Statistical analysis of SiC addition on α-Mg phase in the AZ91/SiC composite

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ABSTRACT: The aim of this work was to compare affect of different SiC mass fraction and different SiC particles size on the nucleation process of magnesium primary phase in AZ91/SiC composite. Authors analyze how SiC particles affect α-Mg primary phase grain size and dimensional homogeneity of grains of this phase. The statistical analysis was performed on experimental data. Normal distribution was assumed to describe distribution of mean diameters of α-Mg grains size.

Keywords: AZ91/SiC composite, statistical analysis, grain size distribution, SiC particle

1. INTRODUCTION

Composites based on magnesium alloys are among the fastest developing structural, lightweight materials for automotive, aerospace and IT industry. Because there is not any stable carbide with magnesium, the SiC particles are more and more often used as a reinforcement in mentioned composites. There are also many publications that show the usefulness SiC as, a potent inoculant for heterogeneous nucleation of magnesium primary phase in the AZ91/SiC composites [1-4].

Grain size of the primary phase is one of the most important characteristics, which decisively affects the mechanical properties of the material. The aim of this paper was to illustrate SiC particles affect on the grain size of magnesium primary phase and also on the nucleation process.

2. EXPERIMENTAL PROCEDURE

2.1. Composites casting

Composites preparation process consisted of two stages. First the AZ91 alloy was melted as a matrix for the tested composites. Then pre-heated (320°C) particles of SiC were put into the liquid AZ91 alloy and were mixed together for about 180s (240s in the case of smaller SiC particles). Different amount of ceramic particles of different size was used. The chemical composition of metal matrix alloy is shown in Tab. 1.

Tab. 1. Chemical composition of AZ91 alloy

Chemical composition, wt. %								
Al	Zn	Mn	Si	Cu	Fe	Ni	Be	Mg
8.5	0.64	0.23	0.03	0.003	<0.002	0.001	10 ppm	rest

The second stage was casting such prepared composite into standard thermoanalysis cronning sand cup with K type thermocouple. In-mould temperature was 100°C. As casted samples differs in reinforcement particles size and content what is shown in Tab. 2.

Tab. 2. Parameters of AZ91/SiC samples

Casting symbol	A1	A2	A3	B	C
SiC particles size, μm		10		40	76
SiC content, wt. %	1.0	2.0	3.5	1.0	1.0

2.2. Samples preparation and Grain diameter measurement

The samples were cut, grinded, polished and then etched for 80-95 s [4-5]. Chemical composition of etching solution is shown in Tab. 3.

Tab. 3. Chemical composition of etchant for AZ91/SiC composite [4-5]

Component	Distilled Water	Ethanol	Acetic Acid
Amount, ml	50	150	1

After this treatment it was possible to distinguish dendritic grains on the specimen surface. For this study an optical microscope Carl Zeiss AXIO Imager.A1 with cross polarized light and λ filter was used. The grains were counted and their diameters were measured.

3. RESULTS AND DISCUSSION

Analysis and verification of received data were made using the Gaussian normal distribution. Results of the statistical analysis are tabulated (Tab. 4-5). The bell curves were drawn (Fig. 1-7) which made it possible to estimate how SiC affects nucleation of α-Mg phase in straight forward.

The first stage of analysis was to compare the data for the composites with different contents of a reinforcing phase (Tab. 4). Mean diameter was taken as the characteristic dimension of grains.

Tab. 4. The mean diameter of grains (d) and the standard deviation (SD) for samples with 10 μm SiC particles size

Casting symbol	Content of SiC, wt. %	d, μm	SD, μm
A1	1.0	128.488	35.278
A2	2.0	89.3425	24.7677
A3	3.5	76.3563	16.2356

Effect of SiC particles on the α-Mg grain size depends on ceramic particles size what is illustrated in Fig. 1-3

