Analysis and Solution of Macroscopic Segregation of Mn-containing Phase in Sand Casting of AZ91 Magnesium Alloy

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Abstract: The AZ91 magnesium alloy exhibits excellent properties, yet the sand casting process utilized in its production may give rise to challenges associated with macrosegregation related to manganese-containing phases. Understanding the mechanisms and factors influencing Mn phase segregation is crucial for optimizing the casting process of large magnesium alloy components and enhancing the performance of such components. This paper elucidates the composition and formation mechanisms of segregation defects in AZ91 (ZM5) magnesium alloy through chemical, non-destructive testing, metallography, and scanning electron microscope micrographs, proposing measures to prevent their occurrence. Initially, macrosegregation defects in magnesium alloy sand castings were detected through non-destructive testing, the morphology of the segregation defects was characterized using metallographic analysis, and the morphology and elemental composition of the segregated phase were analyzed using SEM. Through comparative experiments incorporating different element contents and cooling rates combined with phase diagram analysis, the mechanism and solutions for Mn phase segregation were identified.The outcomes of this study hold significant implications for addressing the Mn phase segregation issue in AZ91 (ZM5) alloy sand casting applications and improving the performance of large castings.

Keywords:AZ91 Magnesium Alloy, Macroscopic Segregation, Al8Mn5 phase

1 Introduction

Presently, research on AZ91 magnesium alloy segregation predominantly focuses on die casting or permanent mold casting processes, with limited emphasis on segregation in sand casting. It was observed that for commercial alloys, solidified manganese undergoes redistribution within the primary dendrites during the solidification process, primarily influencing precipitates within non-uniformly distributed matrix grains.

The results of SEM analysis on the alloying elements segregation in the cast, heat-treated, and aged states of AZ91E alloy indicate that manganese is enriched in the dendritic core structure of the casting structure, and even after 24 hours of heat treatment at 410 °C, these manganese-rich regions remain unchanged.[1]

In some magnesium alloys, Mn-containing Phase are closely related to overheating effects. If the melt is cooled from a high temperature, manganese particles crystallize from the melt during the cooling process.[2]

Although existing literature provides valuable insights into segregation phenomena in magnesium alloys, there are still some knowledge gaps that require further research. The specific interactions between the content of manganese in AZ91 magnesium alloy and other alloy elements, and their influence on segregation behavior, remain of interest for research. In addition, there is a need for in-depth exploration of the influence of specific parameters of sand casting (such as mold material, pouring temperature, cooling speed) on segregation patterns. Addressing these knowledge gaps will help to gain a more comprehensive understanding of the segregation mechanisms in magnesium alloys and facilitate the development of effective strategies to mitigate the effects of segregation during casting processes. The segregation behavior of magnesium alloys is influenced by a variety of factors, including alloy composition, particularly the content of alloy elements such as manganese, which can have a significant impact on segregation tendencies. In addition, pouring parameters (such as pouring temperature and mold material) play a crucial role in controlling the segregation patterns within the structure of the castings. The aim of this research is to address these shortcomings and, building on existing literature on magnesium alloy segregation phenomena, to provide new insights for analyzing and solving the macrosegregation issues related to Mn-containing phases in AZ91 magnesium alloy sand casting. Specifically, the research aims to: 1. Investigate the segregation patterns and distribution of Mn-containing phases in casting samples. 2. Identify the root causes of macrosegregation during large-scale casting processes using sand molds. 3. Propose effective solutions or strategies to minimize segregation defects in AZ91 (ZM5) magnesium alloy sand castings.

2 Experimental procedure

To Conducting a comprehensive investigation into the performance of alloy materials and optimizing their manufacturing processes required the execution of a series of casting experiments involving varied pouring temperatures and manganese (Mn) contents. These parameters were intentionally chosen to delve into their influence on the formation of alloy segregation defects. The experimental procedure initially involved preparing the specific alloy compositions in accordance with the designated pouring temperatures and Mn concentrations.

