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

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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. The optimized heat treatment process for the prepared A356.2 alloy was determined as solution at 520℃ for 1 h and aging at 180℃ for 6 h.

Keywords: A356.2 alloy; electrical conductivity; solution temperature; CALPHAD; mechanical properties

1 Introduction

High pressure die casting (HPDC) is widely used but always causes porosity defect that greatly affect strength and plasticity [1,2]. The castings manufactured by Super-Slow-Speed HPDC (SSS HPDC) can be heat-treated (T6) for property enhancement [3]. A356.2 alloy, usually gravity-cast, is now used in HPDC. Aging treatments without corresponding solution treatment can increase the strength but decreases the elongation [4,5]. This study seeks to develop a heat treatment process for A356.2 in SSS HPDC that balances strength and elongation, utilizing CALPHAD, tensile test and electrical conductivity and thermal expansion measurements.

2 Experimental procedure

A356.2 alloy casting was manufactured 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 mechanical properties 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

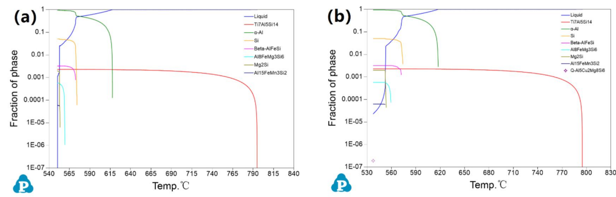

Fig.1 Fraction of phase by Scheil model (a) DB model (b)

Fig.1 show the fraction of phases obtained by the Scheil model (a) DB model (b). The difference is that: in Scheil model, a very small amount of Al15FeMn3Si2 phase is formed at 95% solid phase fraction and the final solidification ends at 550℃; in BD model the end of solidification is at 536℃, where a multicomponent eutectic reaction occurs, containing a very small amount of Q-Al5Cu2Mg8Si6 phase.

Solution heat-treatment process

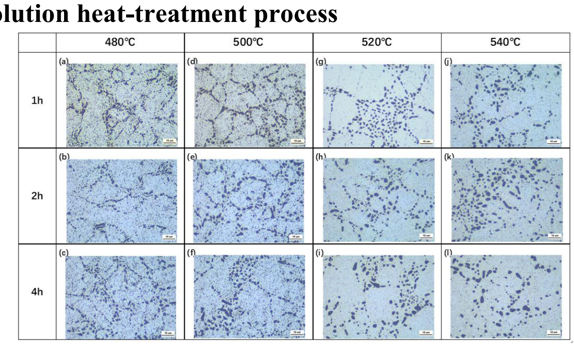

Fig.2 Microstructure after solution heat treatment at 480℃ for 1, 2, 4 h (a, b, c); 500℃ for 1, 2, 4 h (d, e, f); 520℃ for 1, 2, 4 h (g, h, i); and 540℃ for1, 2, 4 h (j, k, l)

Metallographic observation in Fig. 2 reveals that at 480℃ for 1-hour, eutectic silicon becomes segments. 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 are spheroidized significantly, but after 4 hours, Si particles become coarsened again.

Electrical conductivity

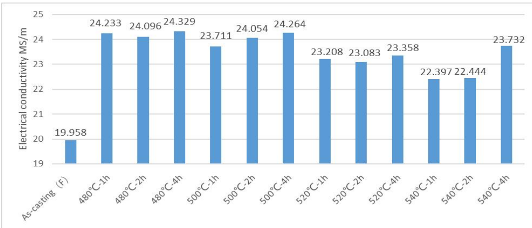

Fig. 3 Electrical conductivity of the studied alloy at different states

Fig. 3 displays the electrical conductivity of the studied alloy in different states. The changes in solution temperature and time results in the variations of Si and Mg in the α-Al matrix and Si phase morphology, thus affecting the alloy's conductivity. The highest conductivity is obtained by solution treatment at 480℃-1h.

Mechanical property

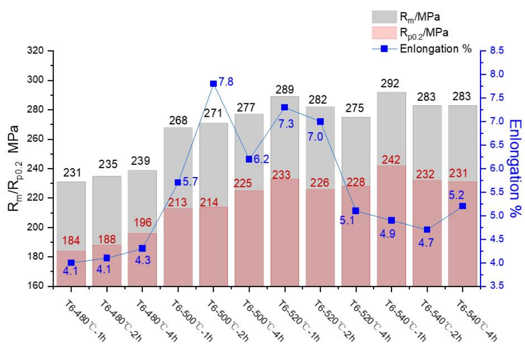

Fig. 4 Mechanical properties of the alloy in different solution states followed by aging at 180℃ for 6 h

It is seen that the highest strength is obtained by solution-treatment at 540℃-1h, the highest elongation is at 500℃-2h, the highest QI is at 520℃-2h from Fig.4.

Thermal expansion/length change

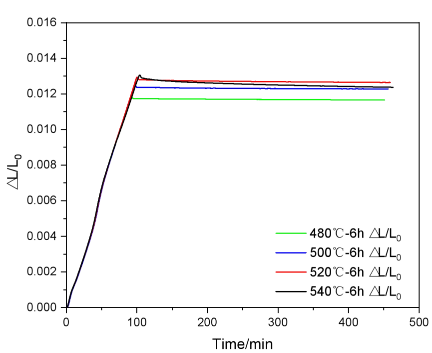

Fig.5 Thermal expansion/ length change at 480℃ to 540℃ for 6 hours

Fig. 5 displays the heating effect on the length of as-cast samples to different temperatures ranging from 480℃ to 540℃ for 6 hours. Local remelting of the material at 540℃ caused a considerable change in size, but in the temperature range of 480℃-520℃, the change of length is very small. Therefore, this temperature range is suitable for castings' solid solution heat treatment.

4 Conclusion

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 during solution treatment. The DB model of thermodynamic phase diagram software is suitable for analyzing the solidification process in super-slow-speed die casting. The highest QI value of 418.5MPa is achieved at 520°C for 1 hour. It is not recommended to use 540°C for solution treatment due to negative size changes. Therefore, the appropriate heat treatment process should be chosen based on specific production requirements.

Reference

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