Investigation on Heat Treatment Process Optimization of Super-Slow-Speed Die Casting A356.2 Alloy

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Abstract: A356.2 alloy die casting is produced by the Super-Slow-Speed die casting process. The phase composition of the alloy under the Scheil model and DB model (modified Scheil model) was analyzed by the CALPHAD-based method. Combined with DSC, conductivity meter, universal testing machine, and thermomechanical analyzer, the heat treatment process, microstructure, and mechanical properties of the material were studied, and the range of heat treatment process parameters required for actual production was determined.

Keywords: A356.2 alloy, Electrical conductivity,Solution temperature, CALPHAD, Mechanical properties;

1 Introduction

High pressure die casting (HPDC) is widely used but can have defects that affect strength and plasticity. Super-Slow-Speed HPDC (SSS HPDC) reduces these issues, enabling heat treatment for property enhancement. A356.2 alloy, known for toughness, is now used in HPDC. Aging treatments can strengthen but may decrease elongation. This study seeks to develop a heat treatment process for A356.2 in SSS HPDC that balances tensile strength, yield strength, and elongation, utilizing CALPHAD, electrical conductivity, and thermal expansion tests.

2 Experimental procedure

The A356.2 alloy was evaluated via SSS HPDC on an 840Ton Büler Ecoline S machine, with specific process parameters and mold temperatures. The casting, used in a vehicle's toolkit, had a 4mm wall thickness. Analysis included chemical composition with a Bruker spectrometer, thermal properties by DSC, electrical conductivity, microstructure via optical microscopy, and tensile tests with an average of three samples. Dimensional changes were measured with a thermomechanical analyzer across various temperatures.

3 Result and discussion

CALPHAD analysis in solidification

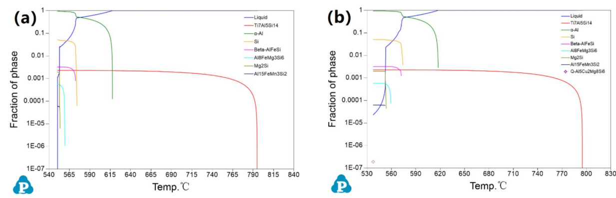

Figure1 Fraction of phase in the Scheil model (a); Fraction of phase in the DB model (b).

The difference is that the Scheil model results in a small amount of Al15FeMn3Si2 phase at 95% solid phase fraction and 550℃ final solidification temperature. BD model results in a termination temperature of 536℃ for multicomponent eutectic reaction due to a very small amount of Q-Al5Cu2Mg8Si6 phase.

Solution heat-treatment process

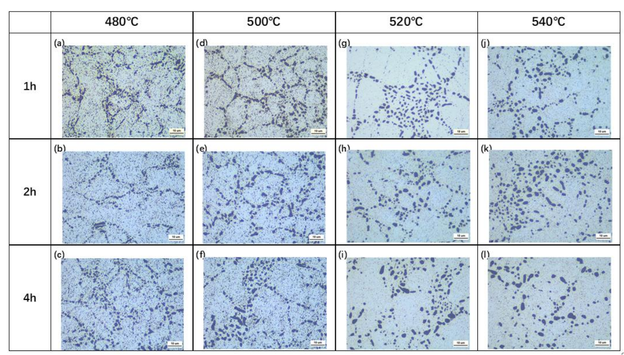

Figure 2 Microstructure after solution heat treatment on 480℃ for 1, 2, 4 h (a, b, c); 500℃ for 1, 2, 4 h (d, e, f); 520℃ for 1, 2, 4 h (g, h, i); and 540℃ for1, 2, 4 h (j, k, l).

Metallographic observations reveal that at 480℃ for 1-hour, eutectic silicon breaks and spreads into the aluminum matrix. Spheroidization occurs at 500℃ for 1 hour and becomes more pronounced with longer holding times. At 520℃ and 540℃ for 1-2 hours, Si particles spheroidize significantly, but after 4 hours, Si particles coarsen again.

