Archives of Materials Science and Engineering

Volume 30
Issue 2
April 2008
Pages 85-88

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Identification of phase composition of AlSi5Cu2Mg aluminium alloy in T6 condition

M. Wierzbińska*, G. Mrówka-Nowotnik
Department of Materials Science, Rzeszów University of Technology,
ul. W. Pola 2, 35-959 Rzeszów, Poland
* Corresponding author: E-mail address: mwierzb@prz.edu.pl

Received 26.01.2008; published in revised form 01.04.2008

ABSTRACT

Purpose: The purpose of this paper is to present the results of studies of AlSi5Cu2Mg cast alloy in T6 condition at an angle of intermetallic phases composition. It was found that the investigated alloy microstructure consists of three different, as regards shape intermatallic phases.

Design/methodology/approach: In this study, several methods were used, such as: optical light microscopy (LM) scanning electron microscopy (SEM) in combination with X-ray analysis (EDS) using polished samples, and calorimetric analysis (DSC), to identify of phase composition in AlSi5Cu2Mg alloy.

Findings: The results show that three intermetallic phases in AlSi5Cu2Mg alloy microstructure presented only one type of the phase, the α–AlFeMnSi phase. The chemical composition, morphology, shape (needle or "Chinese script") and distribution of α – AlFeMnSi phase depend on the parameters of the crystallization process. Netherless, it is possible to change this parameters during heat treatment process.

Research limitations/implications: Although the morphology and α – AlFeMnSi phase particles distribution have a significant impact on the mechanical properties (especially on the crack resistance) of the AlSi5Cu2Mg alloy, the main strengthening factor is the existence of the dispersion phase which was not subjected to examination in the research presented in this paper. Therefore, in order to complete and confirm obtained results it is recommended to perform further analysis of the alloy by using transmission electron microscopy technique (TEM).

Practical implications: From a practical point of view it is important, that there is a possibility to influence morphology, shape and distribution of intermetallic α – AlFeMnSi phase by heat treatment parameters, to obtain optimal mechanical properties of AlSi5Cu1Mg alloy according to application.

Originality/value: This paper proposes the best experimental techniques for analysis of the intermetallic phases occurrnig in the 4xxx series aluminium alloys, provide wide data about their chemical composition, morphology, shape and distribution.

Keywords: Metallic alloys; Electron microscopy; Microstructure; Intermetallic phase

MATERIALS

1. Introduction

The 4xxx-group casting alloys are characterized by low density, good castability, plasticity and mechanical properties, especially relative mechanical strength (R_m/δ), corrosion resistance and thermal conduction [1-7]. For the sake of their properties they are widely used for aircraft and helicopter constructional elements, working in elevated temperature (~250°C). The literature data and research made by the authors of this paper have revealed, that the microstructure, phase composition, and first of all relative volume and morphology of phase components have a significant impact on the strength of these alloys [8-13].

2. Material and methodology

The investigation has been carried out on the AlSi5CuMg casting alloy in the T6 condition (solution heat treatment at 515°C/5h/ water cooling and artificially aged at 225°C/5h/ air cooling. The chemical composition of the alloy is presented in Table 1.

Table 1.
Composition of AlSi5Cu1Mg alloy (% mas.)

Si	Cu	Mn	Mg	Fe	Al
5.0	2.1	0.8	0.4	0.2	rest

There was made a calorimetric analysis by the use of the DSC method and heat effects related with phase transformations during heating at the rate of 4°C/min were estimated by the scanning calorimeter SETERAM SETSYS Evolution – 1200 DSC. Moreover, there was determined the sequence as well as the temperature of transformations taking place in the investigated alloy. Consequently, the studied alloy was subjected to the 20 minutes isothermal heating in the resistant furnace at the temperatures, at which characteristic transformations had been stated by the calorimetric measurements, that is 518, 568, 580, 619 and 629°C. After holding the alloy at the temperature of the certain phase transformation, the microstructure was frozen by the quick cooling in the water with ice. The microstructure was investigated by the means of the metallographic microscope Nikon 300 (metallographic specimens were polished and etched by the reagent of the following composition: 2ml HF + 3ml HCl + 20ml HNO_3 + 175ml H_2O) and the electron scanning microscope HITACHI S-3400 (SEM). The chemical composition of intermetallic phase precipitations was stated by the EDS method, using Thermo – Noran X-ray microanalyzer connected with the HITACHI S-3400 electron scanning microscope.

3. Results and discussion

The microstructure of the AlSi5Cu2Mg alloy (in the T6 state), revealed by the optical and scanning microscopes observations, involves the following four phases of different shape and color: fine dispersic (I), spherical (II), needle – shaped (III), "Chinese script" (IV) (Figs.1a-d). The characteristics of these phases are presented in the Table 2.

