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Solidification analysis of AMMCs with ceramic particles

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ABSTRACT

Purpose: In the research work the result of the reinforcement displacement and solidification analysis for aluminium cast composites with ceramic particles have been presented. The results of research on the solidification process are compared for the applied aluminium matrix alloy (AlSi12CuNiMg2), for composites containing glass carbon particles (Cg) and heterophase reinforcement (mixture of silicon carbide (SiC) + glass carbon particles (Cg)).

Design/methodology/approach: The course of the solidification process was recorded by means of a system which enabled continuous control and measurement of the metal temperature during solidification of the composite suspension. The system was equipped with a thermoelectric cup core QC4080, with an incorporated thermocouple of K type (NiCr-Ni). The application of disposable thermoelectric cup cores of identical heat abstraction coefficient and known, standardized dimensions, ensured identical conditions and rate of heat abstraction during the cooling of the castings. The structure analysis for composite casts was performed by means of optical and scanning microscopy.

Findings: The research has shown, that ceramic particles have an influence on temperature change and the time of aluminium matrix alloy solidification. The changes results, first of all, from disparate physical properties of the glassy carbon particles and silicon carbide particles used (thermal conductivity, mass density), compared to aluminium matrix alloy.

Practical implications: Ceramic particles decrease shrinkage of the casting and change the nature of its crystallization.

Originality/value: Employment of glass carbon particles for matrix reinforcement allows to get flotation in the aluminium alloy. Employment of heterophase reinforcement (glass carbon and silicon carbide particles) allows to get segregation of particles: flotation as well as sedimentation in the matrix, which results in the occurrence of a layered structure.

Keywords: Composites; Casting; Solidification analysis; Silicon carbide; Glass carbon particles

MATERIALS

1. Introduction

Particulate aluminium metal matrix composites (PAMMC) offer better specific stiffness, hardness, and especially wear resistance than for the basic aluminium alloys. They have been applied to the transportation, aerospace, military, electronics, sport and entertainment industry too, [1]. Economical reasons has contributed to a wide application of the liquid methods moreover of mechanical stirring of components for PAMMC producing, [1,2]. On the structure and final properties of the cast composites has a direct influence the casting properties, such as fluidity and viscosity [3,4]. The parameters that influence on the composites castability are the casting temperature, the amount, morphology, size and properties of the particulate reinforcement and the interface reaction between the particulate reinforcement and the matrix [3-18].

Additionally the crystallization rate and the casting's solidification time that determine the structure obtained and particles' distribution in the matrix [3].

The study aimed at determining and comparing the cooling curves obtained for the matrix (AlSi12CuNiMg2) and for composites containing one type of reinforcing particles (amorphous glass carbon) and heterophase composites, where two types of ceramic particles, a mixture of silicon carbide and glassy carbon particles were used as the reinforcement.

2. Aim and researches methodology

The study aim was determining and comparing the structure and cooling curves obtained after solidification process. Researches was performed for the aluminium matrix alloy (AlSi12CuNiMg2), for composites containing only one type of reinforcing particles: silicon carbide (SiC 50μm) or glass carbon particles (Cg 100μm) and for heterophase composites, where two types of ceramic particles reinforcement, a mixture of SiC with amorphous glass carbon particles - Cg were used.

In single-phase composites, of 10% fraction and a 50μm particle size for SiC and 100μm particle size for Cg was used for reinforcement. For heterophase of material a 10% fraction of each powder was applied. Composite suspensions fabricated by the casting method with stirring suspension, described in detail in paper [16], were then subjected to degassing and homogenization under lowered pressure. A testing stand designed and built at the Institute of Composites and Powder Metallurgy, Silesian University of Technology was used to this end. As former research has shown [16,17], the application of vacuum technology with simultaneous homogenization of a composite suspension changes the properties of the liquid suspension, including first of all its castability, and allows removal of gassy regions formed during composite production.

The course of the solidification process was recorded by means of a system which enabled continuous control and measurement of the metal temperature during solidification of the composite suspension [3, 18].

The structure of composite ingots was examined on an MeF-2 Reichert light microscope and a Hitachi S-4200 electron microscope, applying properly made preparations.