Electrical conductivity

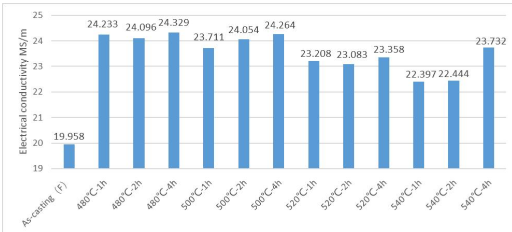

Figure 3 displays the electrical conductivity of an Al-Si alloy that underwent solution treatment at varying temperatures and holding times. The solubility of Si and other alloying elements in the α-Al matrix and Si phase morphology evolution affect the alloy's conductivity.

Mechanical property

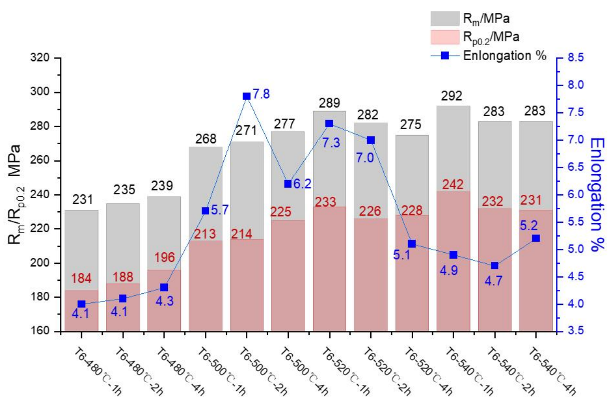

Figure 4 Mechanical properties of different solution treatments followed by aging at 180℃ for 6 h, the highest QI should be 418.5MPa when heating at 520℃ and holding for 1 h.

Thermal expansion/length change

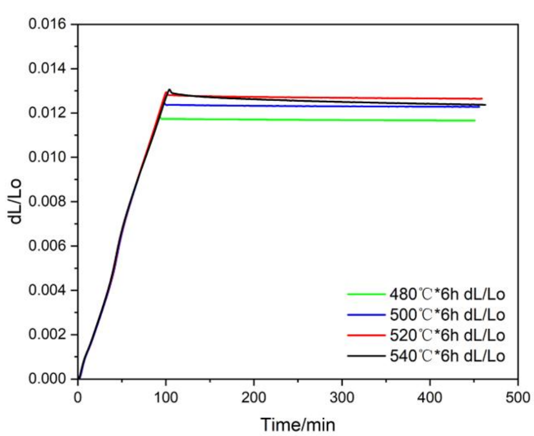

Figure 5 displays the effect of heating as-cast samples to different temperatures ranging from 480℃ to 540℃ for 6 hours. Local remelting of the material at 540℃ caused size deformation, but no significant changes were observed in the temperature range of 480℃-520℃. Therefore, this temperature range is suitable for castings' solid solution heat treatment.

4 Conclusion

The effect of solution treatment on the electrical conductivity of A356.2 alloy is influenced by the solubility of Si and other alloying elements in the α-Al matrix and the morphology evolution of Si phase.

Using the DB model of the solidification module of thermodynamic phase diagram software, the final solidification precipitation temperature was obtained at about 536℃; Combined with the thermal expansion curve at different holding temperatures, the eutectic liquid phase is produced at 540℃, which indicates that the DB model is suitable for the solidification analysis of the material in the super-slow-speed die casting process.

At temperatures of 500℃, 520℃, and 540℃, it is possible to obtain the necessary mechanical properties for the heat treatment process parameters for 1, 2, and 4 hours. The highest QI value of 418.5MPa can be achieved at 520℃ for 1 hour. However, it is not recommended to use the temperature of 540℃ for solution treatment, as it results in a negative size change. In practical production, the appropriate heat treatment process should be chosen according to the specific situation.

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