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MODELING THE EFFECT OF SiC PARTICLE SIZE ON CRYSTALLIZATION OF MAGNESIUM METAL MATRIX COMPOSITE; AZ91/SiC

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ABSTRACT

Goal of this work was to prepare micro-macro AZ91/SiC composite crystallization model that depends on SiC particles size. The model base on temperature and chemical elements concentration, it also takes into account primary α-Mg phase nucleation rate. The behavior of temperature and chemical composition field can be calculated using Fourier – Kirchhoff equation and modified second Fick's law. The nucleation rate for this material was calculated from log-normal Fras equation. Fitting parameters were found using experimental data.

Different composites castings with different size and content of SiC particles were performed. The grain density and undercooling in each case were measured. Obtained data was used as test values during statistical fitting of the unknown model adjustment parameters.

The simulation software on the base of prepared model was written. Experiment for the same composite as set as test data of the simulation was performed. The simulation results were compared with an experimental data. Analysis shows good fitting of presented model results with the real values.

CASTING

Three castings (A, B, C as detailed below, Table 1) were performed for different composites. There was used AZ91 (Table 2) and SiC (different weight percentage) particles of different sizes. Standard thermoanalysis croning sand cups with K-type thermocouple where used.

From these castings thrmoanalysis data and specimens were prepared. Specimens were taken from the region near to thermocouple.

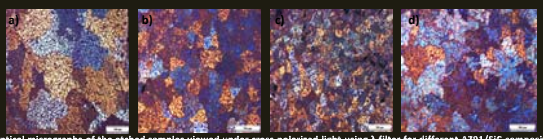
Table 1. Casting conditions

Casting symbol	A	B	C
Particles size, [μm]	10	40	76
AZ91 mass, [g]	5960	6250	5800
Ambient temperature, [°C]	22	22	24
Furnace temperature, [°C]	750	750	750
Particles temperature, [°C]	320	320	320
In-mould temperature, [°C]	100	100	100
Stirring time, [s]	240	180	180

Table 2. Chemical composition of AZ91 alloy

Al	Zn	Mn	Fe	Be	Si	Cu	Ni
8.5	0.64	0.23	<0.002	10 ppm	0.03	0.003	0.001

MICROSTRUCTURE

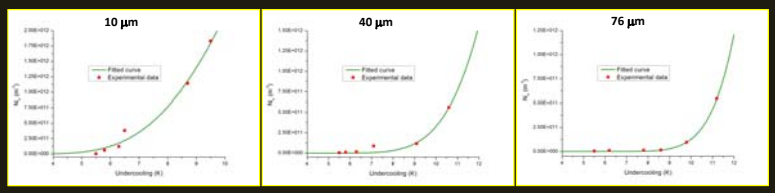


Optical micrographs of the etched samples viewed under cross polarized light using λ filter for different AZ91/SiC composites (Examples of the etching effect):
a) 0% of SiC; b) 2% of SiC, particles mean diameter 40 μm; c) 0.1% of SiC, 10 μm; d) 3.5% of SiC, 76 μm

Etching solution:
50 ml Distilled Water,
150 ml Ethanol,
1 ml Acetic Acid.

Etching procedure:
Specimens were immersed in the etching solution and gently agitated (by slowly moving around) for 80 – 95 s. They were then rinsed in ethyl alcohol (small amount). Then they were put dried from about 50 cm with a blast of room-temperature air. During drying stage the specimens were gently moved so that the remaining liquid still wet their entire surface.

GRAIN DENSITY FUNCTION FITTING PARAMETERS ANALYSIS



N_V on undercooling dependence for 10 μm particles:

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

N_V on undercooling dependence for 40 μm particles:

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

N_V on undercooling dependence for 76 μm particles:

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

BASIS OF MATHEMATICAL MODEL AND NUMERICAL ANALYSIS

$$\frac{\partial T}{\partial \tau} = \frac{1}{c_p \rho} div(-\lambda grad T) + \frac{q}{c_p \rho}$$

Heat transfer:
Fourier – Kirchhoff equation

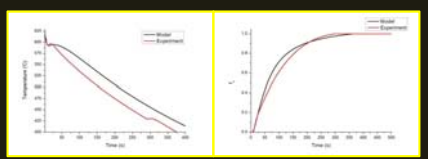
$$N_V(T, d_{SiC}) = \lambda(d_{SiC}) \exp\left(-\frac{b(d_{SiC})}{(T_N - T)}\right)$$

Nucleation rate: Modified log-normal Fras nucleation model

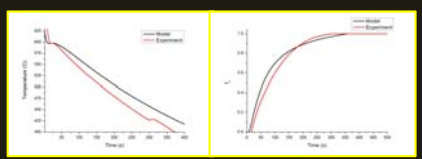
$$(C_L - C_S)\frac{dR}{d\tau} = D_{Al}^{\alpha} \frac{dC}{dr}\Big|_{R^-} - D_{Al}^{L} \frac{dC}{dr}\Big|_{R^+}$$

Mass transfer:
Modified Fick's law

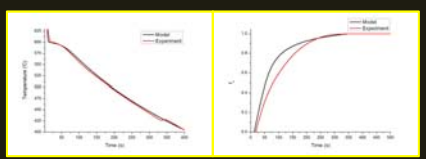
NUMERICAL SIMULATION RESULTS VALIDATION



Cooling curve and solid state fraction function obtained from numerical computations and from experiment; 0% of SiC particles



Cooling curve and solid state fraction function obtained from numerical computations and from experiment; 0.1% of SiC particles



Cooling curve and solid state fraction function obtained from numerical computations and from experiment; 2% of SiC particles

CONCLUSIONS

The experimental data can be used to prepare micro-macro composite crystallization model. The model fits good with an experiment results.

Numerical simulation gives a lot useful data that can give new view on the nucleation and solid fraction growth phenomenon.
This knowledge can be used to optimization those processes.

ACKNOWLEDGEMENTS

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