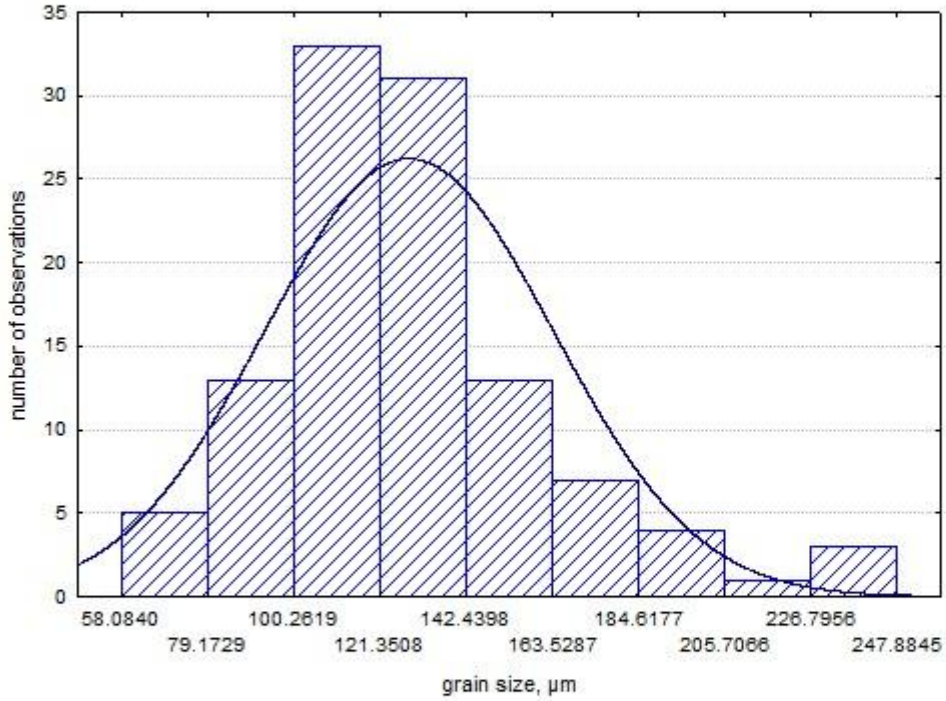

Fig. 1. Histogram of α-Mg grain size with run of a normal distribution for A1 sample

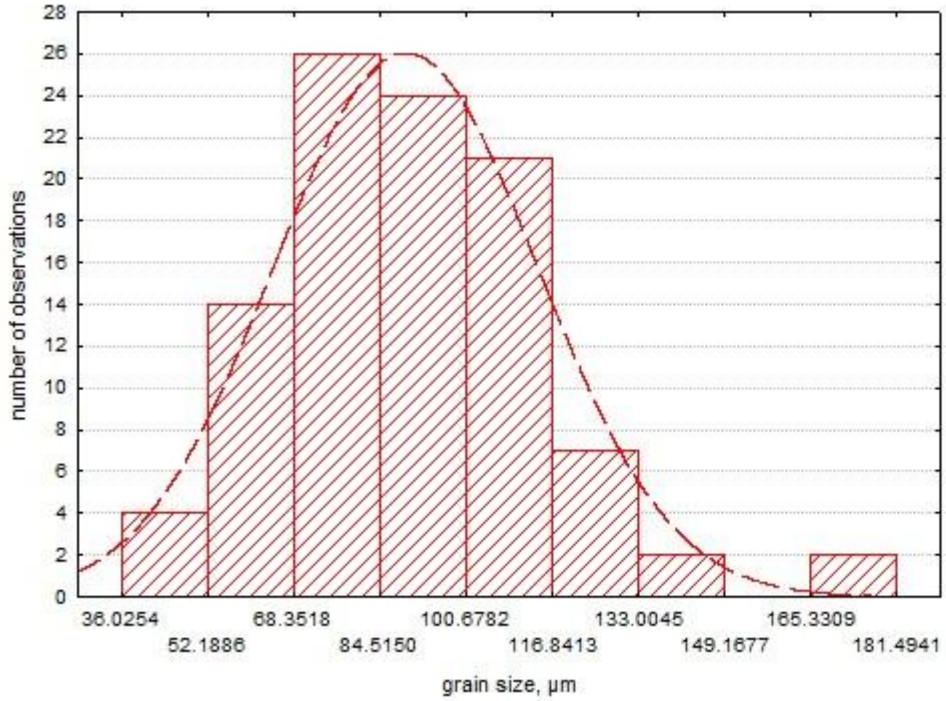

Fig. 2. Histogram of α-Mg grain size with run of a normal distribution for A2 sample

