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Structure and technological properties of AlSi12 –(SiC_p + Cg_p) composites

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Abstract

In the article the structure and technological properties of aluminium cast composites with ceramic particles have been presented. Evaluation of casting properties of selected composite materials was made based on spiral tests. The differences occurring in solidification curves for materials reinforcing by silicon carbide, amorphous glass carbon particles and mixture of silicon carbide and glassy carbon particles were compared. On the basis of macro- and microstructural investigations of composite ingots after solidification at the same conditions the distribution of ceramic particles were estimated. The hardness on the cross section of formed composite ingots were presented in the graphic form.

Keywords: Composites, Casting properties, Solidification curves, Structure, Hardness

1. Introduction

Research on the applications and prospects for composite materials development in various science and technology domains still have undertaken in many Polish and foreign research and scientific centres [1-3]. The today's interest in AMCs results from a number of their creative properties, which can be designed through a proper selection of reinforcing components and technological parameters. Engineering interest in aluminum metal matrix composites (AMCs) has increased, owing to their high specific strength and high specific Young's modulus, as well as better physical and tribological properties compared to monolithic materials [4].

A great portion of the research effort is focused on producing the AMCs by casting methods, which is likely to be more economical and relatively simple in comparison with the competing solid state processing. Cast metal matrix composites reinforced with particles, whiskers or short fibres fabricated by the stir casting technique have the cost advantage over the composites fabricated by the other processing techniques [2,4].

The presence of ceramic particles in the solidifying metal matrix changes the thermodynamical and the physical conditions of the process as compared with the solidification process of metal alloys without any additions [6-8]. The crystallization and solidification processes of casts composites are very important in determining the microstructural features such as: phase composition, grain size and structure, first of all distribution of second phase particles. All of these factors influence the final material properties. [6-13].

The present paper tries to analyze the influence of chosen ceramic particles on the solidification, castability and macrostructures of aluminium metal matrix composites.

2. Materials and research methodology

The aluminium-silicon alloy (AlSi12CuMgNi), with a 2% Mg addition, was used as the matrix material for the fabrication of the composites. One group of composites testing includes a material reinforced with silicon carbide particles with a 20% weight fraction and grain size of 50 µm. The other group is represented by composites reinforced with a 20% of amorphous glassy carbon particles (100µm). In researches applied also heterophase composites consisted of two types of ceramic particles as mixture of 50µm silicon carbide and glassy carbon of 100µm size. For that group of materials, a 20% fraction of each powder was applied. The composite suspensions fabricated by the traditional stirring method, in the laboratory of the Silesian University of Technology at the Institute of Composites and Powder Metallurgy in Katowice. The process of preparing and production of composite suspensions with degassing and homogenization under lowered pressure were described in detail in papers [9-11].

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 [12,13]. Also influence of ceramic particles on casting properties of composites was evaluated basted castability test. Test duct was formed as spiral at self hardening phosphate mould.

The macro and microstructural characteristics of the composites solidified in the same moulds are evaluated using optical microscope NICON EPIPHOT 200.

3. Results and discussion

3.1. Spiral test and structural characteristic

The selected macrostructures and microstructures of the composite ingots obtaining by the solidification processes and view of spiral test of composite's suspension are shown in Figures 1-4. It is observed that the particle distribution in the aluminium matrix shaped during solidification process depends on the kind and properties of reinforcing particles.

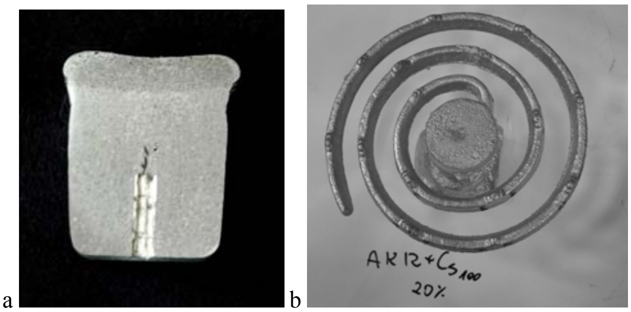


Fig. 1. The AlSi12CuMgNi -Cg_p composite material: a) macrostructure of composite ingot with particles displacement visible in the matrix, b) spiral test of composite suspension.

Glassy carbon particles about large sized (100µm) but low density (ρ_{Cg} =1,4 g/cm^3) show a tendency up to flotation. They are pushing out by the matrix and the next locating themselves in upper part of the cast (Fig. 1). The lower part of these composite ingot does not contain particles and the matrix-composite interface is flat and parallel to its base.

