C. KOLMASIAK, M. ŁĄGIEWKA

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FOUNDRY PROPERTIES OF COMPOSITES ON AlMg10 ALLOY MATRIX WITH SiC AND Cgr PARTICLES

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Preliminary Note – Prethodno priopćenje

This paper presents the results of tests concerning the castability of metal composites based on an aluminium alloy matrix. The castability of composite suspensions containing carbide particles and suspensions containing graphite particles was tested using two tests: spiral and rod tests. It was found that as the volume fraction of particles increases, the castability of composites decreases, with graphite particles having a greater effect on the decrease in castability than silicon carbide particles. The paper also presents the results of research concerning the effect of ceramic particles on the shrinkage of solidifying and cooling composites. The shrinkage test results show a positive effect of ceramic particles introduced into the aluminium alloy, manifested by a decrease in the shrinkage value.

Keywords: foundry properties, AlMg10, silicon carbide, graphite, castability.

INTRODUCTION

The concept of castability is understood as the ability of liquid metal to flow through the channels of a casting mould [1, 2]. Some authors define castability as the ability to fill the mould cavity allowing to obtain a casting with an accurately reproduced shape. An alloy's actability is mainly influenced by factors such as the chemical composition and the alloy's viscosity related to the chemical composition, the surface tension, the mould material, and basically the ability to absorb heat by the mould material, the shape and type of the gating system and the casting conditions [1-5]. Casting shrinkage is defined as the reduction in the dimensions of the casting during cooling and solidification of the alloy in relation to the dimensions of the model [6]. Factors influencing the amount of casting shrinkage include the chemical composition of the casting alloy, superheating temperature, pouring temperature, free shrinkage inhibitors, mould material, and mould cavity design. Research of casting properties of metals and alloys are performed very frequently and the results are presented in many publications, whereas the results of research concerning casting properties of materials such as metal composite materials are rare. In the process of flowing and filling the mould cavity with a composite suspension, its rheological properties are of particular importance. The introduction of solid particles into the liquid increases the viscosity of the suspension, which directly affects the castability [7-8]. Gravity casting of such materials, especially those containing larger amounts of reinforcing particles, causes many problems. The material flowing and filling the cavity of the casting mould is a liquid-solid mixture from the very beginning of filling the casting mould. Additionally, as time passes, the amount of solid phase changes due to the solidification of the casting alloy. Research on shrinkage of metallic composite materials is also interesting because the matrix material and the reinforcement often have different physical and chemical properties (e.g. coefficient of thermal expansion). This implies a change in the properties of the new material, which often has different properties from those of the composite components: the metal matrix and the reinforcement in the form of e.g. ceramic particles. Additionally, each reinforcement material has different physicochemical properties, so it becomes reasonable to determine the influence of the type of reinforcement on the casting properties of composites.

RESEARCH METHODOLOGY RESEARCH MATERIAL

This paper presents the results of research on the castability and shrinkage of composites containing graphite particles and composites containing silicon carbide particles. The composites were made on an AlMg10 alloy matrix. Cgr particles and SiC particles with an average grain size of 40 mm were used as reinforcement of the composites. The volume fraction of particles for both composites was 5, 10, 15 %. The composites were produced by introducing ceramic particles into an intensively stirred metal bath. Suspensions prepared in this way were gravitationally cast at 973 K into previously prepared casting moulds. The actability measurements were carried out using two tests: a spiral test and a rod test. The spiral test was performed in a classic clay-based moulding mass. The measure of act-

C. Kolmasiak (cezary.kolmasiak@pcz.pl),
M. Łągiewka, Czestochowa University of Technology, Faculty of Production Engineering and Materials Technology, Czestochowa, Poland

Tabela 1 **Results of the castability researched materials (spiral test and bar test).**

