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Effect of Heat Treatment on the Formation and Distribution of Dispersoid Particles in AlMgSi

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Abstract - In this paper we studied the effect of heat treatment on the formation and distribution of dispersoid particles which were formed as a function of heat treatment in AlMgSi alloy containing transition elements in AlMgSi alloy which contained the transition elements such as Mn and Cr. The extrapolation technique of Cliff et al (1983) has been used to determine the composition of dispersoid particles.

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Effect of Heat Treatment on the Formation and Distribution of Dispersoid Particles in AlMgSi

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Abstract - In this paper we studied the effect of heat treatment on the formation and distribution of dispersoid particles which were formed as a function of heat treatment in AlMgSi alloy containing transition elements in AlMgSi alloy which contained the transition elements such as Mn and Cr. The extrapolation technique of Cliff et al (1983) has been used to determine the composition of dispersoid particles.

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I. Introduction

Aluminum alloys are widely used for fabricating high strength and light weight structures in automotive and aerospace applications Miao et al (1999). 6XXX alloys (AlMgSi based) have been studied extensively because of their high strength, good formability, weldability and corrosion resistance, Mondolfo (1979).

The addition of small amounts of the transition elements such as Zr, Mn and Cr to AlMgSi alloys showed that these elements inhibit recrystallization when the alloys are pre-heated prior to deformation. The transition elements produce fine dispersoid particles which retard the crystallisation and increase the microstructure stability at high temperature due to their low solid solubility and diffusivity in aluminium, Jones et al (1977), Belov et al (1996). In AlMgSi aluminum alloys, the nucleation of different kinds of dispersoids, i.e., Zr-, Mn-, and Cr-containing dispersoids, which play the role of recrystallization inhibition, has been investigated. Lodgaard et (2000), Cabibbo et al (2006), Lodgaard et al (2000), Jeniski et al (1996). For example the addition of Mn in the AlMgSi alloy is used to produce fine dispersoid particles during homogenization so as to retard recrystallization and grain growth during subsequent processing, Humphreys et al (1995).

The β-Mg_2Si phase and several associated metastable phases, such as β' phase, are considered to be the nucleation sites for the Mn-containing dispersoids. Matsuda et al (2000), Marioara et al (2001).

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II. Experimental Procedures

a) Materials

The AlMgSi alloy was provided by the Banbury Laboratories of Alcan International Ltd. They were prepared by direct chill casting process (DC) in a 178 mm diameter mould The chemical composition of the investigated alloys is given in table I.

b) Heat treatment

The alloy was solution treated at heating rate of 100°Ch-1 for 30 min at 550°C in order to follow the formation and growth of dispersoid, isothermally aged at different temperatures and then water quenched.

c) Thin foil preparation

Thin foils for TEM were prepared by spark machining to form discs 3 mm in diameter. The discs were subsequently grounded with fine silicon-carbide emery paper to about 200 μm thick. Final thinning was by jet polishing using a Struers Tenupol Unit with a solution of 33% HNO_3 in Analar grade methanol at -10 to -15 volts and a temperature of -20 to -30°C. When the electropolishing was completed the specimens were removed from the solution as quickly as possible and washed with Analar methanol. The specimens were dried between filter papers and then stored in a specimen grid box under vacuum.

d) Electron microscopy

Electron microscopy examination was carried out with an EM400T and EM430 analytical electron microscope. It was carried out by using the extrapolation technique of Cliff et al (1983). A liquid nitrogen-cooled decontaminator, an eccentric goniometer and double tilt holder were used in order to prevent the contamination after extended observation of an area of the thin foil.

Table I : chemical compositions of the investigated alloy (wt.%)

Si	Fe	Cu	Mn	Mg	Cr	Al
1.30	0.23	0.004	0.65	0.79	0.001	bal

III. Results and Discussion

Transmission electron micrographs of the alloy showing the development of the microstructure during ramp heating at 100°C h-1 to (a) 300°C, (b) 350°C, (c) 400 °C and (d) 550 °C are shown in Figure 1. Dispersoid

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particles were observed to precipitate after the dissolution of β'-Mg_2Si. They were observed aligned along <100> matrix directions which coincided with the traces of the habit directions of β'- Mg_2Si, figures 1a and 1d. Dispersoid particles coarsened and became heterogeneously distributed after further increase in ageing temperature, figure 1d. Dispersoid particles were observed losing their distribution along <100> matrix directions observed at their early stage of precipitation, with an increase in ageing temperature.