On the cross-section of the AlSi12CuMgNi/SiC_p+Cg_p heterophase composite ingot, sedimentation and segregation were found, which in consequence, enabled the formation of a layered structure (Fig. 2a). 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. 3b). The upper part of the ingot included more of SiC particles and less glassy carbon particles (Fig. 3a). Such distribution of particles in the aluminium matrix alloy can be result of differences in particles' properties, particularly them thermal conductivity, size and density (ρ_{SiC} =3,15 g/cm^3, ρ_{Cg} =1,4 g/cm^3) [12,13]. The matrix-composite interface was flat and parallel to its base similarly like at AlSi12CuMgNi -Cg_p composite.

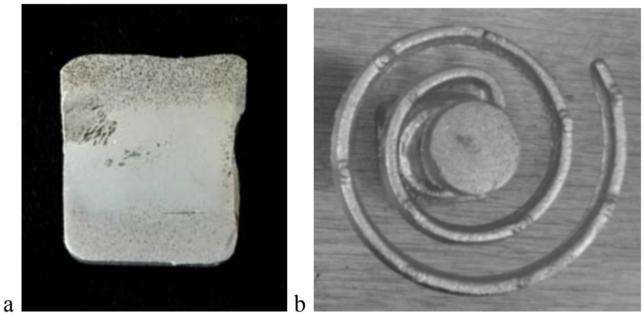


Fig. 2. The AlSi12CuMgNi -SiC_p + Cg_p composite material a) macrostructure of composite ingot with particles displacement visible in the matrix, b) spiral test of composite suspension.

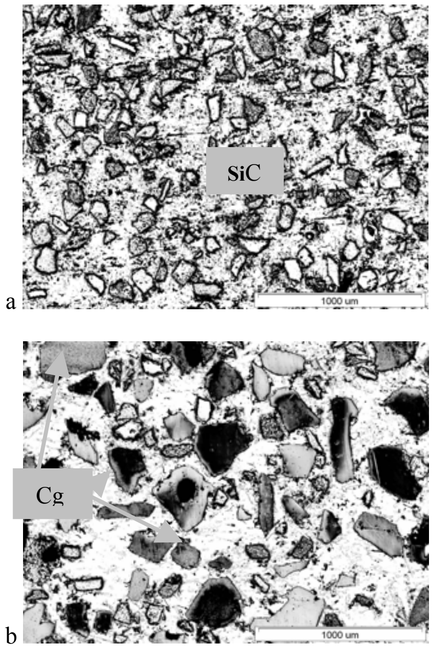


Fig. 3. Microstructure of AlSi12CuMgNi/SiC_p+Cg heterophase ingot, OM: a) lower part of the composite ingot, b) upper part of the composite ingot.

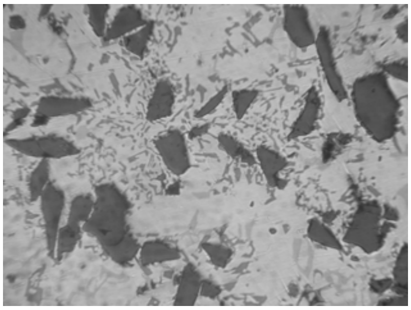


Fig. 4. Microstructure of AlSi12CuMgNi/SiC_p composite ingot.

The selected results of spiral test were presented at Figures 1,2. It was fund, that composites with silicon carbide particles (SiC) filled 10 spiral sections. The composite including glassy carbon particles has a better fluidity and filled 15 spiral sections (Fig. 1b). Otherwise heterophase composites containing particles of silicon carbide and also the particles of glassy carbon filled 11 spiral sections. Probably that was results of influence of silicon carbide particles which accelerated solidification process of composites material and braking the stream of liquid phase in the channel of spiral mould.

3. 2. Cooling curve analysis

The temperature range and time of aluminium matrix and composites crystallization described on the basis of solidification curves obtained after numerical analysis (Figs. 5 and 6). They affirmed that the matrix material solidified during 120s in the temperature range of 572-559^{0}C (Fig. 5). The temperature of crystallization beginning of the composite containing glassy carbon particles was 553^{0}C, with the composite solidifying for 189s in the temperature range of 553-551^{0}C (Fig. 6a). The composite containing a mixture of SiC + glassy carbon particles solidified in the temperature range of 558-551^{0}C, in the time of 160s (Fig. 6b).