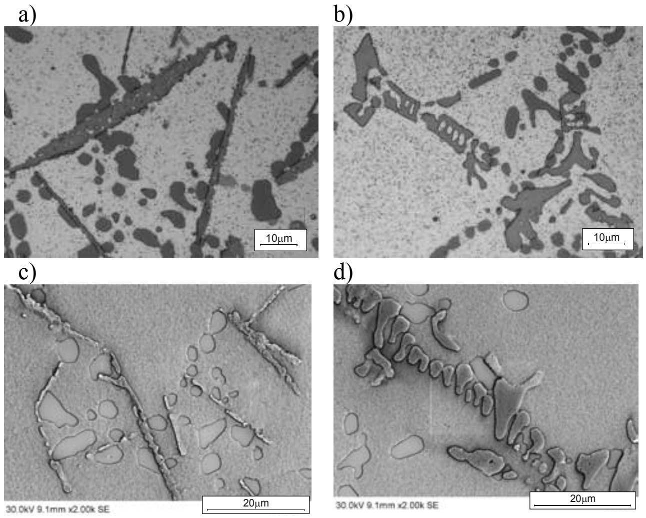

Fig. 1. The microstructure of the AlSi5Cu2Mg alloy in the T6 condition a and b) images form light microscope (LM), c and d) images from scanning electron microscope (SEM)

The EDS analysis revealed, that the spherical inclusions (II) are the eutectic silicon ones, whereas the needle – shaped (III) and "Chinese script" shaped (IV), are inclusions of the phase, consisting of Al, Si, Mn and Fe (Figs. 2-3,Table 3). Fig. 2 presents the surface distribution of the alloying elements in the area of Si and "Chinese script" shaped inclusions occurence whereas Fig. 3 shows exemplary EDS spectrum of the local analysis of "Chinese script" shaped inclusions. The results obtained by the authors of this paper and the literature data [6,11,14,15] justify the statement that it is the quaternary α–AlFeMnSi phase.

The temperature of phase transformations during the AiSi5Cu2Mg alloy heating at the rate of 4°C/min was determined by the calorimetric measurements. As there are two endotermic peaks on the DSC thermogram (Fig. 4), there was carried on the isothermial heating at the temperatures of these peaks, as to analyse these transformation more precisely.

The microscopic analysis showed, that during 20 minutes annealing at the temperature 518°C, the needle – shaped and α–AlFeMnSi inclusions (III Table 2) coagulate to the spherical inclusions, preserving the same distribution (Fig. 5a), whereas "Chinese script" shaped α–AlFeMnSi inclusions (IV Table 1) were partially melted (Fig. 5b).

Table 2.
The characteristics of the phases in the AlSi5Cu2Mg alloy

The characteristics		The phase number			
		I	II	III	IV
Color	Unetched	-	Dark gray	Fair gray	Fair gray
	Etched	-	no changes observed	Well shaped edges, the color changes into dark gray	Well shaped edges, the color changes into dark gray
Shape			Spherical	Needle -shaped	„chinesescript"
Distribution		Uniformly in the whole alloy	In the interdendritic areas of the α-Al alloy	In the interdendritic areas of the α-Al alloy and forming clusters	In the interdendritic areas of the α-Al alloy

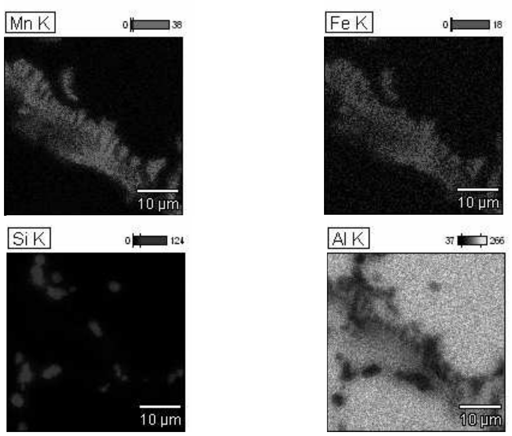

Fig. 2. The surface distribution of the alloying elements in the area of Si and "Chinese script" shaped inclusions occurrence

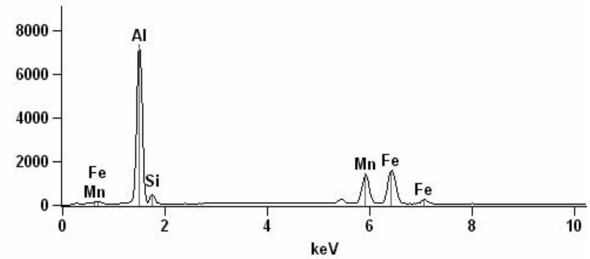

Fig. 3. The EDS spectrum of the "Chinese script" shaped inclusions local analysis

Table 3.
The chemical composition if the intermetallic inclusions in the AlSi5Cu2Mg alloy

