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Effects of melt temperature on as-cast structure and mechanical properties of AZ31B magnesium alloy

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Abstract: The effects of melt temperature on the as-cast structure and mechanical properties of AZ31B magnesium alloy were studied through a home-made electrical resistance furnace. The results show that the equiaxed dendrite size of AZ31B magnesium alloy under water-cooled metal cooling is linearly decreased with increasing the melt temperature below 850 °C, whereas the size changes little over 850 °C. The second phases in the microstructure are firstly refined; however, they are coarsened when the melt temperature exceeds 850 °C. With the increase of melt temperature, the tensile strength, yield strength and elongation of AZ31B magnesium alloy samples are rapidly enhanced first, then are slightly declined. When the melt temperature is increased to 850 °C, the tensile strength, yield strength and elongation reach 260 MPa, 75.4 MPa and 27.57%, respectively. The tensile strength, yield strength and elongation are increased by 15%, 13% and 61%, respectively compared with 750 °C. DSC analysis shows that the nucleation temperature is decreased, the critical nucleus radius is lessened with the increase of melt temperature, which increase the degree of supercooling and heterogeneity nucleation rate in melt, and the growth rate becomes larger with the increase of the degree of supercooling. That is the reason why the grain size is first rapidly decreased, and then is little increased.

Key words: AZ31B magnesium alloy; as-cast structure; mechanical properties; melt temperature

1 Introduction

As the lightest structural material, magnesium alloys taking on high specific strength, super-duper damping and so on, show a powerful attraction in the automotive, aerospace, electronics and other industrial sectors [1,2]. Because magnesium is the close-packed hexagonal structure and dislocation glide is anisotropic, the ductility and formability are poor at room temperature and magnesium alloy applications are restricted. The grain refinement is an important way to improve the deformation capacity [3], so the grain refinement of magnesium alloys has attracted increasing attention.

The methods of refining as-cast structure of magnesium alloys include deteriorating, alloying, exerting external fields and melt superheating. The studies show that the addition of carbon or carbon modificator, such as $MgCO_3$, C_2Cl_6 or CaC_2, can effectively refine Mg−Al-based alloys, and it is thought that a large number of dispersed Al_4C_3 particles in the melt become the crystalline cores [4]. The grain refinements are obtained through adding a small amount of Ca, Sr or traces of Ti, B, Sb, Sn and RE into aluminum-containing magnesium alloys [5−9], or adding Zr into magnesium alloys without containing aluminum [10]. Among these methods, the method of adding carbon or carbon modificator is low price, whereas the use of a large amount of carbon modificator can cause serious environmental pollution. The semi-solid structure with thin and spherical primary phase was prepared through the electromagnetic stirring by MAO et al [11]. XU et al [12] studied the effects of the alternative electromagnetic field on the solidification structure of ZK60 magnesium alloy and it is found that the solidification structure is refined. WANG et al [13] and FANG et al [14] researched the grain refinement of magnesium alloy under external field and achieved some results. However, the external field equipment is relatively complex, and it is difficult to apply to the production.

Melt superheating treatment is an effective method of refinement grain. In the past decades, the effects of

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melt superheating on aluminium alloy and Mg−1.5Si−1Zn alloy have been studied [15,16], and it is found that melt superheating treatment can refine the as-cast structure, whereas the refinement mechanism is not clear so far [17,18]. Because magnesium alloy is easy to oxidize and burn, the researches on the effects of melt superheating on the solidification structure and mechanical properties are few. The aim of this work is to explore the influence of melt superheating temperature on the solidification structure and mechanical properties of AZ31B magnesium alloy, to obtain the optimum treatment temperature, and to analyze the mechanism of grain refinement.

2 Experimental

The commercial AZ31B magnesium alloy was taken as raw materials, of which chemical composition is shown in Table 1. AZ31B magnesium alloy was melt in a home-made electrical resistance furnace with a mild steel crucible, and the melt was protected by the mixture gas of 99.5% CO_2 and 0.5% SF_6 in volume fraction. The schematic diagram of electrical resistance furnace is shown in Fig. 1. In order to accurately control the melt temperature, two thermocouples were designed in the electrical resistance furnace. One was used for measuring the furnace cavity temperature, and the other for measuring the melt temperature. The melt temperature is increased to 750, 800, 850 and 900 °C, respectively, after that the crucible with the protective gas was moved to a prepared cooling device to cool.