Figure 2 illustrates a diffraction pattern obtained from one of the dispersoid particles observed. Indexation of the diffraction pattern indicates that the stronger precipitates spots can be indexed as the $[100]_{\text{zone axis}}$ of the FCC aluminum matrix and the weaker ones as the $[100]_{\text{dispersoid}}$ of the dispersoid with a simple cubic structure and a lattice parameter of 1.26 nm, Westengen et al (1980). The relation orientation between the matrix and particle can be written as ($[100]_{\text{matrix}}$ // $[100]_{\text{dispersoid}}$).

Figure 3-a shows the microstructure of the alloy ramp heated and aged at 550°C for 10 hours and 600°C for 110 hours, respectively. A high density of particles inside the grain was observed to decrease with an increase in ageing temperature or holding time. A typical set data for alloy ramp heated and aged at 550°C for 10 hours and 600°C for 110 hours, is shown in figure 4. The main elements in the dispersoid particles are Al, Mn and Si. Some iron was being found to be incorporated within the type of particles α-$Al_{15}Mn_3Si_2$, with an increase in heating temperature or holding time, figure 4-a. We notice some substitution of Mn by Fe, figure 4-b. Their compositions are determined by the extrapolation technique as $Al_{15}Mn_{2.62}Si_{2.40}$ and $Al_{15}Mn_{2.08}Fe_{0.86}Si_{2.41}$ respectively

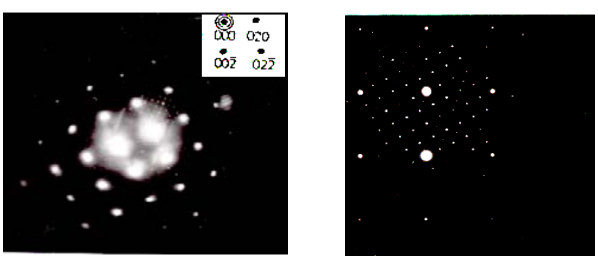
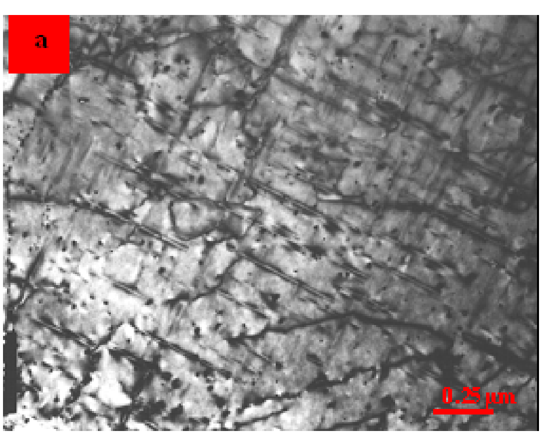


Fig.2 : Selected area diffraction pattern (SADP) from a dispersoid particles of type $Al_{15}(Fe, Mn)_3Si_2$ phase



