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CHARACTERIZATION OF THE STRUCTURAL CHANGES OF Al18SiCuMg ALLOY DURING THE RHEOCASTING PROCESS

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Abstract: In the present paper, the microstructure evolution of semi-solid metal slurry was investigated. The material was tested by rheocasting route. In order to better estimate the materials behavior, the investigation was performed on three series of samples. The rheocasting was conducted different stirring speed of 500, 1000 and 1500rpm and 0.3 solid fraction, before casting. The microstructure was analysed using an optical and scanning electron microscope. The results show that the relationship between the equivalent diameter of Si and α - Al particles with stirring speed can be well fitted to quadratic or linear equation. The results from this study can also be used to optimize the process and study mechanism of the rheocasting process.

Keywords: semi-solid metal; Al18SiCuMg alloy; rheocasting; microstructure

INTRODUCTION

Hypereutectic Al-18Si alloy is widely used as material with favourable physical and mechanical properties (low thermal expansion coefficient, high wear resistance, excellent castability and low density.

All of these properties makes Al-18Si alloy suitable for automotive and aerospace applications [1,2]. As known that morphology of the various phases presence in alloys (eutectic silicon, primary silicon) affects on the mechanical and cavitation behavior of this alloy.

Si content above the eutectic composition causes formation of coarser Increasing primary Si particles, resulting in deterioration in mechanical properties of Al18Si alloy.

For this reason, the properties of Al18Si can be improved by different techniques such as modification treatment [3,4], rapid solidification processing [5,6] some special techniques such as thixocasting and rheocasting [7,8]. The piston alloy has been mostly used for conventional die-castings but these alloy can be cast by semi-solid metal processing - rheocasting. Semi-solid processing has its many advantages over conventional technologies.

A number of fragmentation theories have been proposed for explain of evolution phases in semisolid casting.

One of these is fragmentation agglomeration theory [7,8,9] . This theory is based on the fragmentation of dendrites into small pieces which will transform into spherical particles. The experimental results based on mentioned theory were also discussed.

In this work, the influence of two processing parameters solid fraction and stirring speed on the microstructure of the rheocast alloy was studied. In addition, the goal was also to investigate the possibilities for application of image analysis in monitoring of the changes in the samples during rheocast testing.

MATERIAL AND EXPERIMENT

The chemical composition (in wt%) of aluminum silicon alloy used in this work is given in Table 1.

Table 1. Chemical composition
in wt.% of the matrix alloy

Si	Cu	Mg	Ni	Fe	Zn	Mn	Al
18.06	0.80	0.82	0.92	0.7	0.2	0.2	bala.

The alloy was obtained by rheocasting process in the Department of Materials Science "Vinča" Institute. The experimental set–up used in this work consisted of a laboratory electric resistive 2kW furnace (with additional temperature control equipment) and a mixer.

About 450g Al18Si alloy was charged into crucible of the electro-resistance furnace. The matrix alloy was first melted at temperature of 720°C.

After that, the melt was slowly cooled in the solid–liquid temperature range. As soon as the temperature of the melt reached 690°C, the stirrer was immersed into melt. After that the melt was stirred by stirring speed from 500 to1500 rpm before poured into the mold.

The microstructure changes during mixing were recorded by the SEM (JEOL JSM-5800) and optical microscopy (OM). All of the samples were prepared for metallographic examination in the usual way.

The image analysis was used on the micrographs to determine the equivavalent diameter of microstructure features of the samples. For each stirring speed three micrographs were taken from random locations for further analysis.

In order to determine both an equivavalent diameter of Si particles and the α-Al particles equation (1) was used. In the expression, in order to calculate the equivavlent diameter, A is the diameter of the area occuppied by α - Al particles and Si. The equivalent diameter is calculated as follows:

$$D_{eq} = 2\sqrt{\frac{A}{\pi}} \tag{1}$$

The solid fraction (fs) can be estimated from the image analysis data using the Eq.(2)

$$f_s = \frac{A_p}{A_m} \times 100 \tag{2}$$

where A_p is the total area of the particles and A_m is the total area of the analyzed micrographs.

EXPERIMENTAL RESULTS

Microstructural characterization of the tested alloys was performed in order to understand the difference in distribution and size of all phases in samples.

The changes in appearance of the microstructure samples at 0.3 solid fraction and stirring speeds of 500 -1500 rpm are presented in Figure1.

