

OPTIMISATION OF THE SOLUTION HEAT TREATMENT OF RHEO-PROCESSED Al-Cu-Mg (Ag) ALLOYS A206 AND A201

E.P Masuku^{1, a}, H. Möller^{1, b}, R. Knutsen^{2, c}, L. Ivanchev^{1, d}, G. Govender^{1, e}

¹CSIR: Materials Science and Manufacturing, P.O. Box 395, Pretoria, 0001 South Africa

²UCT: Centre for Materials Engineering, P.O. Box X3, Rondebosch, 7701 South Africa

^aemasuku@csir.co.za, ^bhmoller@csir.co.za, ^crknutsen@uct.co.za, ^dlivanch@csir.co.za, ^esgovender@csir.co.za

Abstract

The traditional solution treatment cycles that are currently applied to rheo-processed A201 are mostly those that are used for conventional castings. These solution treatments are not necessarily the optimum solution treatments for rheo-processing. As a result DSC analysis was done to optimize this heat treatment. The new solution treatment which consists of higher temperatures and shorter times (515°C/5h, followed by 570° C/10h) resulted in slightly higher hardness values for both alloy A206 and A201.

Introduction

A201 aluminium alloy is a high strength casting alloy with a nominal composition of Al-4.6Cu-0.3Mg-0.6Ag. It is strengthened by the Ω (Cu₂Al)-phase and the θ' (Cu₂Al)-phase during heat treatment. It is well known that the optimum strength and ductility can be obtained by precipitating large amount of θ' and Ω phases through T6 heat treatment. The traditional T6 treatment [1] that consists of solution treatment at 513°C for 2 hours, followed by 527° for 17 hours (19 hours of solution treatment time), quenching in water at ambient temperature and artificial ageing at 153°C for 20 hours was employed on the rheo-processed aluminium alloy A201 and A206 in the previous study done by the authors [2]. It was shown that this heat treatment is not necessarily the optimum treatment, as it resulted in a high volume of undissolved θ (Cu₂Al) and Cu₂FeAl₇ on the grain boundaries which gave a lower supersaturation of copper during artificial aging and a decrease in strength in the T6 condition [2]. The objective of this study was to optimize the heat treatment cycles of rheo-processed A206 (Ag free) and A201.

Experimental

Alloys A206 and A201 were supplied in the form of ingots. An electric resistance melting furnace was used to melt the elements to a pouring temperature of 670°C. Chemical analysis was done using a thermal ARL Quantris Optical Emission Spectrometer (OES) before casting to ensure that all elements were within the specified composition.

Stainless steel cups were used for processing in the rheocasting system. Differential Scanning Calorimetry (DSC) analyses were performed in the NETZSCH STA409 thermal analyzer using alumina crucibles under inert (Ar gas). The samples were heat treated to two different temper conditions namely: the traditional T6 heat treatment and a new proposed T6 treatment

which was based on the DSC results reported in this paper. This consists of solution treatment at 515°C for 5h, followed by 570° C for 10h, quenching in water at ambient temperature and artificial ageing at 153°C for 20 hours. Hardness measurements were done using a Vickers machine (20 kg load). The samples were mounted using an electro-conductive resin, polished by standard processes and then etched using 0.5% solution of HF for microstructural characteristics using optical microscopic image analysis and scanning electron microscopy (SEM).

Results and discussion

DSC analysis. The DSC scans for the as-cast and homogenised specimens of the two samples are shown in Fig 1 below. Two distinct endothermic peaks occurred at $535^{\circ}\text{C} \pm 5^{\circ}\text{C}$ and $590^{\circ}\text{C} \pm 5^{\circ}\text{C}$ for the as cast condition, which represents the melting of the eutectic fraction.