Castability /mm		
Researched materials	Spiral test	Bar test
AlMg10	1 480	450
AlMg10+5 %C_{gr}	1 200	350
AlMg10+10 %C_{gr}	730	210
AlMg10+15 %C_{gr}	520	155
AlMg10+5 %SiC	1 030	300
AlMg10+10 %SiC	510	195
AlMg10+15 %SiC	405	135

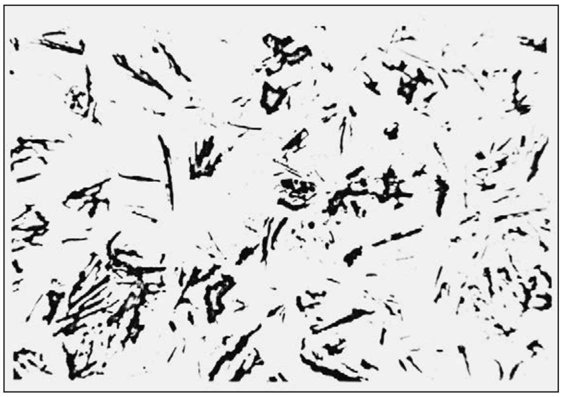

Figure 1 Microstructure of AlMg10 +10 % Cgr composite, mag. 200 x.

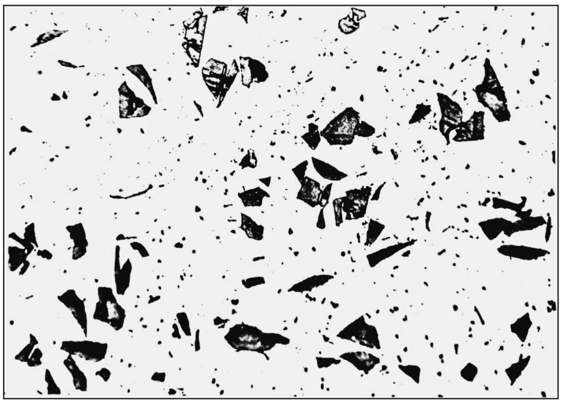

Figure 2 Microstructure of AlMg10+10 %SiC composite, mag. 200 x

ability was the length of the flooded spiral. The rod test with a straight horizontal channel of 7mm diameter was carried out in a metal mould.

The shrinkage test was carried out on a device designed and built at the Foundry Department of the Częstochowa University of Technology. The device's principle of operation bases on continuous processing of the magnitude of the change in length of the casting during its cooling into electrical quantities. In the mould, sample in the shape of cylinder 3 with a diameter of 20 mm and length of 200 mm is cast. One end of the rod is sunk into the liquid material poured into the mould. The other end of the rod extends outside the mould. An inductive sensor is attached to the rod and connected to a recorder. Changes in the length of the cast rod during cooling and solidification cause the sensor core to move which is reflected in the recorder readings. Calculations of shrinkage are based on the recorded changes in the sample's length.

RESEARCH RESULTS

Table 1 shows the castability results of the researched materials. Figures 1 and 2 present examples of the microstructures of the researched materials.

Figures 3 and 4 graphically present the results the conducted castability tests.

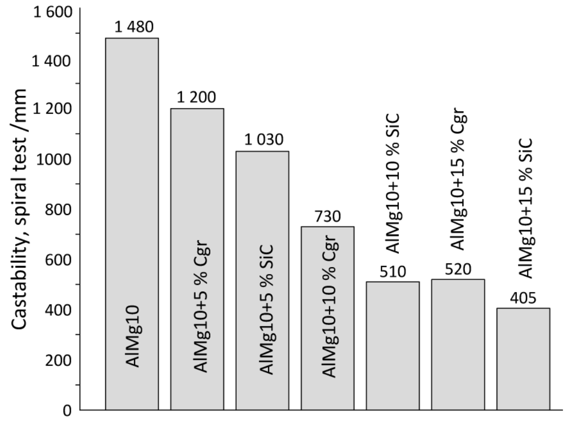

Figure 3 Results the conducted castability tests (spiral test)