3. Solidification curves and structure of materials and their analysis

The solidification curves for the matrix and composites obtained after numerical processing, are presented in Fig. 1. The differences in the course of composite materials' curves are particularly well visible for the heterophase composite, where apart from silicon carbide particles and amorphous glassy carbon particles were used. The differences refer to both time and temperature of the crystallization beginning. The matrix material solidified during 115s in the temperature range of 572-559ºC. The composite containing a mixture of silicon carbide and glassy carbon particles solidified in the temperature range of 558-556ºC,

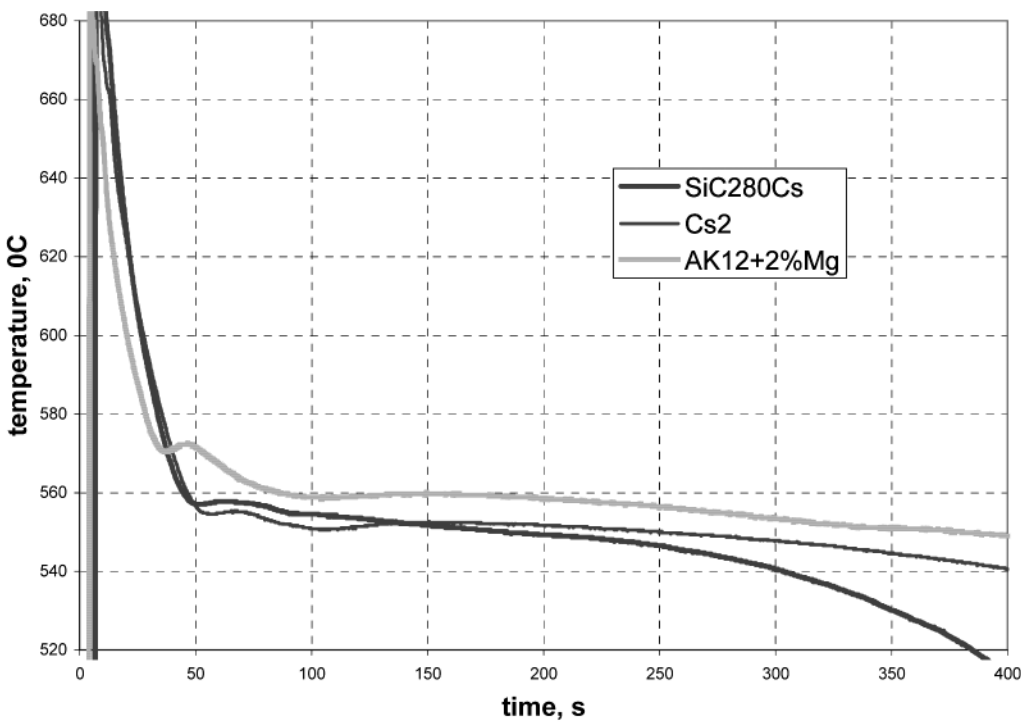
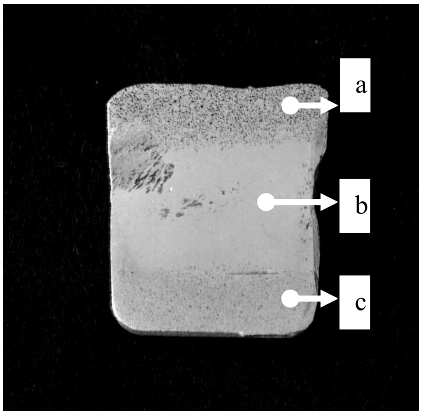


Fig. 1. Solidification curves of aluminium matrix alloy and composites

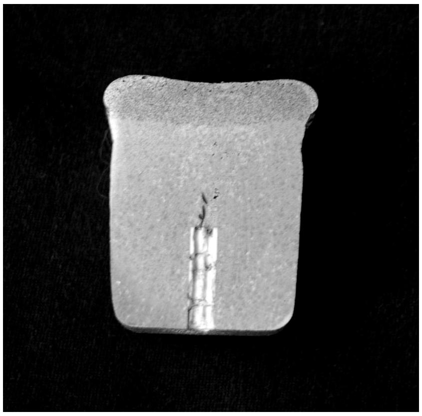
in the time of 20 sec. The temperature of crystallization beginning of the composite containing only glassy carbon particles was 554ºC. These composite solidifying for 135s in the temperature range of 554-552ºC. As results from the data obtained affirmed that ceramic particles, like: glassy carbon and silicon carbide particles, considerably decrease the temperature at the beginning of matrix alloy crystallization. It keep a record of definitely different solidification times of composites. This testifies to a significant influence of kind, size and morphology of particles on the solidification process. The differences in composites' solidification time and temperature may be determined by different properties of the particles applied, especially its of various thermal conductivity coefficients [15].