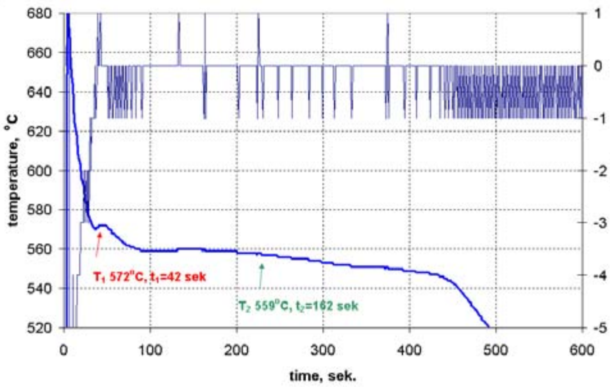


Fig. 5. Solidification curve of the AlSi12CuMgNi aluminium matrix alloy.

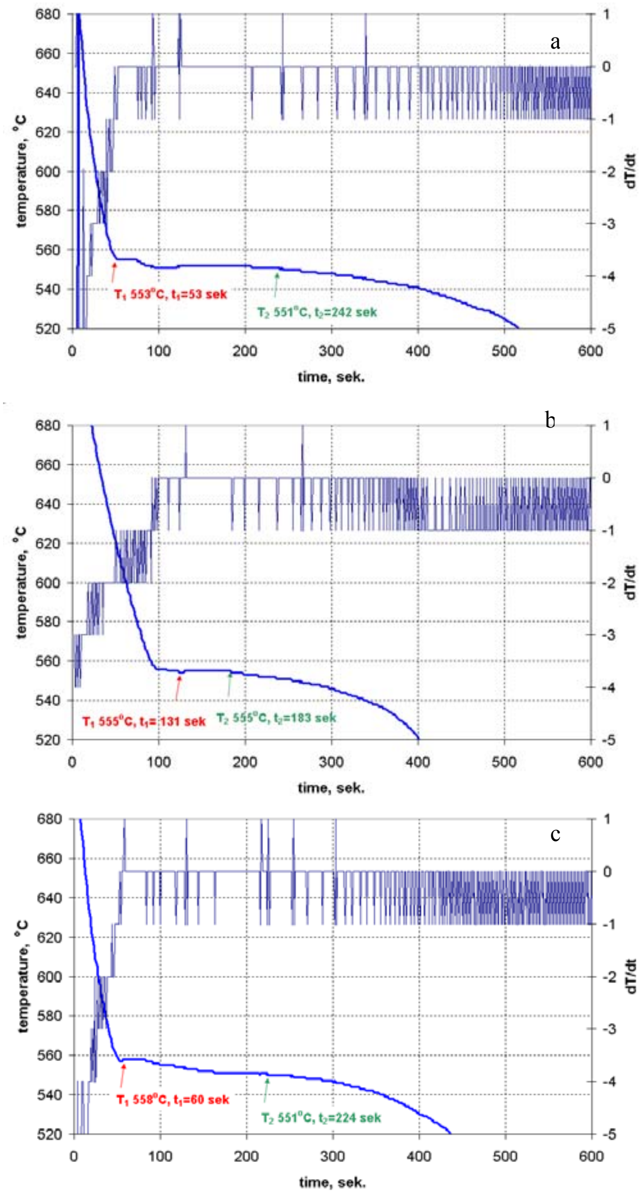
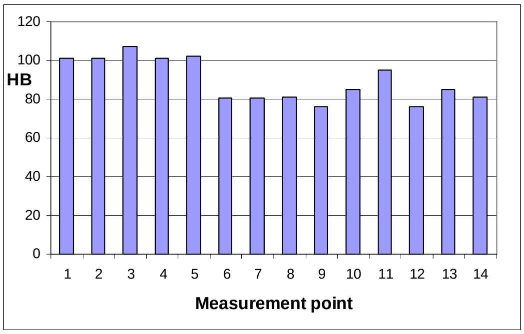


Fig. 6. Solidification curves of the: a) composite with glassy carbon (Cg) particles, b) composite with silicon carbide ceramic particles (SiC), b) AlSi12CuMgNi/SiC_p+Cg heterophase composite.

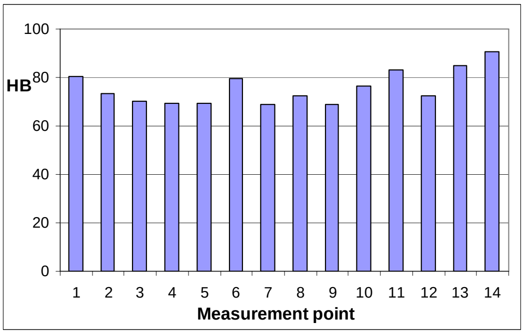
Short time of crystallization (t=52s) was registered for the AlSi12CuMgNi+SiC_p composite in comparison with the other studied materials (Fig. 6c).

