Materials and Design 31 (2010) S44–S49

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Optimisation of solution treatment of cast Al–Si–Cu alloys

E. Sjölander *, S. Seifeddine

Materials and Manufacturing – Casting, Department of Mechanical Engineering, School of Engineering, Jönköping University, Box 1026, 551 11 Jönköping, Sweden

ARTICLE INFO

Article history:
Received 9 July 2009
Accepted 20 October 2009
Available online 28 October 2009

Keywords:
Cast aluminium alloys
Solution treatment
Microstructure
Diffusion
WDS
Dissolution
Homogenisation

ABSTRACT

The influence of solidification rate on the solution treatment response for an Al–8Si–3.1Cu alloy has been investigated. The alloy was cast using the gradient solidification technique to produce samples with three different solidification rates. The samples were solution treated at 495 °C for various times between 10 min and 10 h. The concentration of copper in the matrix was measured using the wavelength dispersive spectroscopy technique, WDS.

The results show that the coarseness of the microstructure clearly affects the solution treatment time needed to dissolve particles and obtain a homogenous distribution of copper in the matrix. A short solution treatment time of 10 min is enough to achieve a high and homogenous copper concentration for a material with a fine microstructure (secondary dendrite arm spacing, SDAS of 10 μm), while more than 10 h is needed for a coarse microstructure (SDAS of 50 μm). A model was developed to describe the dissolution and homogenisation process. The model shows good agreement with the experimental results.

1. Introduction

AlSiCu(Mg) alloys can be heat treated to achieve an increase in strength through precipitation hardening. A T6 heat treatment is often used for sand and gravity die cast components. The T6 heat treatment process consists of solution treatment, quenching and artificially ageing [1]. The solution treatment is carried out at a high temperature close to the eutectic temperature. The purpose of the solution treatment is to [2]:

- Dissolve particles formed during solidification containing Cu and Mg.
- Homogenise the alloying elements in the matrix.
- Spheroidise the eutectic silicon particles.

The solution treatment process needs to be optimised because too short solution treatment means that not all alloying elements added will be dissolved and made available for precipitation hardening, and too long solution treatment means usage of more energy than is necessary. Other important factors include the negative influence of residual Cu-containing particles on the elongation to fracture, as well as the coarsening of Si particles. A successful solution treatment depends on the as-cast microstructure (volume fraction, distribution, morphology and composition of phases, degree of modification of Si particles), in combination with the solution treatment parameters (temperature, time) chosen.

In the as-cast condition the Al_2Cu phase can have different morphologies; as compact block-like Al_2Cu particles, as eutectic (Al–Al_2Cu) phase, or as a mixture of both types [3,4]. The Al_2Cu phases nucleate on β-Al_5FeSi plates or on coarse eutectic Si particles during the last stage of solidification [3,5,6]. Fine individual particles of Al_2Cu can also be formed on the surface of small eutectic Si particles [3]. A high solidification rate promotes the formation of the eutectic (Al–Al_2Cu) phase [3,6], while Sr modification increases the fraction of the blocky Al_2Cu phase [3–5]. The blocky Al_2Cu phase is harder to dissolve during solution treatment than the eutectic (Al–Al_2Cu) phase [7]. The dissolution of eutectic (Al–Al_2Cu) phase takes place by fragmentation of the Al_2Cu particles into smaller segments that spheroidise and finally dissolve by radial diffusion of Cu atoms into the surrounding matrix [5,7]. The blocky Al_2Cu phase is harder to dissolve due to its lower interfacial area with the matrix and its long uniform shape [8]. The blocky Al_2Cu phase does not fragment, but dissolves by spheroidisation and diffusion, which takes longer times [7].

The dissolution and homogenisation processes are faster at high temperatures and more Cu and Mg can be dissolved in the matrix. The disadvantages of high solutionising temperatures are higher thermal stresses induced during quenching and the risk of localised melting of Cu-rich phases. The choice of solution treatment temperature depends on the Cu and Mg concentrations of the alloy. According to Samuel et al. [9] Cu-containing phases start to melt at 519 °C in an A319 alloy with low Mg concentration, while melting starts at 505 °C in an A319 alloy with 0.5 wt.% Mg, due to the formation of the Q-$Al_5Mg_8Si_6Cu_2$ phase. In a Cu-free alloy a higher temperature of 540 °C can be used [10]. Dissolution and homogenisation of AlSiCu(Mg) alloys need longer times than AlSiMg alloys,

* Corresponding author. Tel.: +46 36 101669; fax: +46 36 166560.
E-mail address: emma.sjolander@jth.hj.se (E. Sjölander).

0261-3069/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2009.10.035

due to the lower temperature allowed and the slower diffusion of Cu atoms in the matrix.

Previous studies have been made to understand the solution treatment process of Al–Si–Cu alloys [5–7]. The fraction of Al_2Cu particles [5,6], as well as the concentration of Cu in the matrix [6,7] have been measured after various solution treatment times at several temperatures. Li et al. [5] studied the influence of Sr and Fe, Han et al. [7] the influence of Mg, and Han et al. [7] and Samuel et al. [6] the influence of temperature on the dissolution and homogenisation.

In the abovementioned studies many parameters have been varied systematically, but not the coarseness of the microstructure. The present research attempts to investigate the influence of the coarseness of the microstructure on dissolution and homogenisation through measurements of the Cu concentration over secondary dendrite arms after various solution treatment times at 495 °C. Solidification rates, expressed as the secondary dendrite arm spacing, SDAS, covering processes such as high pressure die casting to sand casting with SDAS ~10 μm and ~50 μm, respectively, have been used. The aim is to optimise the solution treatment process with respect to the as-cast microstructure. A numerical model and experimental results are presented, where the focus is on the dissolution and homogenisation processes.