On the cross-section of a composite ingot, different distribution of particles, connected with reinforcement segregation, were observed (Figs. 2 and 3). On the cross-section of a heterophase composite ingot, sedimentation and flotation were found, which in consequence enabled the formation of a layered structure (Fig. 2). On the basis of quantitative and qualitative analyses affirmed, that lower part of the ingot contained more of SiC particles and less glassy carbon particles (Fig. 4c). The upper part of the ingot included more of SiC particles and less glassy carbon particles (Fig. 4a). Such distribution of particles in the aluminium matrix alloy can be result of differences in particles' size and density ($\rho_{SiC} = 3{,}15$ g/cm^3, $\rho_{Cg} = 1{,}4$ g/cm^3). The matrix-composite interface is flat and parallel to its base. The microstructure of the matrix-reinforcement interface area and of the region from the upper and lower part of the ingot, with visible reinforcement, is shown in Fig. 4.



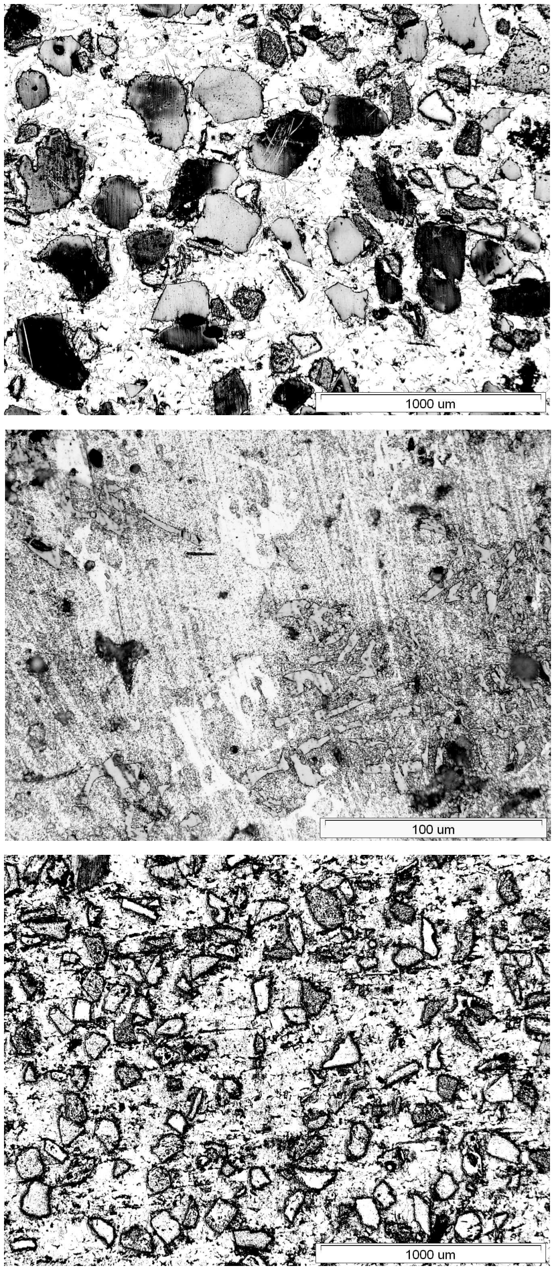
a.

Fig. 2. Macrostructure of AlSi12CuNiMg2/10% SiC 50µm + 10 % Cg. composites with layered particles displacement visible in the matrix.



b.

Fig. 3. Macrostructure of AlSi12CuNiMg2 + 20% Cg composites with particles displacement in upper part of the cast visible in the matrix.



a. b. c.

Fig. 4. Microstructure of AlSi12CuNiMg2/10% SiC 50µm + 10 % Cg composite, OM; a) upper part of the composite ingot, b) middle part of the composite ingot, c) lower part of the composite ingot.