	Chemical composition (%wt)		
	II	III	IV
	Si 85-95,0	Si: 7,3-9,8 Mn: 13,5-21,5 Fe: 4,2-6,0	Si: 7,3-9,8 Mn: 13,5-21,5 Fe: 4,2-0,0
Phase	Si	α-AlFeMnSi	α-AlFeMnSi

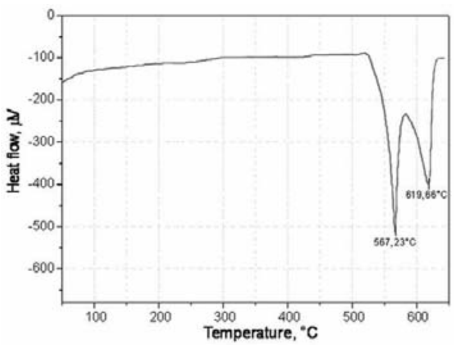

Fig. 4. DSC thermogram of the AlSi5Cu2Mg alloy in the T6 conditions to the temperature 625°C at the rate of 4°C/min

a) b)

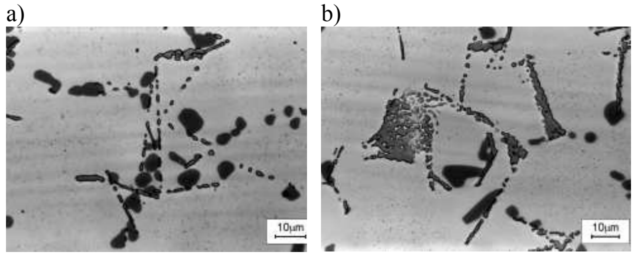

Fig. 5. The AlSi5Cu2Mg alloy microstructure after 20 minutes annealing at 518°C

The 20 minutes annealing at the temperature 568°C caused the partial dissolution of both kinds of the α–AlFeMnSi phase, that is the needle-shaped (III) and "Chinese script" (IV), in the solid solution α–Al. During cooling, the α–AlFeMnSi (III) phase precipitated as a spherical microeutectic inside the α–Al dendrites and on their boundaries (Fig. 6a), whereas the α–AlFeMnSi (IV) phase precipitated in the interdendritic areas forming the microeutectic (Fig. 6b).

a) b)

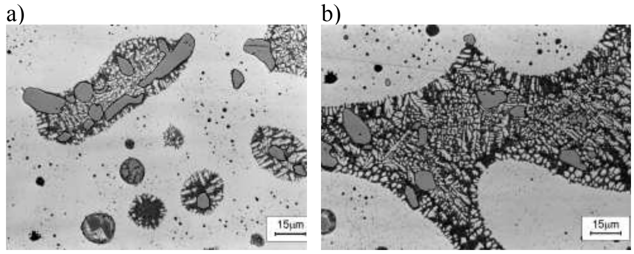

Fig. 6. The AlSi5Cu2Mg alloy microstructure after 20 minutes annealing at 568°C

The complete dissolution of the α–AlFeMnSi (III and IV) phase was observed after 20 minutes annealing at 580°C. The spherical microeutectics inside dendrites α–Al were not noticed (Fig. 7a), but α–AlFeMnSi phase occurred as super fine eutectic in the interdendritic areas (Fig. 7b). Moreover, the α–Al dendrites partial melting was observed (Fig.7).

a) b)

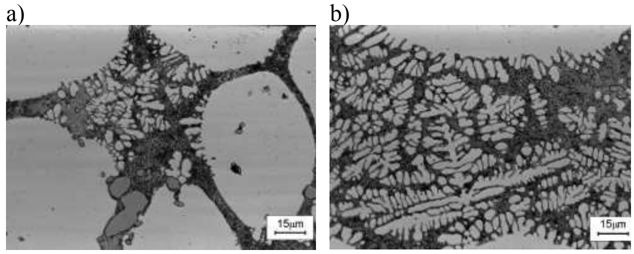

Fig. 7. The AlSi5Cu2Mg alloy microstructure after 20 minutes annealing at 580°C

The AlSi5Cu2Mg alloy annealing at 619°C for 20 minutes resulted in the complete melting of the α–AlFeMnSi (III and IV) phase particles, followed by their precipitation as the microeutectic in the innterdendritic areas of the α – Al solution.

