. After aging treatment , compare to the as-cast alloy the microstructures become more uniform.

Table 2. The tensile properties of Mg–5Gd–3Y–2Sr-0.5Zr alloy

Temperature	Tensile Strength [MPa]	Elongation [%]
RT	190.7	2.83
200C	186.0	3.21
250C	185.0	5.05
300C	154.3	7.09

The tensile properties, including tensile strength and elongation of the aging treatment experimental alloys are listed in Table 2. It is observed from Table 2 that the tensile strength of the Mg–5Gd–3Y–2Sr-0.5Zr alloy decreases with the increasing of the temperature. However, as the temperature increases, the elongation of the aging treatment experimental alloys increases.

Conclusions

1) The as-cast Mg–5Gd–3Y–0.5Zr alloy mainly consists of α-Mg solid solution, Mg_5Gd, $Mg_{24}Y_5$ and $Mg_{17}Sr_2$ phases.

2) With the increase of the temperature, the tensile strength of the aging treatment experimental alloys decreases and the elongation increases.

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