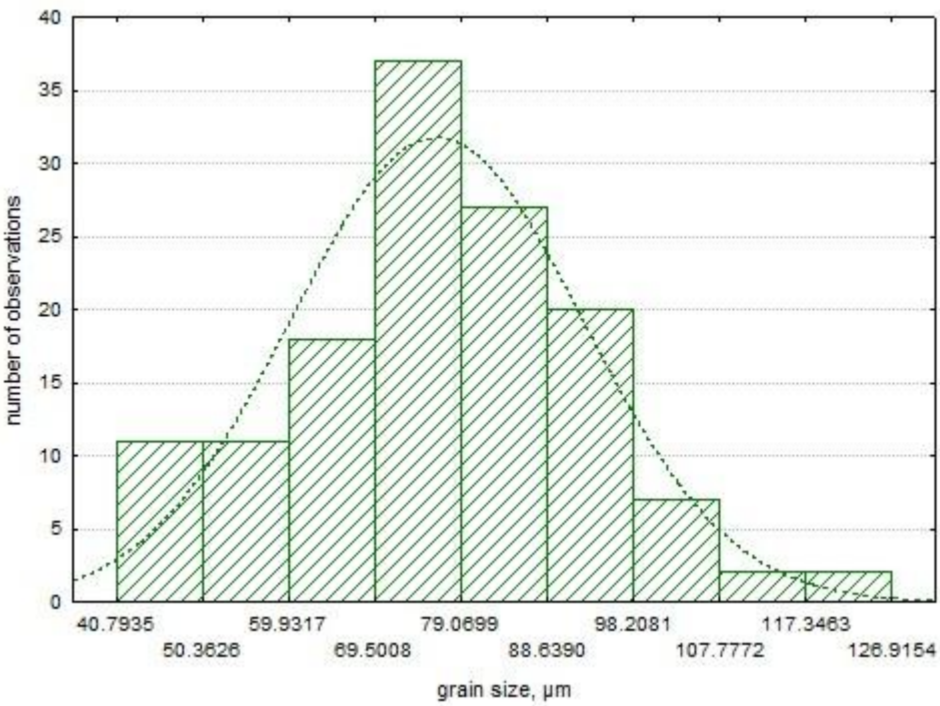

Fig. 3. Histogram of α-Mg grain size with run of a normal distribution for A3 sample

Results of this effect comparison were shown in Fig. 4.

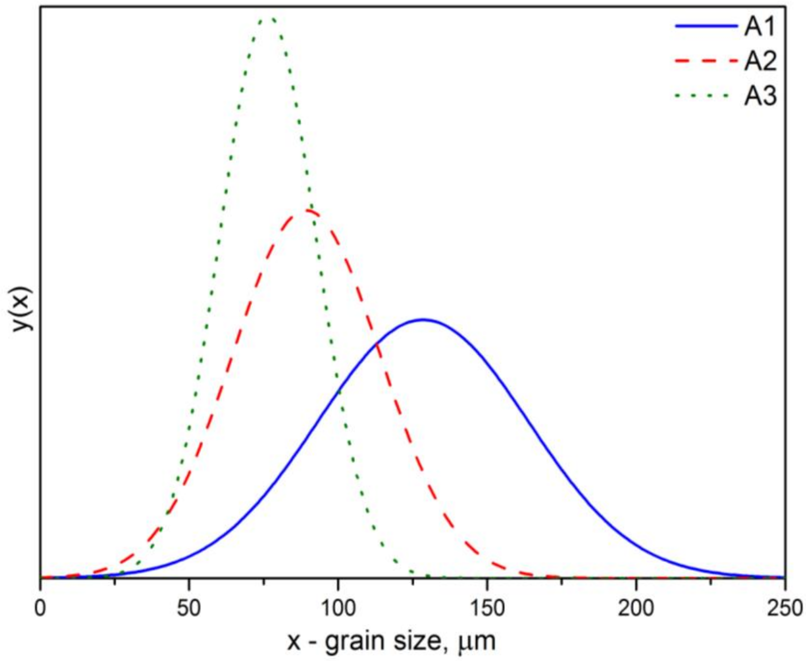

Fig. 4. Run of bell curves for 10 µm of SiC particles size and different contents of a reinforcing phase (1.0, 2.0, 3.5 wt. %)

With the increase of SiC content in the composite the maximum of the bell curve move to the left and curve is getting sharper. The shape of the curves (Fig. 4) proves that with the increasing of reinforcing phase content the average grain size of α-Mg phase decreases and the differences between the size of individual grains are getting smaller.

