

Effect of Solution Heat Treatment Time on a Rheocast Al-Zn-Mg-Cu Alloy

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Abstract. During rheo-high pressure die casting (R-HPDC) of Al-Zn-Mg-Cu alloys a coarse eutectic phase is formed. This eutectic phase is difficult to take into solution because of its size and it would require longer solution heat treatment times. The objective of this work was to determine the time for sufficient dissolution of the eutectic phase in this Al-Zn-Mg-Cu alloy. Solution heat treatment was carried out at 473°C for various time periods and the samples were quenched in water. The samples were then artificially aged at 120°C for 24 hrs. A component of the eutectic was observed to have dissolved and another component transformed to new intermetallic phases for all solution heat treatment times at 473°C.

Introduction

During rheo-high pressure die casting (R-HPDC) of Al-Zn-Mg-Cu alloys a coarse eutectic phase is formed [1]. This is a result of the solute redistribution during solidification which leads to microsegregation of elements. The eutectic phase is difficult to take into solution because of its size and it would require longer solution heat treatment times. The coarse eutectic phase has a significant effect on the properties of the 7xxx aluminium alloys [1-4]. When Al-Zn-Mg-Cu alloys are solution treated the eutectic dissolves and new intermetallic phases are formed which require higher solution treatment temperatures and longer times to dissolve [2, 5]. It was also observed that the mechanical properties increased considerably with no loss of ductility after stepped heat treatment [5]. The corrosion resistance was observed to improve after solution treatment of the similar AA7150 alloy [6]. The aim of this work was to determine a sufficient time for complete dissolution of the eutectic phase in this rheocast Al-Zn-Mg-Cu alloy.

Experimental Procedure

The Al-Zn-Mg-Cu alloy with the composition (6.7 Zn, 2.6 Mg, 2.0 Cu, 0.06 Fe, Si not detected and balance Al, in wt.%) was used for rheo-high pressure casting of the plate samples with dimensions 100 mm x 55 mm x 6 mm. The alloy material was melted in a 20 kg resistance heated tilting furnace and degassed with argon. A sample was analyzed for chemical composition by optical emission spectroscopy (Thermo Quantis OES). Thermodynamic properties of the alloy were calculated with an aluminum thermodynamic database (ProCast 2009.1) from the specific OES composition. A pouring temperature of 650 °C and a SSM processing temperature of 615 °C which corresponded to a solid fraction of 30% were used from experience with the system. The sequence for casting was as follows. Liquid metal was poured from the tilting furnace into the stainless steel processing cup (about 400 g) which was then manually transferred to a single coil version of the CSIR-RCS (induction stirring with simultaneous forced air cooling) where processing starts when the cup enters the coil. The thermocouple was used to measure the semi-solid temperature of the material in the cup. Processing stopped after the thermocouple signal reached the preset SSM temperature of 615 °C. The cup was then ejected from the coil and manually transferred to the

HPDC machine (LK DCC130). The injection shot was manually triggered when the SSM billet was in the shot sleeve. The piston followed the set computer controlled injection velocity profile. The plate sample was then sectioned and solution heat treatment was performed at different time intervals to assess the effect of time on the dissolution of the eutectic phase. The solution heat treatment was carried out at 473°C for 15 minutes intervals up to 5 hrs and at 4 hr intervals up to 24 hrs, followed by quenching in water (25°C), giving the T4 temper condition. Artificial ageing was performed at 120°C for 24 hrs for all the T4 samples. Vickers hardness was measured on the samples cross-sections after T4 and T6 samples using a 10 kgf load and the average of nine readings is presented. Metallographic samples were prepared for optical microscope evaluation. A Joel JSM-6510 Scanning Electron Microscopy (SEM) equipped with the Thermo Scientific UltraDry X-ray Energy Dispersive Spectroscopy (EDS) was used to analyse the phases before and after solution heat treatment. The samples were evaluated in the unetched condition.

Results and Discussion

The hardness after solution treating at 473°C and quenching in water (25°C) at different time intervals seemed relatively insensitive to the solution treatment time (Fig. 1). The error bars show maximum and minimum values for the plotted average values. The hardness peak observed after near 5hrs of solution treatment could be a result of the indentation falling on more patches of the eutectic. Overall, longer solution heat treatment times do not seem to be significant. Fig. 2 shows the as-cast microstructure consisting of globular alpha grains and the coarse eutectic phase, shrinkage porosity was also observed in the eutectic areas. The pores coalesced and became large with longer solution heat treatment time. Fig. 3(a) and 3(b) show the appearance of the eutectic areas after 5hrs and 24 hrs. Intermetallic phases were observed to have formed in the eutectic and these intermetallic phases coarsened with longer solution treatment time. The phases were analysed by EDS and they were found to have compositions as outlined in Table 1. The two phases in the solution treated samples have stoichiometric compositions close to the AlCuMgZn for Phase 1 and Al₂CuMg for Phase 2. The Al₂CuMg phase has been observed to appear after 30 min of homogenization at 460°C for another Al-Zn-Mg-Cu alloy [3] which seems to be the case for this study. The Al₂CuMg phase was observed to have grown and coarsened into isolated patches Fig. (3b) after 24hrs of solution heat treatment. Solution heat treatment for 24 hrs at 473°C was sufficient to dissolve the eutectic for this alloy but higher temperatures are required to completely dissolve the product intermetallic phases.

