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# The influence of the composite casting wall thickness on the arrangement of particulate within the matrix

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## Abstract

The work presents the investigation results concerning the structure of composite pressure die castings with AlSi13Cu2 alloy matrix reinforced with SiC particles. The arrangement of the reinforcing particles within the matrix has been qualitatively assessed in specimens cut out of the castings of diverse wall thickness. Various pressure die castings have been used for the assessment, e. g. the castability test specimens with the wall thickness changed continuously from 3 mm to 0.2 mm. Examination has been held for composites containing various fractions of SiC particles, i.e. 10, 20, or 30 volume percent. An increase in uniformity of arrangement of SiC particles within the matrix accompanying the increase in the reinforcement fraction in composite volume has been observed. No differences caused by changes in casting wall thickness have been found in the reinforcement arrangement. Composites containing over 20 and 30 volume percent of SiC particles exhibit almost ideally uniform reinforcement arrangement. The uniform arrangement of reinforcing particles has been observed even for a casting of wall thickness equal to 0.2 mm.

**Keywords:** Pressure die casting; Metal matrix composites (MMCs); Structure.

## 1. Introduction

A great deal of metal matrix composites is produced using multi-stage technologies where one of stages consists in producing stable and uniform composite suspension which after matrix solidification turns finally into a composite. Production of stable and uniform composite suspension depends on a set of surface phenomena occurring at the interface between metal and the non-metallic particle, such as wetting, dipping, adhesion, chemical reactions, and diffusion. They are decisive for the strength of bonding between components, as well as for the reinforcement arrangement in the composite volume, which in turn provides for achieving the demanded level of composite material properties.

The main problem in achieving the uniform arrangement of ceramic particles in the metal matrix is that there occur difficulties in obtaining proper bonding between metal matrix and the particles because the latter are poorly wettable by liquid metal [1-3]. The wettability of components can be improved by surface preparation of particles or by liquid metal modification [4-6]. The non-uniform arrangement of reinforcing particles in the matrix can be caused by sinking down or floating up of the particles during composite flow. Frequently such a phenomenon occurs during gravity casting of composite suspensions. The arrangement of particles is also influenced by the crystallization process, during which the particles can be engulfed or pushed out by the moving crystallization front what finally results in placing them within interdendritic areas [7-10]. Ceramic particles cause the increase in viscosity of the flowing liquid so the problem of proper filling of the mould or die cavity arise [11-14].

This disadvantageous phenomena can be practically eliminated by employing the pressure die casting method for composite casting production. Then casting parameters can be selected by controlling the injection speed, pressure, and the gate thickness so as to achieve a sound casting containing reinforcing particles uniformly distributed within the matrix [15].

Achieving the high quality of pressure casting depends on the mechanism of filling the die cavity with molten metal [16]. The way of cavity filling is in turn influenced by multiple factors, among which there are the shape and massiveness of a casting, the mass ratio between the casting and the die, the arrangement of the runner and gating system, the shape and the area of the main sprue, the volume of the die cavity, the area and the arrangement of air vents, the injection speed and pressure, and the intensification pressure [17, 18]. Filling of the die and subsequent metal cooling and solidifying strongly depends on such physical properties of cast alloy as its viscosity, solidification range, latent heat of solidification, density, thermal conductivity, and metal temperature, as well as on the die temperature at the moment of pouring [19].

If the pressure die casting technology is applied for particulate composites, the temperature difference between the metal and the die should be kept at the lowest possible level. The best solution here is to increase the die temperature first, and then the metal temperature when the viscosity of metal increases. This means that the pressure casting should proceed at the lowest possible temperature of the cast metal. It is common practice to maintain the casting temperature only slightly exceeding the liquidus temperature, and quite often, if an alloy exhibits wide solidification range, to keep it even below the temperature of crystallization beginning. Casting of composites in the semi-solid state is possible only by means of the cold chamber diecasting machines, because high pressure can be applied during pouring operation. The strongly turbulent flow through the gating system results in intensive suspension mixing, what accompanied by quick solidification in the metal die promotes the uniform distribution of reinforcing particles within the volume of matrix.