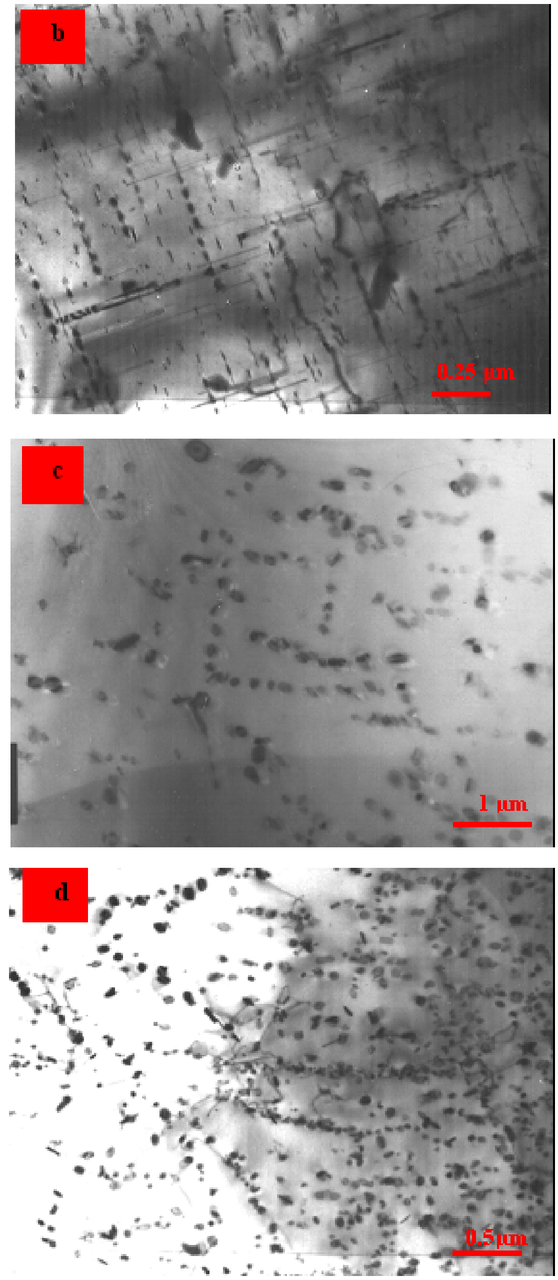
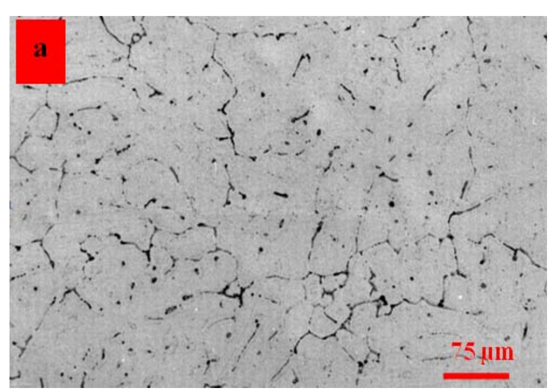


Fig.1 : Transmission electron micrographs showing the development of the microstructure during ramp heating at 100°C h-1 to (a) 300°C, (b) 350°C, (c) 400°C and (d) 550°C