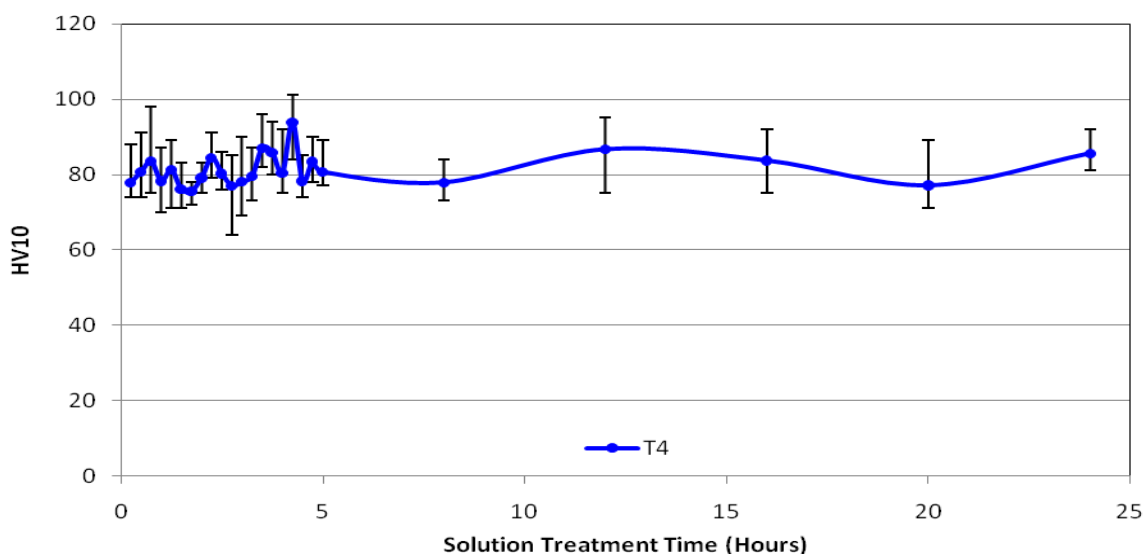


Fig. 1. Vickers Hardness Curve for the rheocast Al-Zn-Mg-Cu alloy after solution heat treatment at 473°C and water quench (25°C).

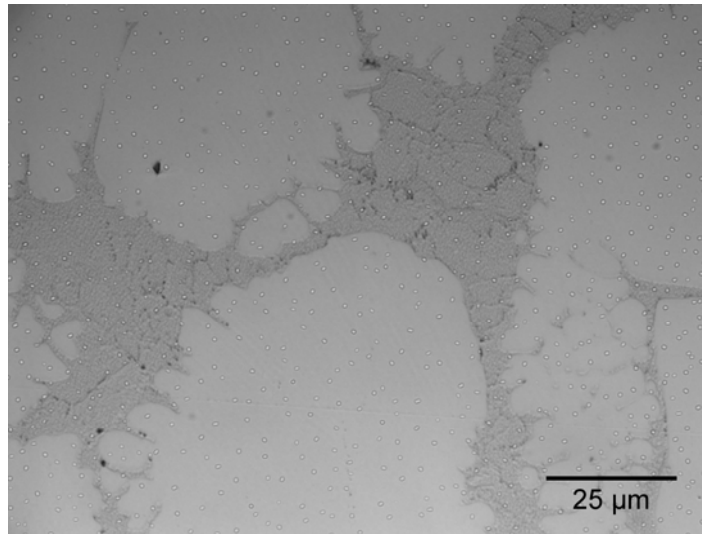


Fig. 2. Optical micrograph of the as-cast Al-Zn-Mg-Cu alloy.