In the second step samples with different size of SiC particles were compared (Tab. 5).

Tab. 5. The mean diameter of grains (d) and the standard deviation (SD) for samples with 1.0 wt.% of a reinforcing phase

Casting symbol	SiC particles size, µm	d, µm	SD, µm
A1	10	128.488	35.278
B	40	210.250	61.041
C	76	377.999	106.719

Results of the analysis were shown in Fig. 1, 5-6

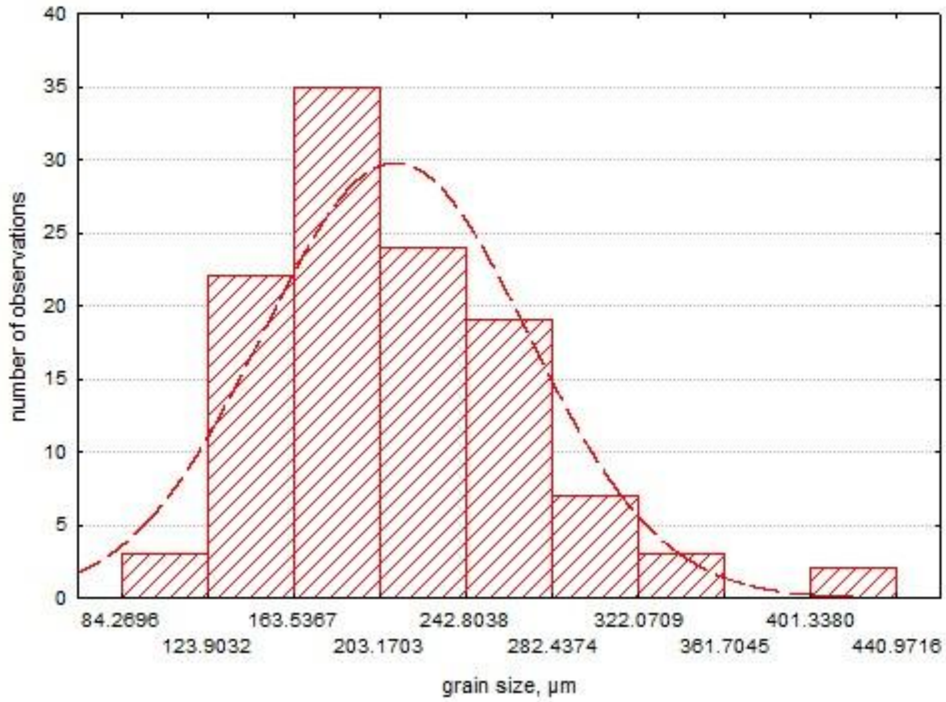

Fig. 5. Histogram of α-Mg grain size with run of a normal distribution for B sample