Subsequent to meticulous blending, the molten alloy were cast into meticulously crafted molds. Post-casting, a thorough anatomical examination of the alloy specimens was carried out to scrutinize the internal morphology and distribution of segregation defects. Employing sophisticated flaw detection methodologies, such as ultrasonic and X-ray testing, enabled a comprehensive assessment of the samples, facilitating precise identification of defect locations and sizes. Complementary metallographic analyses were conducted to delve deeper into the microstructural characteristics and properties of the alloy materials.

Table 1. Composition of Alloy .(wt%)

alloy	Al	Mn	Zn
A	8.2	0.15	0.5
B	8.1	0.25	0.49

3 Result and discussion

1. Non-destructive testing results for segregation defects:

Figure 1 shows the results of X-ray detection, indicating the presence of numerous point-like segregations.

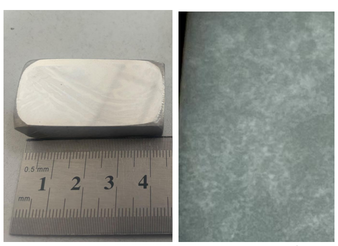

Figure 1 the X-ray testing result photograph of the casting and its corresponding actual location on the sample.

2.Metallographic testing of segregation defects

Figure 2 illustrates the outcomes of metallographic testing conducted on the segregation defects. From the metallographic images in the as-cast, T4, and T6 states, it is evident that numerous short rod-like precipitates are distributed both within and along the grain boundaries, and these precipitates cannot be dissolved through solution treatment.

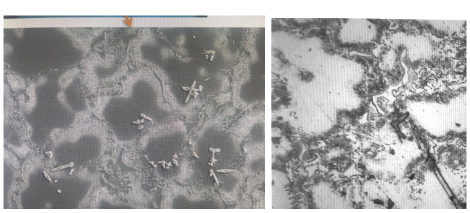

Figure 2 Optical image of the segregation defects area of the cast pattern

[3] .

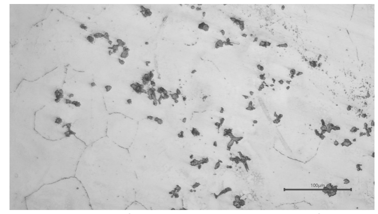

Figure 3 Optical image of the segregation defects area of the T4 pattern

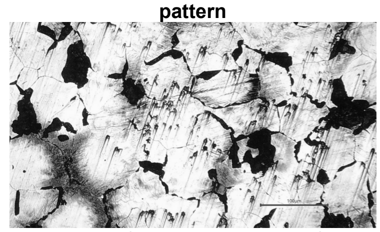

Figure 4 Optical image of the segregation defects area of the T6 pattern

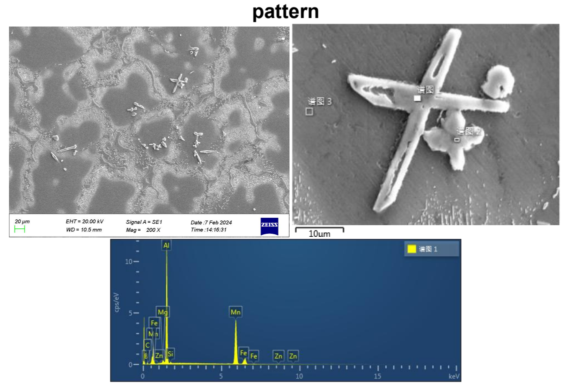

Figure 5 SEM images of the segregation defects area

4 Conclusion

By combining phase diagrams and experimental analysis, it is concluded that during the cooling process of the alloy from 600 °C to 510 °C, the Al8Mn5 phase precipitates from the solid phase. Measures to address macrosegregation of manganese-containing phases include:
1. Reducing the Mn content to the lower limit permitted by the alloy composition range.
2. Shortening the solidification time of the alloy at defect locations in the temperature range of 680-510 °C, increasing the cooling rate to minimize the precipitation of Al8Mn5 phase.
3. Appropriately raising the casting temperature; if the casting temperature is excessively low, close to 680-700 °C, the alloy may prematurely form Al8Mn5 phase locally due to compositional variations.

References

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