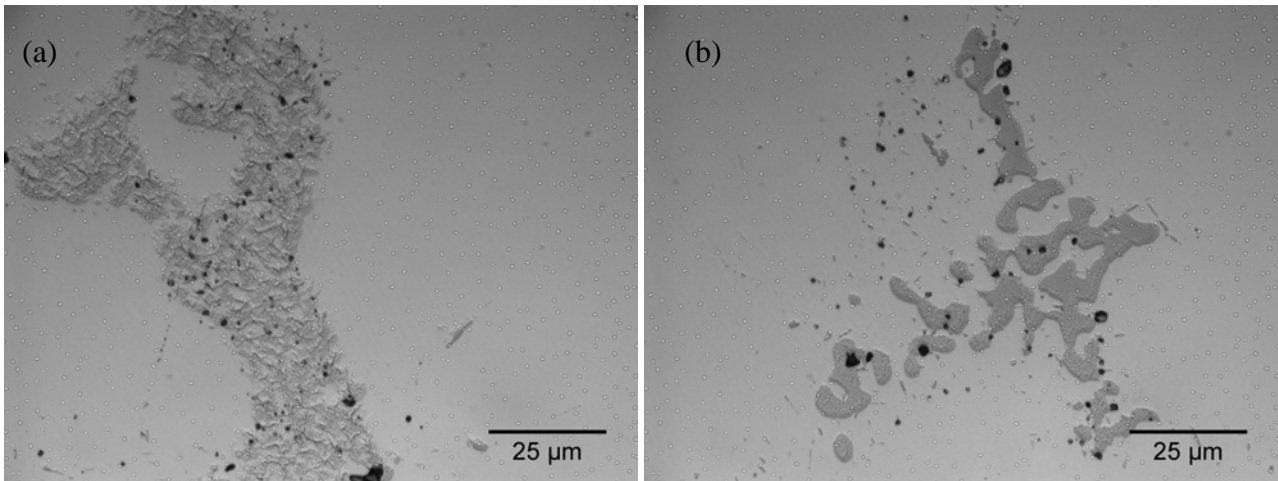


Fig. 3. Optical micrographs of (a) Al-Zn-Mg-Cu alloy after solution heat treatment at 473°C for 5 hrs and (b) after solution heat treatment at 473°C for 24 hrs.

Table 1: Results of EDS analysis of various types of the Phases shown in Fig. 2. (at. %)

Second Phase structure	Al	Zn	Mg	Cu
As-cast	58	16	18	8
Phase 1	27	24	29	20
Phase 2	50	2	22	26

The hardness in the T6 condition was used to further assess the effect of solution heat treatment (Fig. 4). Overall, the hardness increased over that of T4 condition. As more Mg, Zn and Cu dissolve with longer solution treatment time, the hardness increased after precipitation hardening. A high concentration of Cu was still present as an intermetallic phase as it could not be taken into solution at 473°C. Higher hardness could be expected with a high concentration of Cu in solid solution as it will participate in the precipitation hardening [7].

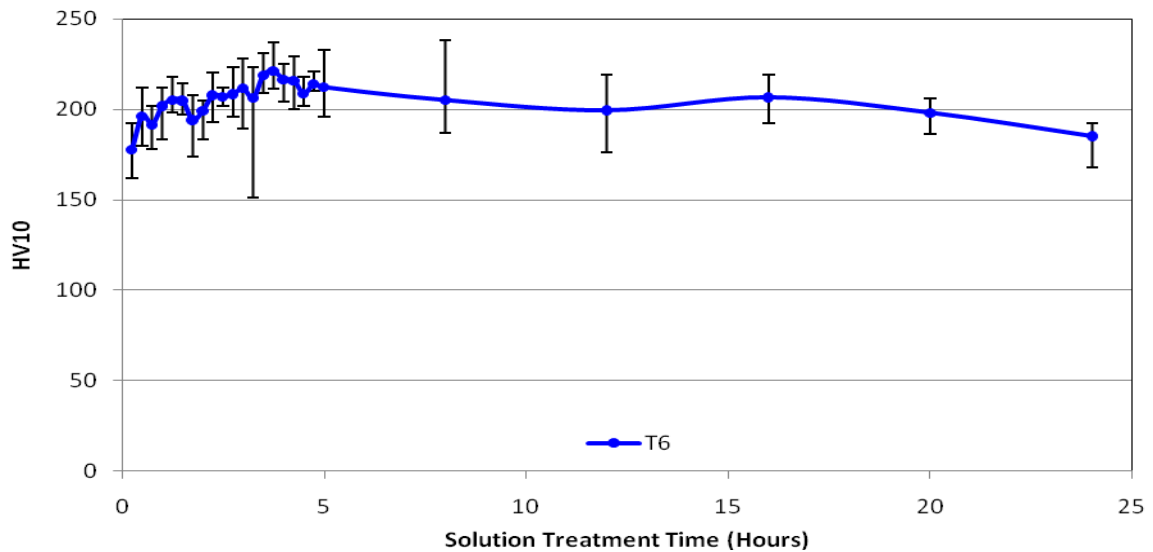


Fig.4: Vickers Hardness Curve for rheocast Al-Zn-Mg-Cu alloy after artificial ageing at 120°C for 24 hrs.

Conclusions

The effect of solution heat treatment at 473°C on the coarse eutectic phase formed during rheo high pressure die cast (R-HPDC) of the Al-Zn-Mg-Cu alloy was that the eutectic was observed to have dissolved and transformed to AlMgCuZn and Al₂CuMg intermetallic phases after solution heat treatment at 473°C. Both intermetallic phases were still present even after 24 hrs of solution treatment. Solution heat treatment for 24 hrs at 473°C was sufficient to dissolve the eutectic for this alloy but higher temperatures are required to completely dissolve the product intermetallic phases.

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