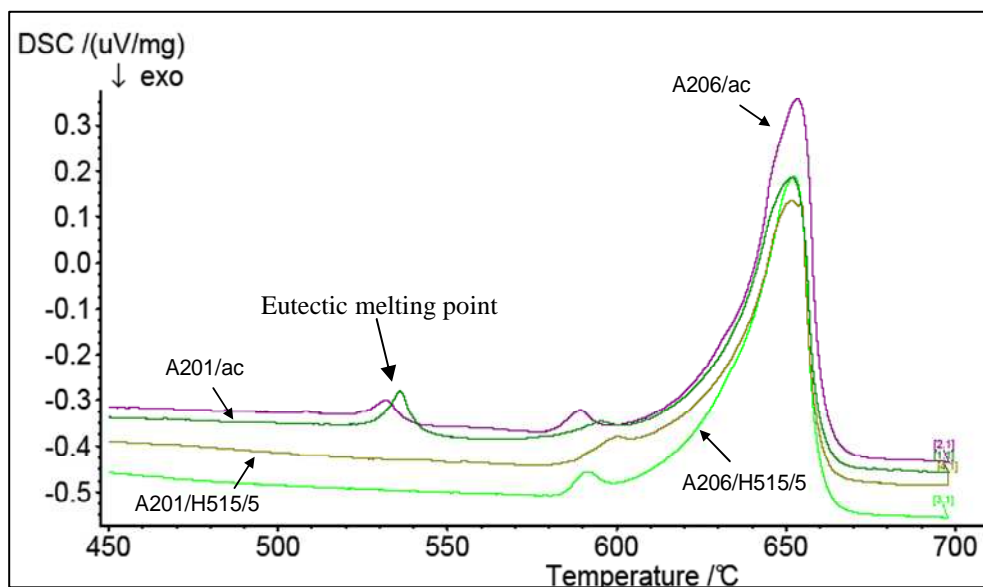


Fig 1. DSC scans for (i) A201 and A206 in as cast condition (A201/ac and A206/ac) and (ii) A201 and A206 after homogenisation (A201/H515/5 and A206/H515/5).

The major endothermic peak occurring at about $650^{\circ}\text{C} \pm 1^{\circ}\text{C}$ represents bulk melting of the alloys. The as cast samples were homogenised at 515°C for 5 hours and DSC scans were repeated (see fig 1). In both alloys the eutectic melting peaks at lower temperatures have disappeared which means that the homogenisation treatment has been successful in removing the eutectic structures. The higher solution treatment temperature, namely $570^{\circ}\text{C}/10\text{hr}$ has two potential beneficial effects. Firstly, shorter solution treatment times can be employed (10hrs vs. 17hrs) and secondly, it could result in the dissolution of more of the θ (CuAl_2) phases.

Chemical composition. The chemical composition (wt %) of A206 was 4.8Cu-0.47Mg-0.45Mn-0.07Fe and of A201 was Al-4.7Cu-0.28Mg-0.27Mn-0.63Ag-0.07Fe. Iron tends to form a needle-like intermetallic compound of Cu_2FeAl_7 , which is hard and brittle and tends to decrease the amount of copper in solid solution which was supposed to be available for the strengthening precipitates. The Cu_2FeAl_7 -phase is known to have a detrimental effect on the mechanical properties of the 200 series alloys, especially the ductility [3].

Microstructure. Fig. 2(a-b) display typical light micrograph images of rheoprocessed A206 and A201 in as-cast condition. The microstructure of these alloys after rheo-processing consists mainly of globular aluminium primary crystals. A continuous Cu-rich segregation zone identified as CuAl_2 (θ) appeared at the grain boundaries of the α -Al matrix. This was quantified using phase mapping with SEM where alloy A206 and A201 contain 1.5vol% and 1.9vol% respectively of the grain boundary segregation. The traditional T6 and the new T6 treatments resulted in dissolution of the Cu-segregated phase. However, a small amount of this phase remained after the solution treatments. It appears as if the higher temperature (570°C for 10h) did not result in a significantly lower volume fraction of the CuAl_2 (θ) phase after solution treatment (see fig 3(a-d)).

Hardness measurements. The average Vickers hardness value of the alloys in the as-cast condition was 58 for both alloy A206 and A201. For the traditional T6 treatment, the values are 105 and 133 for alloy A206 and A201 respectively. The new T6 treatment resulted in hardness values of 113 and 137 for alloy A206 and A201 respectively. The as-cast hardness values clearly show that the solution treatment is necessary to obtain optimum mechanical properties as most the strengthening alloying elements are not in solution. Slightly higher hardness values are obtained using the new proposed solution treatment compared to the traditional treatment. This implies that the higher temperature (570°C) did indeed dissolve slightly more of the CuAl_2 (θ) phase than the traditional treatment (527°C). Furthermore, the extended pre-treatment at 515°C for 5hr decreases the likelihood of incipient melting occurring during the second stage solution treatment (570°C for 10hr) since the first melting peak at approximately 530°C is eliminated.

