Segregation Defect Analysis for Magnesium Alloy Structural Parts in Squeeze Casting Technology

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Abstract: Magnesium alloy squeeze casting technology has been widely used in aerospace, automotive, and military industries, with promising application prospects. However, issues such as magnesium alloy's susceptibility to oxidation, combustion, cold shut defects, and solute segregation hinder the progress of this process. This study focuses on the macroscopic segregation defects that occur during magnesium alloy squeeze casting. Taking ZM5 magnesium alloy partition components as an example, we investigate the distribution of segregation in castings at different pouring temperatures. The results indicate that the higher the pouring temperature, the greater the macrosegregation area in the casting.

Keywords: Squeeze casting; magnesium alloy; Macroscopic segregation

1 Introduction

Magnesium alloy possesses numerous excellent properties such as low density, good seismic performance, high specific strength, high specific stiffness, and good recyclability [1]. Squeeze casting is a near-net-shape forming technology that can reduce macroscopic defects and achieve excellent mechanical properties when used to prepare magnesium alloy products [2-3].

This study focuses on investigating the design of pouring temperature in the Squeeze casting process. Indirect Squeeze casting experiments were conducted according to the designed experimental scheme, and the microstructure of ZM5 magnesium alloy baffle components produced were analyzed [4]. The microstructure is mainly composed of α-Mg matrix and the second phase $Mg_{17}Al_{12}$. The Squeeze casting process has a certain crushing effect on dendritic crystals [5].

2 Experimental procedure

In this experiment, commercial ZM5 magnesium alloy was used as the experimental material. During the experiment, 4 sets of process parameters varying with pouring temperature were designed for comparison, and the key process parameters used are shown in Table 1. The same squeeze pressure and casting rate were used in all processes, and the same amount of protective gas was introduced.

Table 1. Casting process parameters of ZM5 partition components

Group number	Pouring rate （L/min）	Mold temperature （°C）	Pouring temperature （°C）
A1	9.0	240	700
A2	9.0	240	720
A3	9.0	240	740
A4	9.0	240	760

3 Result and discussion

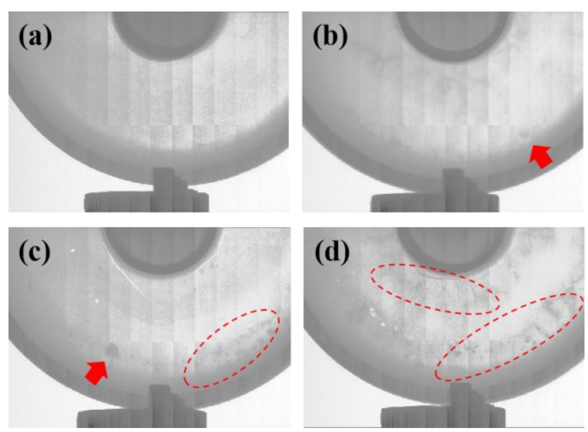

Fig.1 X-ray flaw detection results of partition plates 700 °C, (b) 720 °C, (c) 740 °C, (d) 760 °C

Fig. 1 is an X-ray flaw detection diagram of four groups of separators. The X-ray inspection image reveals that the normal part of the casting appears as a bright area, while the segregation bands appear black, exhibiting a band-like and dot-like distribution. it can be inferred that segregation phenomena often occur at the edges of castings, and the microstructure is observed by optical microscope at this location. As can be seen in Fig. 1, as the casting temperature increases, the area proportion of the segregation zone increases significantly.

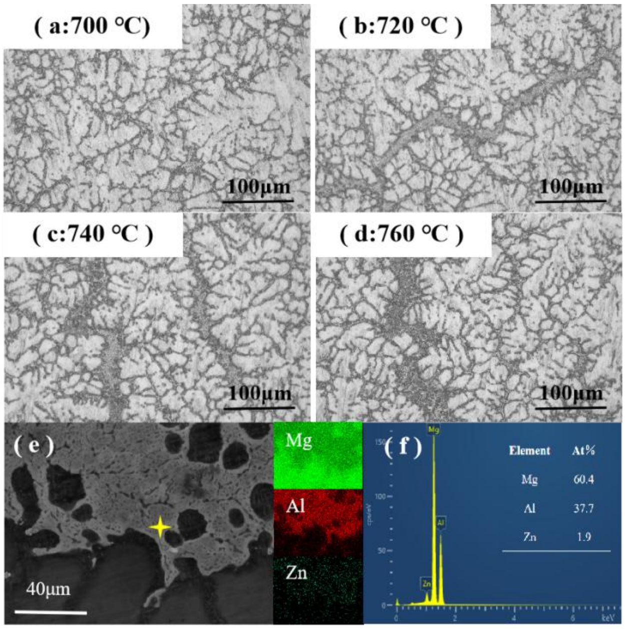

Fig.2 (a)(b)(c)(d) Morphology of segregated regions under light microscopy (OM), (c) Surface scanning, (f) Point scanning

Fig. 2 shows the microstructure of the four sets of partition plates observed using an optical microscope. As can be seen from the figure, the grain growth near the segregation zone is significantly affected, the grain size near the segregation zone is smaller than in the normal area. At the same time, it was found that with the increase of temperature, the grain size increased, the width of the segregation zone increased, and the color became darker. Fig. 2 is a scanning electron microscope (SEM) scan, and the defect band can be seen as a solute separation band enriched by the Al element. As shown in Fig. 2(e) and (f), the energy spectrum analysis of the segregation site showed that the components of the two tissues were mainly Mg, Al and Zn. The results indicate that the ratio of Mg to Al in the segregation area is approximately 17:12, confirming that the segregation phase primarily exists in the form of $Mg_{17}Al_{12}$.

Combining the distribution characteristics of segregation bands, it can be inferred that in the early stages of solidification, the surface layer first contacts the low-temperature mold, resulting in a higher degree of undercooling, which increases the solidification rate and leads to rapid surface cooling. Due to the shear stress induced by the flow of melt beneath the semisolid region, the grain network formed in the semisolid region gradually deforms. Once the shear stress exceeds the shear strength limit of the grain network, it collapses as the grains slide and rotate. Consequently, the semisolid region expands, allowing grains and dendrites to enter this region, ultimately forming segregation bands.

4 Conclusion

(1) For ZM5 magnesium alloy, the segregation band is enriched with Mg and Al elements, mainly in the form of $Mg_{17}Al_{12}$ phase, and the grain size near the segregation is smaller than in normal regions.

(2) Selecting the appropriate casting temperature plays a significant role in suppressing segregation. At 700 °C, the cooling rate is faster, resulting in fewer segregation phenomena and higher performance of the castings. As the temperature increases, the cooling rate slows down, leading to coarser grains in the casting. Meanwhile, the duration of the melt in the semisolid region prolongs, making segregation more likely to occur, thus affecting the mechanical properties of the casting.

Acknowledgments

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