The purpose of the present work is an assessment of the arrangement of reinforcing phases in pressure cast composites in relation to the casting wall thickness.

# 2. Methodics and the investigation results

The examined composites have been made of AlSi13Cu2 alloy matrix reinforced with 10, 20, or 20 vol. % of SiC particles. This matrix alloy is commonly used in pressure die casting and its composition assures good wettability of particles. The alloy exhibits good casting properties and narrow solidification range what enables production of castings with diverse wall thickness and complex shape [13, 14]. Silicon carbide particles of 70-100 μm size have been used for preparing the composites.

Composite suspension has been prepared by mechanical mixing method. In order to do that the metal has been melted in the induction crucible furnace and overheated up to the temperature of 973 K. Then reinforcing particles have been introduced into the stirred molten alloy by means of a dosing spout. Mixing has been done by turbine mixer of 0.05 m diameter equipped with four blades of the angle of slope equal to 45º, which have been placed at the distance equal to one-third of the height of the liquid metal from the bottom of crucible in its axis. The mixing time has been 10 minutes and the angular velocity of mixer has been set for 500 rpm. Composite production process parameters selected in this way have enabled the uniform distribution of SiC particles within the matrix volume.

Composite suspensions have been pressure cast by means of cold chamber horizontal pressure diecasting machine with 2 MN clamping force. Each single shot has allowed for casting 4 tensile specimens, 4 impact test pieces and a castability test casting. Ten shots have been made for each composite suspension type. Casting has been performed at the plunger velocity equal to 3.5 m/s in the second stage of injection, the intensification pressure value of 40 MPa, and the 2 mm gate thickness.

The values of pressure and plunger velocity have been recorded by means of the DMC 200 type sensors made by EMTEC Company. The following constant values have been assumed for the experiments: the diameter of pressing plunger $d_k$=40mm, the constant plunger velocity in the first stage of injection 0.3 m/s, the degree of the cold chamber filling is 60%, the area of castings with flow-offs and the gating system is 175 $cm^2$ in the die parting plane, the thickness of the castability test casting vary within a range of 0.2÷3.0 mm , the wall thickness of tensile specimen equals to 10 mm, dynamic viscosity of composite containing particles in quantities 10% to 30% by volume is $\mu = 0.7 \cdot 10^{-5} - 10^{-5}\ m^2/s$.

The arrangement of SiC particles in composite matrix has been qualitatively assessed for pressure castings of wall thickness equal to 10, 1.4, and 0.2 mm. Structures of the examined composites presenting the arrangement of the reinforcing particles are shown in Figs 1-9.

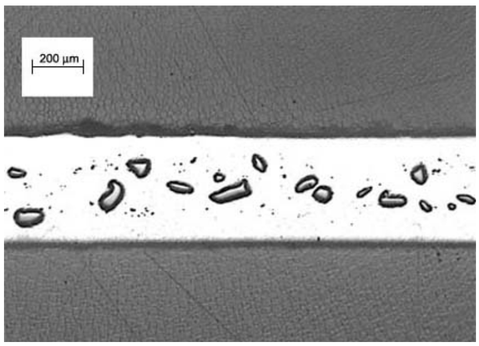


Fig. 1. The arrangement of SiC particles in composite casting of 0.2 mm wall thickness containing 10 vol. % of reinforcing phase

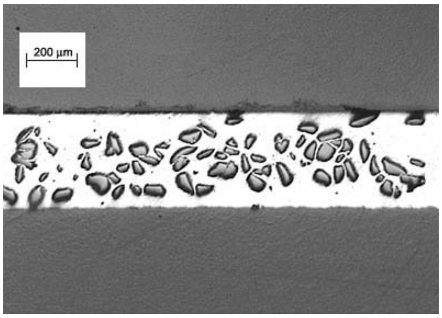


Fig. 2. The arrangement of SiC particles in composite casting of 0.2 mm wall thickness containing 20 vol. % of reinforcing phase