3.3. Brinell hardness

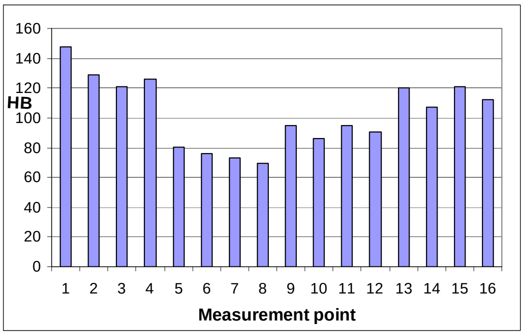
The research of the hardness for composite ingots after solidification process was carried out on the Brinell testing machine. A steel ball was used about the 5mm diameter and load equal 250N. Examinations were made in a dozen or so measuring points on the cross section of composite ingots visible on the Figures 1,2. Gotten results were presented in the form of columnar diagrams in Figure 7. It was found that the higher hardness on the cross sections of ingots has heterophase composite (Fig. 7c) especially in the upper part of the cast. Differences in the measured values of hardness may indicate an specific distribution of reinforcing phases in individual casts and with presence of the second phase (glassy carbon particles) in aluminium matrix.



a



b



c

Fig. 7. Brinell' hardness on the cross section of composite ingots: a) AlSi12CuMgNi -Cg_p, b) AlSi12CuMgNi -SiC_p, c) AlSi12CuMgNi/SiC_p+Cg_p.

4. Conclusions

1. Introduction of ceramic particles (SiC and Cg) into the AlSi12CuMgNi matrix alloy decrease the temperature at the beginning of matrix alloy crystallization.
2. Silicon carbide particles fundamentally decrease the time at the beginning of matrix and composite crystallization.
3. All ceramic reinforcement used for examinations have influence on the casting properties of composites suspension, reducing they castability, most of all silicon carbide.

Acknowledgements

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References

[1] Degischer H. P., Prader P., San Marchi Ch., Assessment of Metal Matrix Composites for Innovations - intermediate report of a European Thematic Network. Composites Part A. 32 (2001), p. 1161-1166.
[2] Taha M.A. Practicalization of cast metal matrix composites (MMCCs), Materials and Design 22 (2001) p. 431-441.
[3] Dolata-Grosz A., Dyzia M., Śleziona J., Wieczorek J.: Composites applaied for pistons, Archies of Foundry Engineering, Vol. 7/1 (1/2), 2007, p. 37-40.
[4] Kaczmar J.W., Pietrzak K., Włosinński W., The production and application of metal matrix composite materials, Journal of Materials Processing Technology 106 (2000), p. 58-67.
[5] Hashim J., Looney L., Hashmi M.S.J, Metal matrix composites: production by the stir casting method, Journal of Materials Processing Technology 92-93 (1999), p.1-7.
[6] E. Fraś: Particles intereaction with solidification front, Archives of Foundry , Vol. 6, No 18 (1/2), 2006, p. 339-344.
[7] 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, Vol. 1, No 1 (2/2), 2001.
[8] M. Łągiewka, Z. Konopka, A. Zyska: Krzepnięcie kompozytów hybrydowych AlMg10/SiC+C_{gr}, Archives of Foundry, Vol. 6, No 18 (1/2), 2006, p. 325-330.
[9] Śleziona J., Dyzia M., Wieczorek J. Casting properties of AlSi-SiC composite suspensions, Archies of Foundry, Vol. 6, No 22, 2006, p. 540-545.
[10] Dolata-Grosz A., Wieczorek J., Śleziona J., Dyzia M.: Possibilities of the use of vacuous technologies for composite mixture quality rising, Archives of Foundry, Year 2006, Vol. 6, No 18 (1/2), p. 285-290.
[11] Śleziona J., Wieczorek J., Dolata-Grosz A.: The influence of the degassing process on the structure of aluminium composites containing glass carbon and silicon carbide particles, Material Science No 3 (151), 2006, p. 665-667.
[12] A. Dolata-Grosz, M. Dyzia, J. Śleziona, J. Myalski: Analiza procesu krzepnięcia kompozytu heterofazowego, Archives of Foundry, Vol. 6, No 22, 2006, p. 145-151.
[13] A. Dolata-Grosz, M. Dyzia, J. Śleziona: Solidification and structure of heterophase composite, Journal of Achievements in Materials and Manufacturing Engineering, Vol. 20, Issues 1-2, 2007, p.103-106.