In Situ Determination of Nonmetallic Inclusions in AlMg6Si2MnZr Alloy

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Abstract: The study investigates the influence of impurities on the metallurgical quality of the AlMg6Si2MnZr alloy, a relatively new alloy for pressure die casting. Experimental techniques included in situ thermal analysis, electrical resistivity measurement, microscopy, and calorimetry. Findings suggest that improper handling during melting significantly impacts chemical composition and microstructure, necessitating careful process control. From electrical resistivity measurements in liquid, during solidification and in solid it is possible to estimate the quantity of nonmetallic inclusions.

Keywords: AlMg6Si2MnZr, Thermal analysis, Microstructure, Impurities, Pressure die casting.

1 Introduction

The AlMg6Si2MnZr alloy, noted for its enhanced mechanical properties, is less explored metallurgically. High magnesium content increases the likelihood of non-metallic inclusions, affecting the alloy's performance. This study aims to characterize these effects and provide insights for industrial application.

2 Experimental procedure

Methods included thermal analysis, electrical resistance measurements, optical and electron microscopy, and differential scanning calorimetry. A database for virtual casting process calculations was developed and calibrated using cooling curves.

Thermal analysis provided insights into phase transformations and solidification behavior. Electrical resistance measurements evaluated changes in the material's conductivity, indicating its purity and structural characteristics. Optical microscopy observed the overall microstructure, while electron microscopy examined finer structural details and phase distribution. Differential scanning calorimetry measured the heat flow associated with melting and solidification, providing crucial thermal property data.

Additionally, a database for virtual casting process calculations was established and calibrated using experimental cooling curves. This enabled accurate simulation of microstructural evolution and defect prediction during solidification, aiding in the optimization of the alloy's casting process. These combined methods provided a comprehensive understanding of the material's behavior under various processing conditions.

3 Result and discussion

Thermal analysis revealed that there are differences in cooling rates for various melt preparations, though these differences are not significant. In particular, the double 'in situ' thermal analysis indicated that the alloy's tendency for non-metallic inclusions to immerse in the melt and remain is higher compared to traditional aluminum alloys. The experimental series demonstrated that variations in melt preparation influenced the cooling curves to some extent, though significant differences were not observed.

Metallographic analysis provided insights into the microstructural characteristics of the alloy. Optical and electron microscopy revealed a dendritic structure of primary α_{Al} crystals, along with a binary eutectic mixture of α_{Al} and Mg_2Si, and a ternary eutectic of α_{Al}, Mg_2Si, and $Al_6(MnFe)$. The presence of polygonal particles based on Al, Mg, and Si, containing minor concentrations of Mo and V, and Chinese script particles based on Al, Si, Fe, and Mn, were noted. Fine intermetallic compounds such as $(AlSi)_3Zr$ were also observed.

The influence of impurities was investigated through differential scanning calorimetry and thermodynamic calculations, which examined slight variations in element concentrations. These analyses corroborated the presence of non-metallic inclusions, which were found to affect the quality of the alloy. The measured enthalpies of melting were lower for samples containing inclusions, confirming the detrimental impact of impurities on the alloy's quality.

The study underscores the critical need for stringent process control to mitigate the inclusion of impurities during the melting process. Proper handling and careful monitoring are essential to preserve the desired properties of the alloy, ensuring its suitability for industrial applications.

In Figure 1 a comparison of specific electrical resistivities of the investigated alloys is shown depending on the edge sample temperatures for measuring specific electrical resistivity.

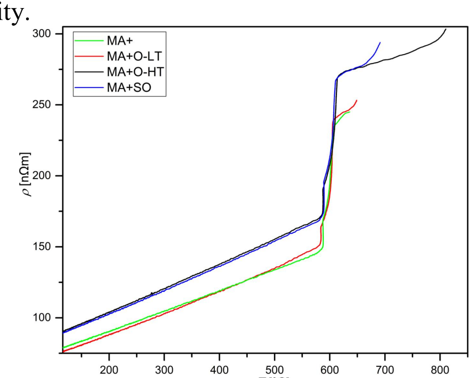

Figure 1: Comparison of resistance charts depending on edge cell temperatures for all investigated series.

The following diagram (Fig. 1) shows, depending on the investigated series, certain average areas between the derivative of the cooling curve and the linear baseline (A), sample masses (m), area-to-mass ratios (A/m), correlation factors of area-to-mass ratios with measured average DSC melting enthalpies of samples (A/m-DSCcor), and average measured DSC melting enthalpies (DSCavg). The correlation factors were determined as the ratio between A/m and DSCavg and calibrated according to the value MA+. Thus, the MA+ sample has a value of 1, while the others show a relative deviation from 1.

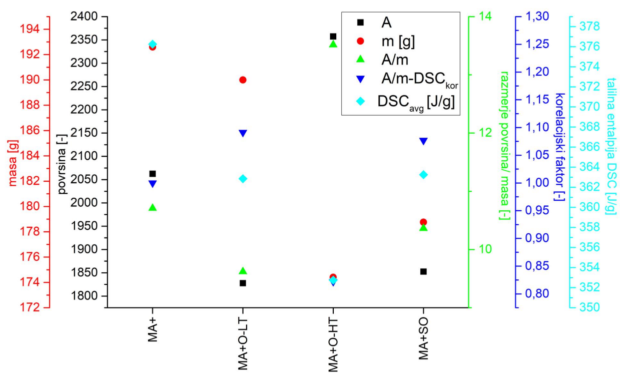

Figure 2: Crucial results from simple thermal analysis and enthalpies for all investigated series.

Conclusion

The study underscores the importance of strict process control in maintaining alloy quality. The presence of impurities significantly affects both microstructural characteristics and mechanical properties, emphasizing the need for precise melting practices.

References

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