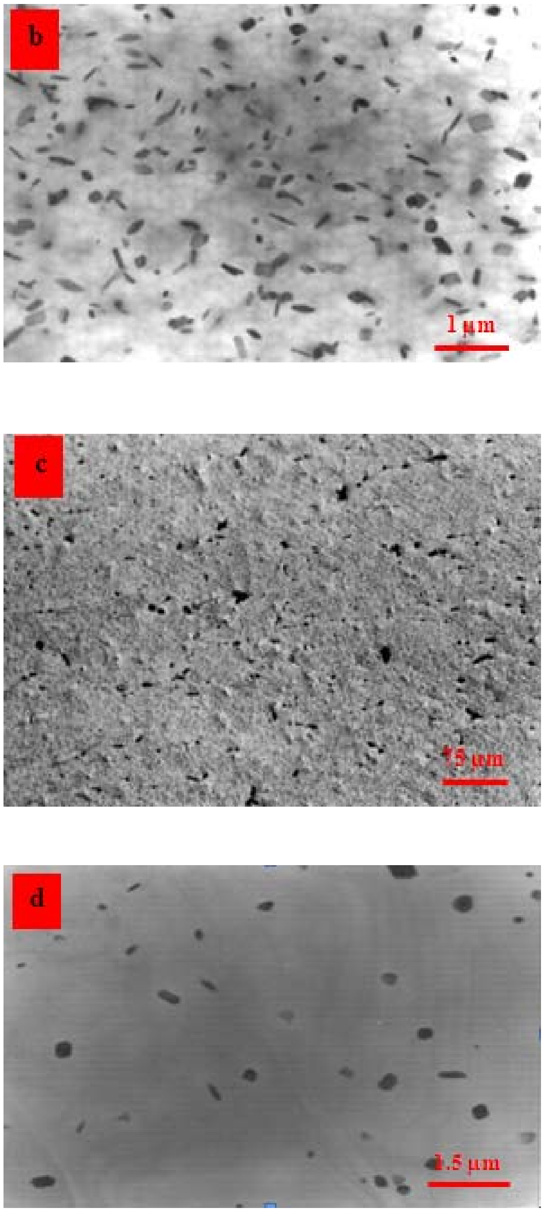


Fig.3 : Optical and transmission micrographs quenched after ramp heating and ageing for
- 10 hours at 550°C (a) and (b)
- 110 hours at 600°C (c) and (d)

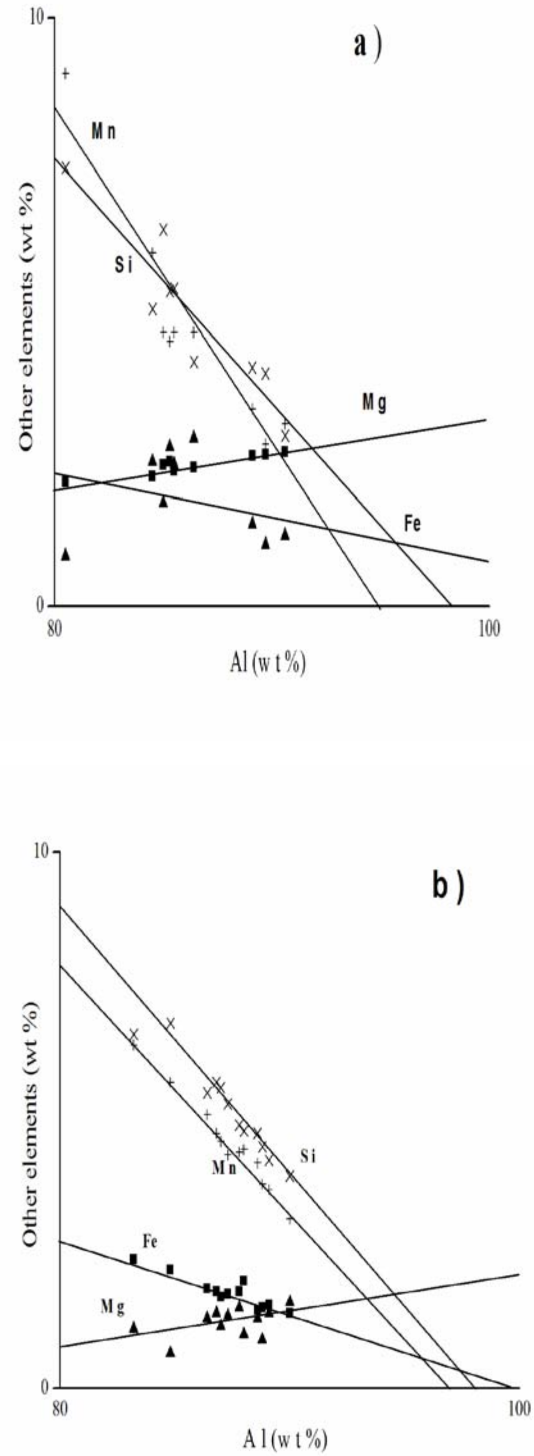


Fig.4 : Chemical composition data of the dispersoid particles in alloy II water quenched after ageing for a) 10 hours at 550°C. The main elements are Al, Mn and Si.
b) 110 hours at 600°C. The main elements are Al, Mn, Fe and Si.

IV. Conclusion

The main experimental results and conclusions can be summarized as follows:

The formation and distribution of the dispersoid particles in the alloy occurred along <100> matrix directions which coincide with the traces of the β' Mg_2Si phase. This orientation is lost and the dispersoid particles become randomly distributed after further increase in ageing temperature.

Precipitation of dispersoid particles of type $Al_{15}Mn_3Si_2$ and $Al_{15}(Mn, Fe)_3Si_2$ were observed after appropriate heat treatments. Some Fe was found to be incorporated with an increase in ageing temperature.

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