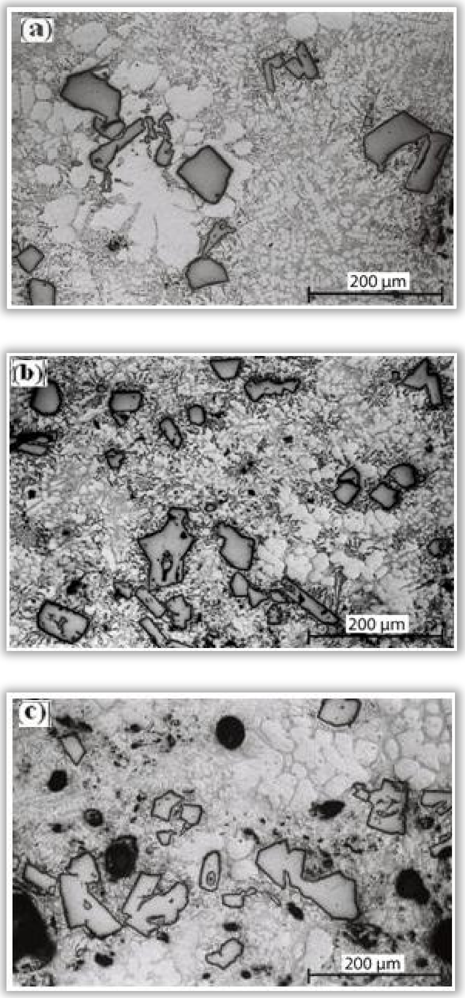

Figure1. Rheocast microstructures at 0.3 solid fraction and stirring speed of (a) 500 rpm, (b) 1000 rpm and (c) 1500 rpm

The microstructure of the rheocast samples of hypereutectic Al-Si alloy produced with application of different stirring speed during solidification consisted of primary silicon particles and eutectic matrix (eutectic silicon particles, and eutectic aluminum cells).

Primary Si phase (light gray in the images) in different shapes, from plate-like to polygonal, surrounded by eutectic, where some micro-shrinkage porosity could be detected Figure 1a-c. The image analysis showed that the smallest primary silicon particles found in all samples.

In Figure1a, there are small primary silicon particles, some of them are connected to each other. These mean that single Si particles grew and their size increased significantly. The congregation phenomenon almost appeared during mixing of melt with stirring speed of 1500rpm (see, Figure 1c)

The effects of stirring speed on the average equivalent diameter of primary Si particles of Al18Si samples are displayed in Figure 2.

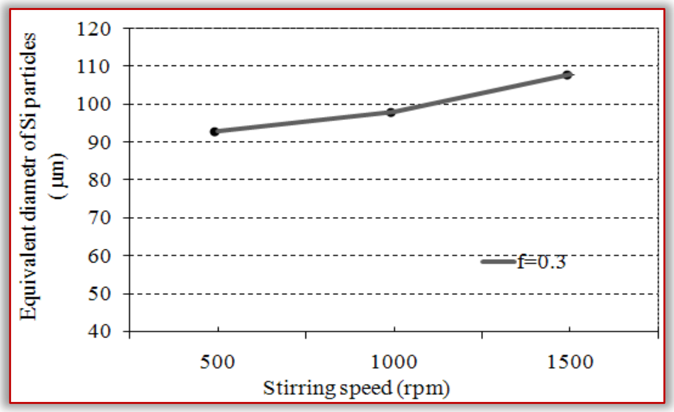

Figure 2. Equivalent diameter of the Si particles at different stirring speed

The data points in Fig 2. may be fitted to the linear equation

$$y = 84.3333 - 0.015 * x \tag{3}$$

where x is the stirring speed. Simulated curve (related to equivalent diameter of Si particles versus stirring speed) for considered conditions is presented in Figure 3.

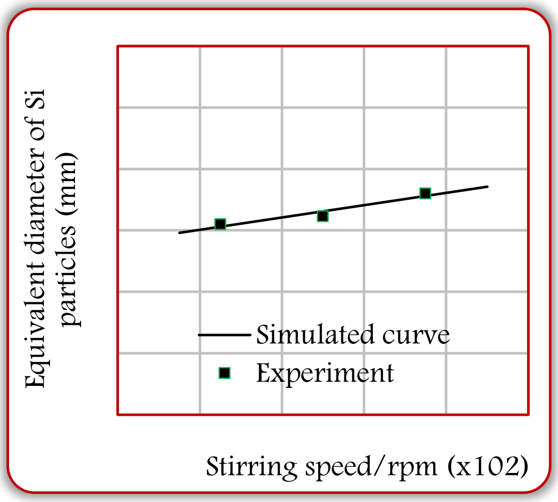

Figure 3. Equivalent diameter of Si particles versus stirring time 1-Liner equation

In Figure 4, the morphology of α-Al phase in microstructure of all samples processed at 0.3 primary solid and various stirring speeds is reported.