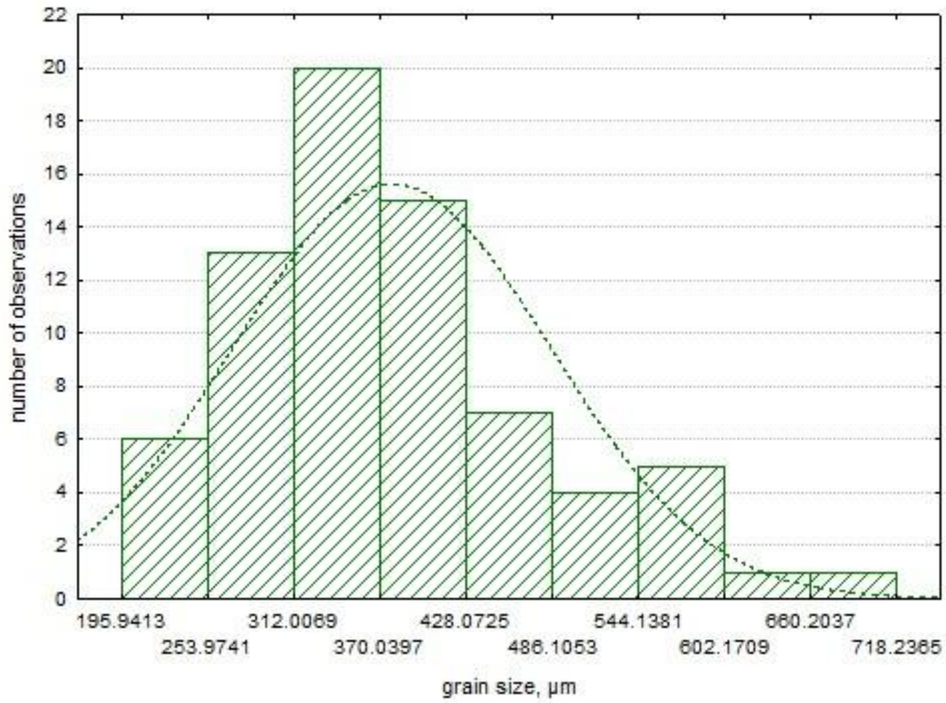

Fig. 6. Histogram of α-Mg grain size with run of a normal distribution for C sample

Effect of SiC particle size on a grain size of primary magnesium phase is illustrated in Fig. 7.

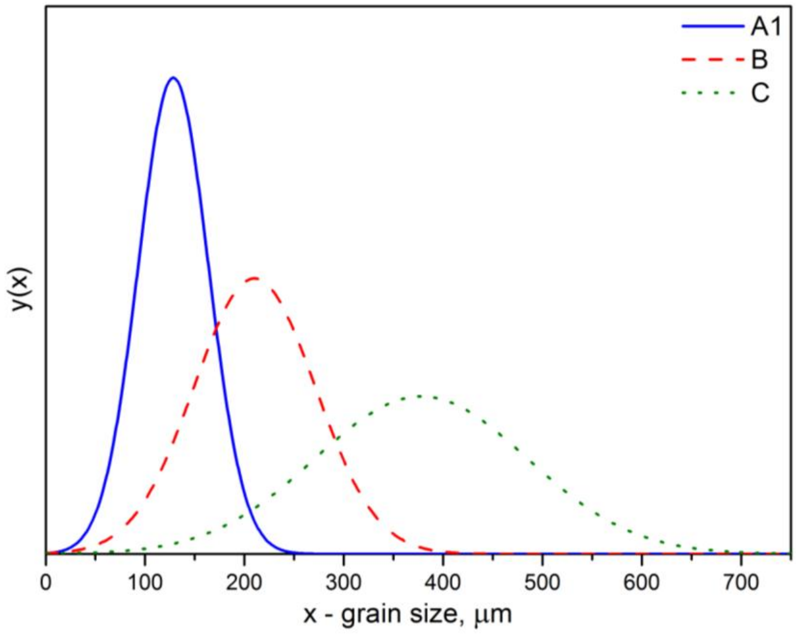

Fig. 7. Run of bell curves for 1.0 wt. % of reinforcing phase and different size of SiC particles: A1-10, B-40, C-76 µm

With the increase of SiC particles size, the maximum of the bell curve moves to the right. It means that with increasing of SiC particles size, the α-Mg average grain size increase. Also coarse structure leads to decreasing the strength properties of composite. With the increasing of particle size also the standard deviation increasing. The bell curve for 1.0 wt. % of 76 µm, as it can be seen in Fig. 7, is flattened which suggesting a great diversity of α-Mg grain size.

4. CONCLUSIONS:

- Smaller particles of SiC made it possible to achieve finer microstructure and increase in homogenization of grain size.
- The increase in content of SiC particles causes reduction of α-Mg grain size and reduction of differences between sizes of individual grains.
- Future research should focus on defining the optimal content and size of reinforcing phase for AZ91/SiC composite, taking both mechanical properties and economy of the manufacturing process into consideration.

5. ACKNOWLEDGEMENTS:

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