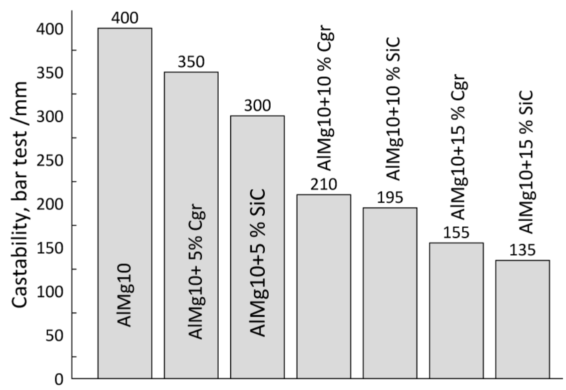

Figure 4 Results the conducted castability tests (bar test)

Curves illustrating the shrinkage of the sample of the tested materials during solidification and cooling were obtained from the recorder. The shrinkage values for the matrix alloy and the produced composites were read from the charts. The results of linear shrinkage tests and its values after 480 min are presented in Figure 5.

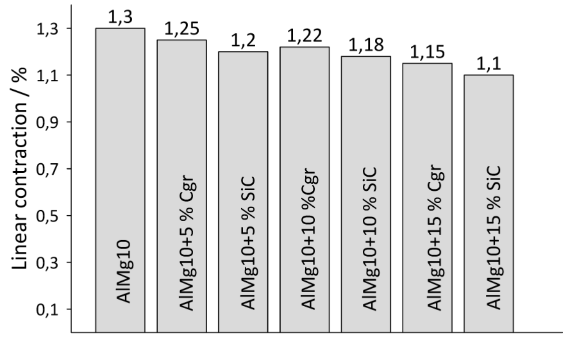

Figure 5 Final linear shrinkage values of tested materials.

SUMMARY

Results of the actability measurement performed with both the spiral and rod tests show that with an increase in the amount of introduced ceramic particles, the castability decreases, regardless of the type of particles. The decrease in castability is mainly due to the large increase in suspension viscosity when even a small number of particles are introduced into the liquid metal. The actability of composites containing SiC particles is much worse than that of composites containing Cgr particles. The viscosity of the suspension increases with increasing amount of ceramic particles regardless of the type of these particles. The deterioration in the viscosity of composites containing SiC compared to composites with Cgr particles is probably influenced by the density or specific gravity of the particles. Both these values are higher for SiC particles, which hinders the flow of the suspension in the channels of the casting mould cavity. In addition, the metal solidifies as it releases heat, thus increasing the proportion of solid phase, which causes a further increase in viscosity. A large proportion of solid phase in the liquid matrix essentially affects the ability to fill the mould cavity and makes it difficult to obtain a casting with a well reproduced shape. In order to improve the castability of composites with large volume shares of graphite particles, it would be necessary to change the casting parameters, especially the pouring temperature and the mould temperature.

The graph showing the values of linear shrinkage after solidification and cooling of the casting (Fig. 5) indicates a clear effect of ceramic particles on the casting shrinkage of the researched materials. With an increase in the amount of reinforcing phase, the linear shrinkage decreases. For the matrix material it is 1,3 %, for the composite containing 15 % SiC it is 1,1 %, while for the composite containing 15 % Cgr it is 1,15 %. The reduction in linear shrinkage for the composites is probably due to the difference in the coefficients of thermal expansion of the matrix material and the reinforcing phases. The coefficient of linear thermal expansion of silicon carbide particles is much smaller than the matrix and is $0,4*10^{-5}$ K^{-1}, for graphite $0,6*10^{-5}$ K^{-1}, while the coefficient of thermal expansion for the matrix alloy AlMg10 is $2,6*10^{-5}$ K^{-1}. In metal composites which have a higher thermal expansion coefficient it is 5, 10, and 15 % less (volume fraction of reinforcing particles), hence the shrinkage value of the matrix alloy differs from that of the tested composites.

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Note: The professional translator for English language is Agnieszka Chmielewska, Koszalin, Poland.