The complete melting of the α–AlFeMnSi (III and IV) phase particles and the α–Al solution took place after 20 minutes annealing at 629°C. Subsequently, the fine, homogeneous dendritic structure of the α–Al solution was formed (Fig. 8).

a) b)

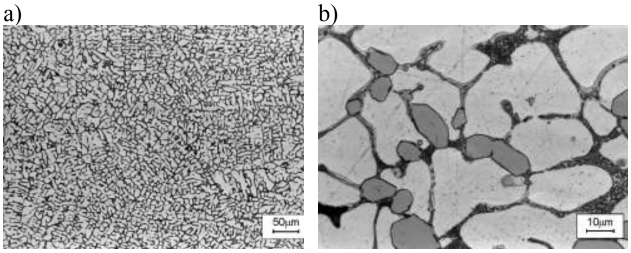

Fig. 8. The AlSi5Cu2Mg alloy microstructure after 20 minutes annealing at 629°C

The microeutectic of α–Al + α–AlFeMnSi (III and IV) and α–Al + Si came to existence in the interdendritic areas (Fig. 8b).The shape and morphology of the Si crystals remained the same in the whole range of the annealing temperatures (519–629°C), except the insignificant melting at the edges (Figs. 5-8).

4. Conclusions

The EDS method revealed that AlSi5Cu2Mg alloy microstructure involves only one type of the intermetallic phase, the α–AlFeMnSi phase. As the EDS method is considered as a preliminary one, the thorough investigation by the use of the X-ray method is carried on and the results will be published soon. Nevertheless, even the preliminary analysis revealed, that the chemical composition, morphology, shape (needle or "Chinese script") and distribution of the intermetellic phase depend on the parameters of the crystallization process and heat treatment. Therefore, it is possible to influence them by the crystallization and heat treatment parameters. Although the morphology and α–AlFeMnSi phase particles distribution have a significant impact on the mechanical properties (especially on the crack resistance) of the AlSi5Cu2Mg alloy, the main strengthening factor is the existence of the dispersion phase – (I, Table 3), which was not subjected to examination in the research presented in this paper. Therefore this phase will be carefully investigated in the next work of the authors of this article.

Acknowledgements

This work was carried out with the financial support of the Ministry of Science and Information Society Technologies under grant No. 3T08A 048 30.

References

[1] Aluminium Handbook, Fundamentals and Materials. Aluminium-Verlag Marketing and Kommunikation GmbH, Düsseldorf, 1999.

[2] G. Gustafsson, T. Thorvaldsson, G.L. Dunlop, The influence of Fe and Cr on the microstructure of cast Al-Mg-Si alloys, Metallurgical Transactions 17A (1986) 45-52.

[3] F. King, Aluminium and its alloys. John Willey and Sons, New York – Chichester – Brisbane – Toronto, 1987.

[4] L.F. Mondolfo, Aluminium Alloys, Structure and Properties, Butterworths, London – Boston, 1976.

[5] Y.L. Liu, S.B. Kang, H.W. Kim, The complex microstructures in as-cast Al-Mg-Si alloy, Materials Letters 41(1999) 267-272.

[6] J.W. Martin, Preciptation Hardening, Oxford, Pergamon Press, 1968.

[7] I.J. Polmear, Light alloys, Metallurgy of the light metals, Arnold, London – New York – Sydney – Auckland, 1995.

[8] L.A. Dobrzański, R. Maniara, M. Krupiński, J.H. Sokolowski, Microstructure and mechanical properties of AlSi9CuX alloys, Journal of Achievements in Materials and Manufacturing Engineering 24/2 (2007) 51-54.

[9] M. Kciuk, S. Tkaczyk, Structure, mechanical properties and corrosion resistance of AlMg5 and AlMg1Si1 alloys. Journal of Achievements in Materials and Manufacturing Engineering 21/1 (2007) 39-42.

[10] M. Takeda, A. Komatsu, M. Ohta, T. Shirai, T. Endo, The influence of Mn on precipitation behavior in Al-Cu, Scripta Materialia 39 (1998) 1295-1300.

[11] M. Warmuzek, G. Mrówka, J. Sieniawski, Influence of the heat treatment on the precipitation of the intermetallic phases in comercial AlMn1FeSi alloy, Journal of Materials Processing Technology 157-158 (2004) 624-632.

[12] S. Zajac, B. Bengtsson, C. Jönsson, Influence of cooling after homogenization and reheating to extrusion on extrudability and final properties of AA6063 and AA6082 alloys, Materials Science Forum 396-402 (2002) 399-404.

[13] G. Mrówka-Nowotnik, J. Sieniawski, Proceedings of the 13th Scientific International Conference „Achievements in Mechanical and Materials Engineering" AMME'2005, Gliwice – Wisła, 2005, 447-450.

[14] G. Mrówka-Nowotnik, J. Sieniawski, M. Wierzbińska, Intermetallic phase particles in 6082 aluminium alloy, Archives of Materials Science and Engineering 28/2 (2007) 69-76.

[15] G. Mrówka-Nowotnik, J. Sieniawski, M. Wierzbińska, Analysis of intermetallic particles in AlSi1MgMn aluminium alloys, Journal of Achievements in Materials and Manufacturing Engineering 20 (2007) 155-158.