Table 1
Alloy composition in wt.%.

Si	Cu	Fe	Sr	Ti	Al
7.8	3.1	0.12	0.035	0.13	Bal.

2. Materials and experiments

Commercial pure aluminium, silicon and copper were melted in a resistance furnace. The alloy was Sr modified using an Al-10Sr master alloy and grain-refined using an Al–5Ti–1B master alloy. The composition is presented in Table 1. Cylindrical rods (length 18 cm, diameter 1 cm) were cast in a preheated permanent mould. The rods were remelted with the gradient furnace technique which gives samples with a low content of porosity defects thanks to the good feeding. Further information about the gradient solidification technique can be found elsewhere [11]. Different solidification rates were used to achieve different coarsenesses of the microstructure. Rods with SDAS of approximately 10, 25 and 50 μm were produced. Solution treatment was conducted at 495 °C in an electrical furnace for various times, from 10 min to 10 h. The time for heating the samples to the solution treatment temperature was 10–15 min and is excluded from the times presented. The samples were quenched in 50 °C water. The microstructures were studied using a scanning electron microscope equipped with energy dispersive spectrometer (EDS) and wavelength dispersive spectrometer (WDS). The area fraction of Al_2Cu particles, the distance between Al_2Cu particles and the length of intermetallic phases were measured in the as-cast samples. Cu concentration measure-

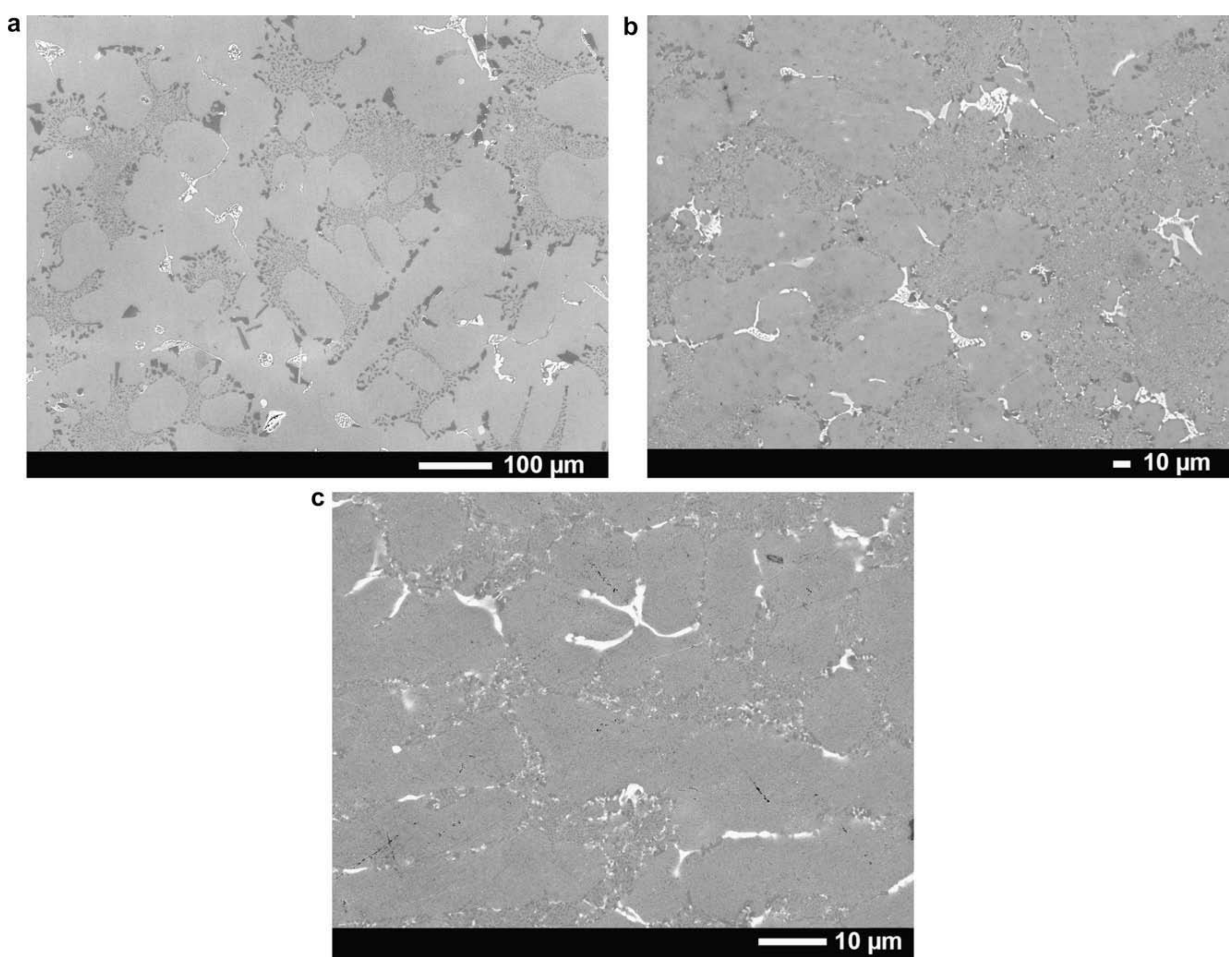

Fig. 1. As-cast microstructure for (a) SDAS 50 μm, (b) SDAS 25 μm and (c) SDAS 10 μm.