4. Conclusions

As the research has shown that ceramic particles in the form of silicon carbide and amorphous glassy carbon have an influence on both temperature change and the time of aluminium castings solidification. They also have influence on the structure and particles displacement of the casts. The changes results, first of all, from disparate physical properties of the particles used (thermal conductivity, mass density) [18,19]. The presented research results represent a preliminary study and they require completing. The on-going research refers to the influence of the type, size and volume fraction of reinforcing particles on solidification and crystallization of heterophase composites.

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References

[1] J.W. Kaczmar, K. Pietrzak, W. Włosiński, The production and aplication of metal matrix composites material, Journal of Materials Processing Technology 106 (2000) 58-67.
[2] J. Hashim, L. Looney, M.S.J. Hashim, Metal matrix composites: production by the stir casting method, Journal of Materials Processing Technology 92-93 (1999) 1-7.
[3] A. Dolata-Grosz, M. Dyzia, J. Śleziona, Solidification and structure of heterophase composite, Journal of Achievements in Materials and Manufacturing Engineering 20/1-2 (2007) 103-106.
[4] C.B. Lin, Y.W. Hung, W.C. Liu, S.W. Kang, Machining and fluidity of 356Al/SiC(p) composites, Journal of Materials Processing Technology 110 (2001) 152-159.
[5] D.J. Lloyd, Solidification microstructure of particulate reinforced aluminum / SiC composites, Composite Science Technology 35 (1989) 159-179.
[6] M.K. Surappa, Microstructure evolution during solidification of DRMMCs: state of art, Journal of Materials Processing Technology 63 (1997) 325-333.
[7] B. Dutta, M.K. Surappa, Microstructure evolution during multidirectional solidification of Al-Cu-SiC composites, Composites 29/A (1998) 565-573.
[8] J. Braszczyński, A. Zyska, Analysis of the influence of ceramic particles on the solidification process of metal metal matrix composites, Materials Science and Engineering 278/A (2000) 195-203.
[9] S. Nagarajan, B. Dutta, M.K. Surappa, The effect of SiC particles on the size and morphology of eutectic silicon in cast A356/SiCp composites, Composite Science and Technology 59 (1999) 897-902.
[10] J.W. Garvin, H.S. Udaykumar, Particle-solidification front dynamics using a fully coupled approach, part II: comparison of drag expressions, Journal of Crystal Growth 252 (2003) 467-479.
[11] M. Cholewa, Simulation of solidification process for composite micro-region with incomplete wetting of reinforcing particle, Journal of Materials Processing Technology 164-165 (2005) 1181-1184.
[12] M. Dyzia, A. Dolata-Grosz, J. Śleziona, J. Wieczorek, Structure of AK12+2%Mg composites reinforced by ceramics particles received in different heat transfer conditions, Archives of Foundry 1/1 (2001) 88-93 (in Polish).
[13] E. Fraś, Particles intereaction with solidification front, Archives of Foundry 6/18 (2006) 339-344 (in Polish).
[14] J. Braszczyński, M. Cisowska, Test of solidification estimate of AlMg/SiC+Cgr hybrid composites, Solidification of Metals and Alloys 40 (1999) 55-64 (in Polish).
[15] J. Myalski, J. Śleziona, M. Dyzia, Characteristic of solidification aluminium alloys matrix composites, Archives of Foundry 3/10 (2003) 61-66 (in Polish).
[16] A. Dolata-Grosz, J. Wieczorek, J. Śleziona, M.Dyzia, Possibilities of the use of vacuous technologies for composite mixture quality rising , Archives of Foundry 6/18 (2006) 285-290 (in Polish).
[17] J. Śleziona, J. Wieczorek, A. Dolata-Grosz, The influence of the degassing process on the structure of aluminium composites containing glass carbon and silicon carbide particles, Materials Science 3 (2006) 665-667 (in Polish).
[18] A. Dolata-Grosz, M. Dyzia, J. Śleziona, J. Myalski, The analysis of solidification process of heterophase composite, Archives of Foundry 6/22 (2006) 145-151 (in Polish).
[19] J. Myalski, Aluminium metal matrix composites material reinforced glass carbon particles, Materials Science 6 (2002) 745-748 (in Polish).