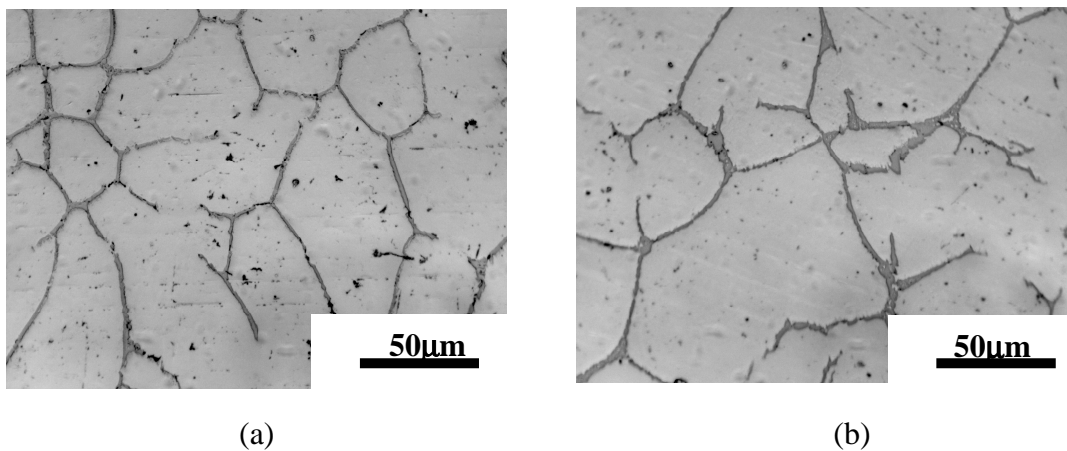


Fig 2 Light micrographs of (a) A206 in as-cast (b) A201 in as-cast

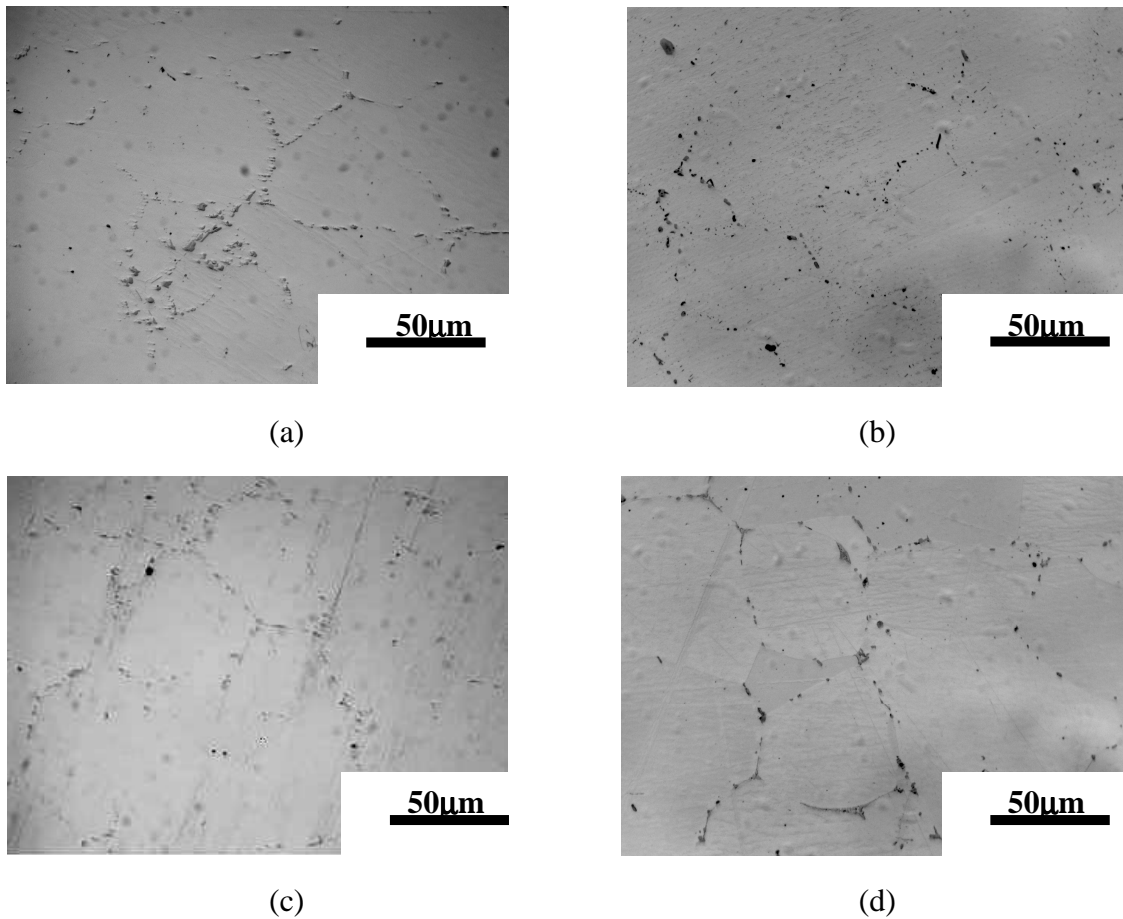


Fig 3 Light micrographs of (a) A206 (traditional T6), (b) A206 (new T6) , (c) A201 (traditional T6) and (d) A201 (new T6)

Conclusions

The new proposed heat treatment for rheo-processed alloys A206 and A201 only gives slightly higher hardness values, but the total solution treatment time is reduced compared to the traditional treatment. Furthermore, the possibility of incipient melting leading to porosity development is avoided by elimination of the first melting peak during the extended 5 hours solution treatment at 515° C. In future, even shorter times at 570° C will be investigated to optimize the heat treatment cycle further.

References

- [1] D. Liu, H.V. Atkinson, P. Kapranos, W. Jirattiticharoen, H. Jones: *Materials Science and Engineering A* , Vol. 361 (2003), p. 213.
- [2] E.P Masuku, G. Govender, L. Ivanchev, H. Möller, *Solid State Phenomena*, Vol 141-143 (2008) p. 151-156
- [3] C-H. Chang, S-L. Lee, J-C. Lin, M-S. Yeh and R-R. Jeng: *Materials Chemistry and Physics*, Vol. 91 (2005), p. 454.