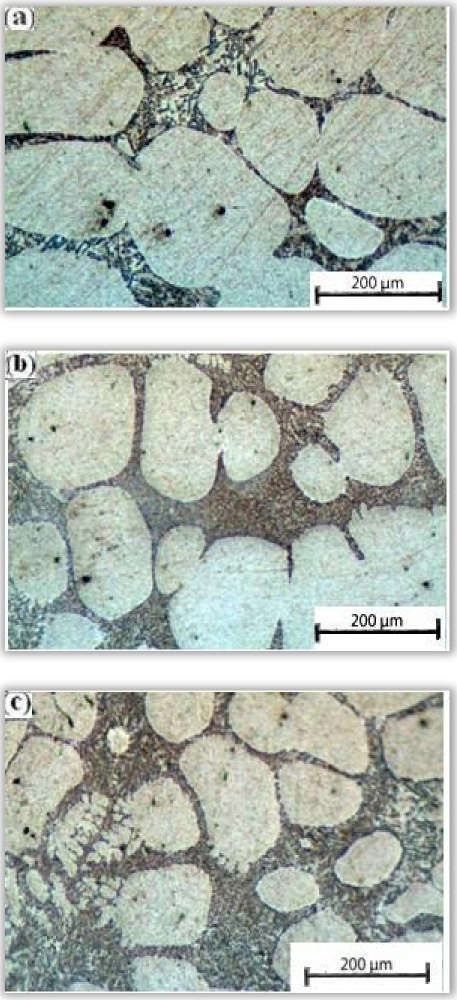

Figure 4. Rheocast microstructures of the α-Al particles

The fragmentation of the dendrite arms into smaller arms occurred during mixing. According to fragmentation - agglomeration mechanism [8,9], an increased in stirring speed produced smaller particles. The change of particles morphology from rosette—like to spherical as clearly shown in Figure4a-c.

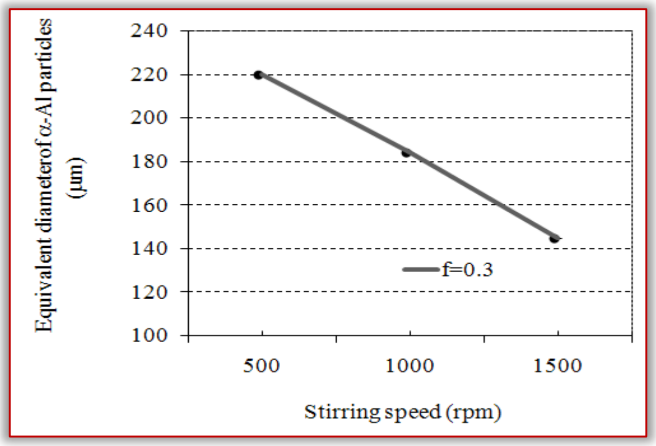

Figure 5. Equivalent diameter of the α-Al particles at different stirring speed

Figure 5 presents the variation of average diameter of the α-Al particles versus stirring speed.

The results showed that average diameter decreased slightly first and then decreased as stirring speed further increased.

Moreover, the results of experiment investigations show that the relationship between the equivalent diameter of α-A particles and the stirring speed can be approximated by a quadratic equation.

Function between equivalent diameter and stirring speed (see Figure 5) can be simulated by the following relationship.

$$y = 253 - 0.063 * x - 6 * 10^{-6} * x^{2} \qquad (4)$$

Simulated curves (related to equivaqlent diameter versus stirring speed) for considered samples either as linear or quadratic are presented in Figure 3 and Figure6. All curves are in a good correlation with experimental results in the domain from 500rpm to about 1500rpm.Those relationships can be used as a control of equivalent diameter in the rheocasting condition.

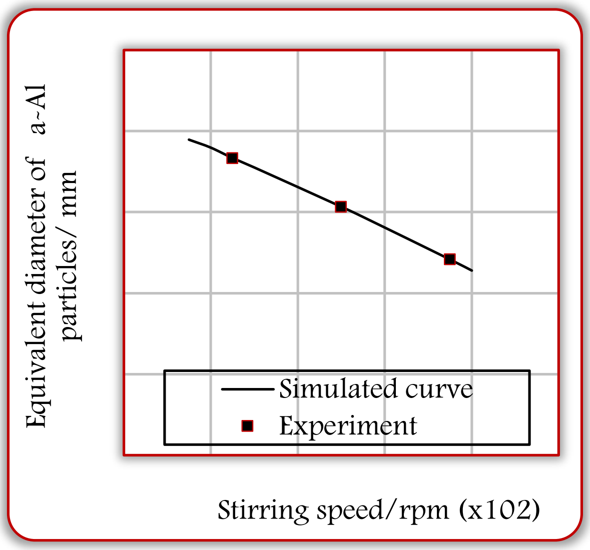

Figure 6. Equivalent diameter of the α-Al particles versus stirring time 1- Quadratic equation

CONCLUSION

In this paper the image analysis was applied to characterize the particle size and distribution of Si and α - Al particles under a given set of rheocasting conditions. The data for the particles size of Si and α - Al, can be described by different equations. In this study, based on experimental results linear and quadratic equations are suggested. Equivalent diameter of Si particles has linear trend with stirring speed while equivalent diameter of α - Al particles has quadratic trend with stirring speed. These equations can be used as a control tool for optimize process and to study the growth mechanism during the rheocasting process.

Note:

This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, organized by Faculty of Mechanical Engineering, University of Banja Luka, BOSNIA & HERZEGOVINA, co–organized by Faculty of Mechanical Engineering, University of Niš, SERBIA, Faculty of Mechanical Engeneering Podgorica, University of Montenegro, MONTENEGRO and Faculty of Engineering Hunedoara, Unversity Politehnica Timisoara, ROMANIA, in Banja Luka, BOSNIA & HERZEGOVINA, 24–25 May 2019.

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