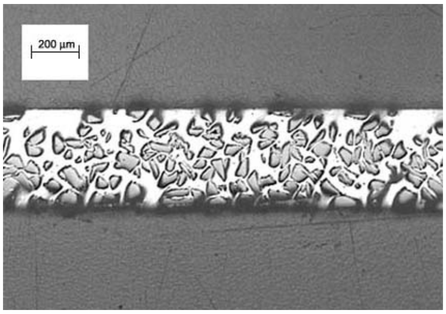


Fig. 3. The arrangement of SiC particles in composite casting of 0.2 mm wall thickness containing 30 vol. % of reinforcing phase


Fig. 4. The arrangement of SiC particles in composite casting of 1.4 mm wall thickness containing 10 vol. % of reinforcing phase

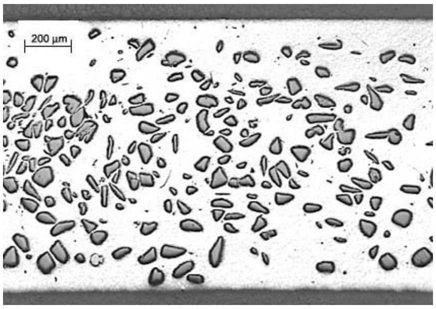


Fig. 5. The arrangement of SiC particles in composite casting of 1.4 mm wall thickness containing 20 vol. % of reinforcing phase


Fig. 6. The arrangement of SiC particles in composite casting of 1.4 mm wall thickness containing 30 vol. % of reinforcing phase

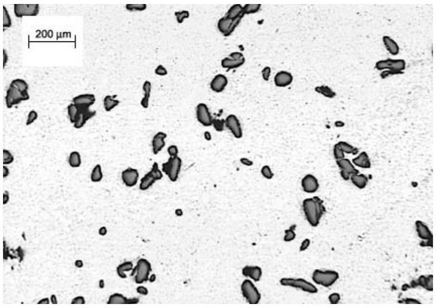


Fig. 7. The arrangement of SiC particles in composite casting of 10 mm wall thickness containing 10 vol. % of reinforcing phase

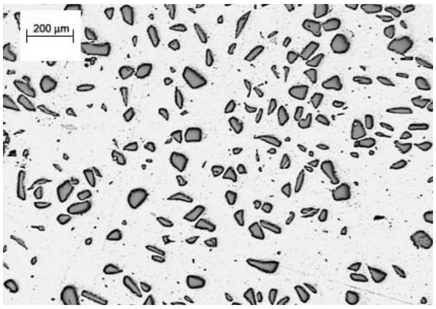


Fig. 8. The arrangement of SiC particles in composite casting of 10 mm wall thickness containing 20 vol. % of reinforcing phase

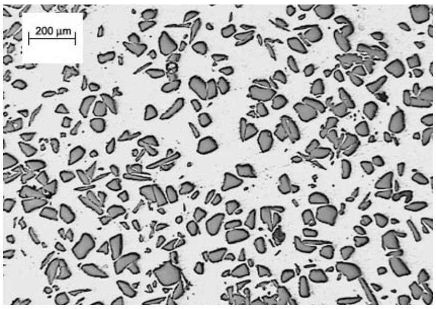


Fig. 9. The arrangement of SiC particles in composite casting of 10 mm wall thickness containing 30 vol. % of reinforcing phase

## 3. Conclusions

The obtained results confirm the possibility of producing the thin-walled composite castings with aluminium alloy matrix containing SiC particles uniformly distributed within the matrix volume. The pressure die casting technology ensures production of composite casting of wall thickness equal to 0.2 mm containing even 30 vol. % of reinforcing particles in the matrix. At lower particle percentages the greater non-uniformity of their arrangement is observed. It is probably caused by their increased agglomeration during the die filling. At high percentages of particles their arrangement is much more uniform due to the die filling of the “mass flow” type caused by significantly increased suspension viscosity. In this case it can be called casting in the semi-solid state. The optimisation of reinforcing phase arrangement demands for quantitative examination of composite structure, which are planned, and for evaluation of the influence of casting parameters. The previously held investigations point to the significant influence of die filling rate and the intensification pressure on the quality of castings.

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