Table 1 Chemical composition of AZ31B magnesium alloy (mass fraction, %)

Si	Fe	Cu	Mn
≤0.005	≤0.05	≤0.05	≤0.2~0.5
Ni	**Zn**	**Al**	**Mg**
≤0.05	0.5~1.5	2.5~3.5	Bal.

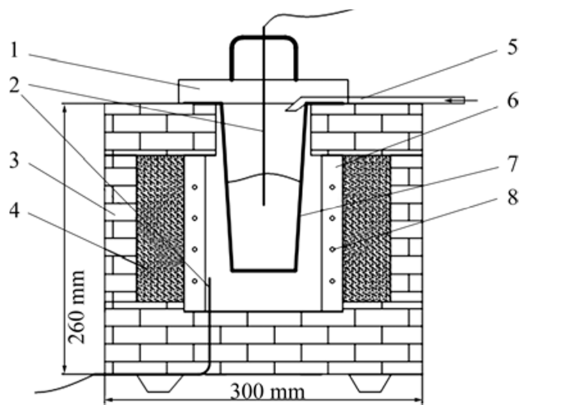

Fig. 1 Schematic diagram of melting device of magnesium alloy: 1—Furnace lid; 2—Heat electric couple; 3—Refractory brick; 4—Mineral flax; 5—Gas-guide tube; 6—Internal furnace; 7—Crucible; 8—Resistance wire

The as-cast ingots were cut along the longitudinal surface, and three tensile samples of *d*8 mm×40 mm are obtained on each as-cast ingot, as shown in Fig. 2. The tensile tests were done on a electronic universal testing machine (CMT5305) at the stretching speed of 2 mm/min. The microscopic specimens were intercepted at the end of the tensile samples. The microscopic specimens were etched with a solution containing 5.5 g picric acid, 5 mL glacial acetic acid, 90 mL alcohol and 10 mL water after they were shined and polished, and then the microstructures were observed by a metallographic microscope (Axiovert200MAT) and a scanning electron microscope (S−3000N). The grain sizes were measured through the average linear intercept method. A rotating X-ray diffraction instrument of Japan Science (D/max-RB 12 kW) was applied to determining the phases in AZ31B magnesium alloy. A synthesis thermal analyzer (Setaram) was used to study the effects of the melt temperature on the nucleation temperature and solidification range during the solidification process of AZ31B magnesium alloy.

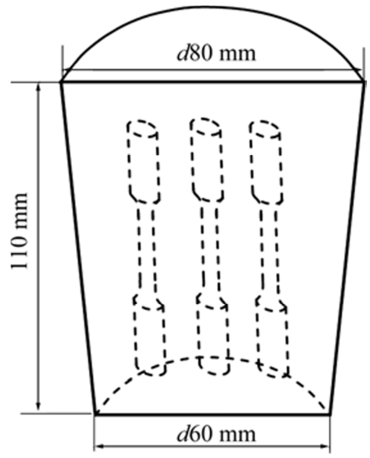

Fig. 2 Schematic diagram of casting and sampling location

3 Results and analysis

3.1 Effects of melt temperature on as-cast structure of AZ31B magnesium alloy

The as-cast structures of AZ31B magnesium alloy under different melt temperatures are shown in Fig. 3, and XRD patterns are shown in Fig. 4. It can be seen from Fig. 3 that the as-cast microstructure of AZ31B magnesium alloy is typical dendrite, and many spherical non-equilibrium eutectic phases are distributed in the interdendritic and at the grain boundary. When the melt temperature reaches 750 °C or 800 °C, the equiaxed dendrite is very coarse, as shown in Figs. 3(a) and (b), whereas the equiaxed dendrite is obviously refined at 850 °C (Fig. 3(c)). As the melt temperature continues to rise, the equiaxed dendrite changes little (Fig. 3(d)).