INFLUENCE OF SiC PARTICLES SIZE AND UNDERCOOLING ON AZ91 BASED COMPOSITE HETEROGENEOUS NUCLEATION MODEL PARAMETERS

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Introduction

The world industry is facing increasing challenges to reduce machinery impact on environment and to achieve low fuel consumption without sacrificing vehicles and other devices performance. Magnesium alloys and their composites, because of their low density, are fulfilling request for low specific weight materials that can face those challenges. Modelling of their properties allow to reduce the production costs and number of defective products. [1,2].

Grain size is one of the most important structural characteristic that determining mechanical properties. Predicting element microstructure is possible after using micro-macro model of crystallization. Experimental data after applying statistical methods let us find approximated values of the so-called "fitting parameters" in the mentioned models [1, 3-5].

Grain density model

In this article the continuous nucleation model is taking into account. It is based on log-normal model introduced by Fras et. al in [4]:

$$N_V = \lambda \exp(-b/\Delta T_{\max}),\ [m^{-3}] \qquad (1)$$

where: λ [m^{-3}], b [K] are model adjustment parameters, that should be find experimentally, ΔT_{max} denotes maximal undercooling. In this model the immediately nucleation is taken into account. Theoretical analysis of nucleation phenomena [6] shows that its character is similar to that proposed by Fras (1). Authors propose some modifications to this model, that would let to use it within simulation software, this model takes also into account SiC particles size:

$$N_V(\Delta T, d) = \lambda(d)\exp(-b(d)/\Delta T),\ [m^{-3}] \qquad (2)$$

where: d [m^{-3}] denotes average SiC particle diameter, ΔT [K] is actual undercooling.

Experimental procedure and microstructure analysis

The composite based on AZ91 alloy reinforcement with SiC particles specimens were prepared. Three castings were performed. For each casting about 6000g of AZ91 alloy was used and different content (0, 0.1, 0.5, 1, 2, 3.5 %) of SiC particles of different sizes: 10, 40, 76 μm. The samples were casted into standard thermoanalysis croning sand cup with thermocouple K type. The specimens for microsturcture analysis were taken from the region near to the thermocouple.

Grain measurement was prepared after specimens polishing and etching. The etching solution and procedure was analogous to that presented by Maltais [7]. The etched specimens were examined using a light optical microscope Carl Zeiss AXIO Imager.A1 with cross polarized light and λ filter. The images on computer display reveals arms of different dendritic grains as areas with different colours.

Results

The grain measurement results (Figure 1) were than taken into statistical analysis. The analysis was performed with *Statistica 8.0*. Results of statistical analysis lead to nucleation models for each SiC particles size:

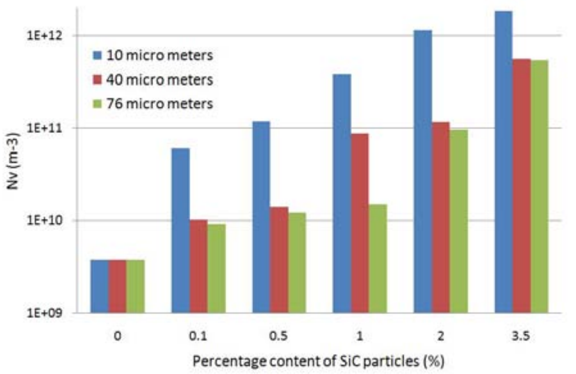

Figure 1. Mean grain density dependence on size and content of reinforcement SiC particles, logarithmic scale

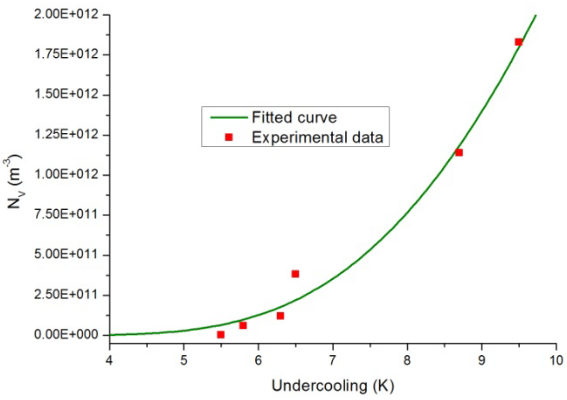

Figure 2. Grain density versus undercooling - statistical fitting graph for 10 μm SiC particles

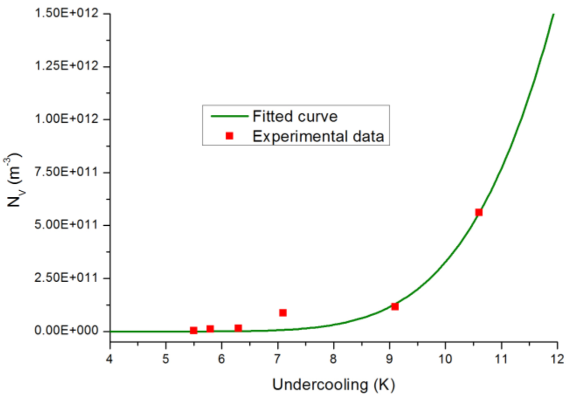

Figure 3. Grain density versus undercooling - statistical fitting graph for 40 μm SiC particles

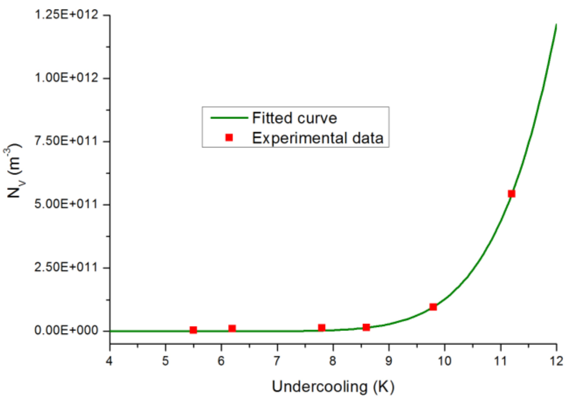

Figure 4. Grain density versus undercooling - statistical fitting graph for 76 μm SiC particles

10 μm: The formula for grain density dependence on undercooling is (Figure 2):

$$N_V(\Delta T) = 1.7 \cdot 10^{14} \exp\left(-\frac{43.21}{\Delta T}\right), \ R^2=0.993 \quad (3)$$

40 μm: The formula for grain density dependence on undercooling is (Figure 3):

$$N_V(\Delta T) = 3.9 \cdot 10^{15} \exp\left(-\frac{93.83}{\Delta T}\right), \ R^2=0.984 \quad (4)$$

76 μm: The formula for grain density dependence on undercooling is (Figure 4):

$$N_V(\Delta T) = 9.4 \cdot 10^{16} \exp\left(-\frac{135.09}{\Delta T}\right), \ R^2=0.999 \quad (5)$$

General nucleation model including the particles size can be describe with following equation:

$$N_V(\Delta T, d) = 9.1 \cdot 10^{14} \exp\left(3.1 \cdot 10^4 - \frac{32.6 + 1.4 \cdot 10^6 d}{\Delta T}\right), R^2 = 0.932 \ (6).$$

Conclusions

AZ91/SiC nucleation parameters can be described with mathematical formulas. Unknown adjustment parameters can be found using experimental data and statistical algorithms.

The mean volumetric grain density function shows how grain density dependend on composite actual under-cooling and particles mean diameter. This knowledge can be very useful for technologists.

After setting the particles size and derivation, the mean volumetric grain density function gives information about nucleation rate. This is the key parameter for AZ91/SiC composite micro – macro model of crystallization.

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