# TECHNOLOGICAL ASPECTS OF PRODUCTION HETEROPHASE (SIC + C) COMPOSITE SUSPENSIONS

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**Keywords**: *AlMMCs ,ceramic particles, mould casting ,composite pistons*

## 1 Introduction

Composites with an aluminium alloy matrix (AlMMC) are a group of materials which due to their properties (high specific elasticity modulus, high stiffness) are more and more frequently used in modern engineering constructions. Composites reinforced with ceramic particles ($Al_2O_3$, SiC) are gradually being implemented into production in automotive or aircraft industries, first of all due to high resistance to friction wear [1-4]. Another application of aluminium matrix composites is in the electronics industry, where the dimensional stability and capacity to absorb and remove heat is used in radiators [5]. Therefore, numerous research institutes conduct research to create efficient and cheaper methods of production of metal composites. The main problems are still: a reduction of production costs, developing methods of composite material tests and final product quality assessment, standardisation, development of recycling and mechanical processing methods. Currently, composite parts using the squeeze casting technology are manufactured in larger quantities by such companies as Toyota or Kolberschmidt AG. This technology is based on high-pressure infiltration of porous ceramic preform [6].

## 2 Materials and technology

Composite production technologies, based on liquid-phase methods, and the shaping of products by casting methods, belong to the cheapest production methods. In comparison with preform infiltration techniques, casting methods are cheaper and lets of possibility existing equipment for production. In point of view technology following factors are important: matrix alloyôs preparation (refining, modification of chemical composition, overheating), ceramic particles preparation (chemical preparation, thermal treatment) and the intensity of stirring the suspension. The conditions of homogenisation are crucial for even distribution of the ceramic reinforcement among the whole volume of liquid metal, which in turn influences the structure of the composite material formed by casting. Undesirable results of sedimentation or floatation and agglomeration of the ceramic particles may influence castability and thus hinder casting the product or even make casting impossible. This effect may also impact the process of crystallization and solidification of a composite material [7].

Application of a suspension method for the production of composites with heterophase reinforcement may be a new material and technological solution.

Research works carried out at the Department of Materials Technology, Silesian University of Technology have confirmed good casting properties of heterophase composite suspensions [8-10]. The application of SiC and glassy carbon particles enables stabilizing the friction coefficient and, most of all, reducing the wear of the friction partner. These properties may be used in a tribological piston-cylinder system, were dimensional stability, strength and durability are required [11].

The aim of research carried out under the research and development project PBR N RO7 001106 the transfer production procedure of composite suspensions, developed at a laboratory scale by the authors, to a semi-industrial scale of production, so as to enable die-casting of air-compressor pistons in industrial conditions. So far the process was conducted at two stages. Before the introduction of ceramic reinforcement into the matrix, the alloy composition was modified by adding Mg and Sr. Ceramic particles (mixture of SiC and glassy carbon) were preheated at a temperature of 350ºC and next, introduced into the liquid metal at 720ºC. At the second stage, the crucible with the composite

suspension was placed in a hermetic chamber which facilitates degassing and homogenization under reduced pressure conditions. This way, 2.5 kg of ingot was obtained, which then was remelted and stirred for 30 minutes in the production conditions of the foundry. At this stage of tests, series consisting of five composite pistons were cast (fig.1) in metal mould [12]. That technological tests confirmed the possibility of formation composite pistons from utilization the technology of mould casting

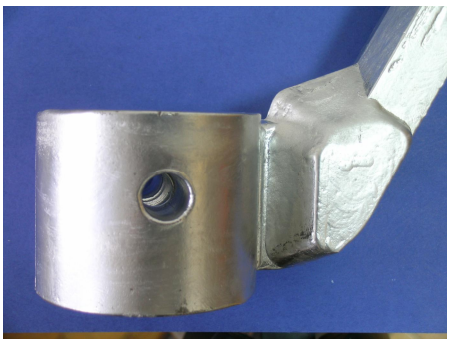

Fig.1. Seimi-finished composite piston casted in metal mould.

New equipment designed at Silesian University of Technology make possible to obtain approximately 50 kg of composite suspension in one cycle, in the joint processes of metal preparation, introduction of reinforcement and homogenization (fig. 2).

Fig.2. Autoclave furnace for composites suspension production

The stand consists from hermetic chamber of furnace in which the crucible is built, as well as the movable cover with mixing system and feeding of ceramic particle unit. Composite suspension is obtained in several stages. After melting of the alloy the process of refinement is put on, with applying of the argon blow-by liquid metal from utilization the graphite stirrer. Next the additions of master alloy are introduced then the chemical constitution of the matrix alloy, and in next stage the ceramic particles are introduced. By the control of rotational speed of the feeding screw the velocity of introducing the reinforcement particles on liquid metal is limited. In the last stage the process of homogenizing suspension and the degassing in conditions of reduced pressure is put into [13].

## 3 Experimental researches

In the first phase of testing a composite suspension was made using parameters established in previous studies carried out on a laboratory scale. As the base of matrix alloy was applied AlSi7Mg alloy. After melting and preheated at temperature 720$^{o}$C alloy has been subjected to the fifteen minutes process of refinement (the flow of argon 0,5 dm$^3$/h). Then the master alloys AlMg25 and AlSr were introduced to liquid metal enlarging the part of magnesium in melt about 1% weights and modifying chemical composition with addition of 0.03 % Sr. After hold at temperature 350$^{o}$ C SiC particles were poured into hopper. Particles were introduced in vortex area of liquid metal with velocity approx. 4 kg/h. Homogenization of suspension was subjected in reduced pressure (500Ã10$^2$ Pa) in 60 minutes time. All stages of preparation the suspension were performed in a protective atmosphere of argon.

After this process, the furnace chamber was opened and began the process of hand casting of pistons with a diameter of 65 mm with applying a five-core metal mould. During the casting suspension was mixed with a pouring cup. Also in that stage the protective gas atmosphere was provided. Under the same conditions was prepared the heterophase composites reinforced with SiC and glassy carbon particles ($C_g$). Amount of obtained composites suspension allows the use permanent mould casting machine GM110 working in the casting line ñZğteckiò company. All technological parameters of casting process were according to productive standards non reinforced pistons. Carried

out tests confirmed the possibility of forming composite pistons with applying casting technology (fig. 3). First of all, confirmed the major assumptions used in the construction of the furnace stand. Also confirmed the stability of the suspension and the possibility of casting composite pistons in trial batch series. In the manufacture of composite suspensions is very important to obtain uniform and stable distribution of reinforcement in the matrix. The structure analysis confirmed a uniform distribution of reinforcing particles in the matrix and a slight porosity in the cast (fig. 4).

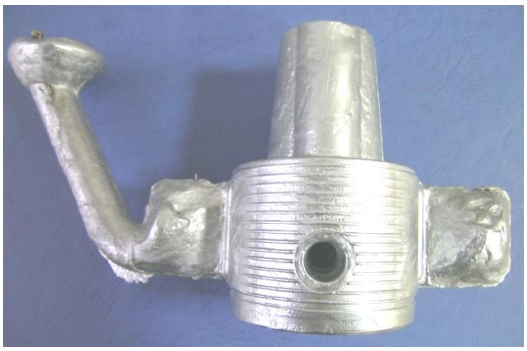

Fig.3. Seimi-finished composite piston casetd in permanent mould machine GM110

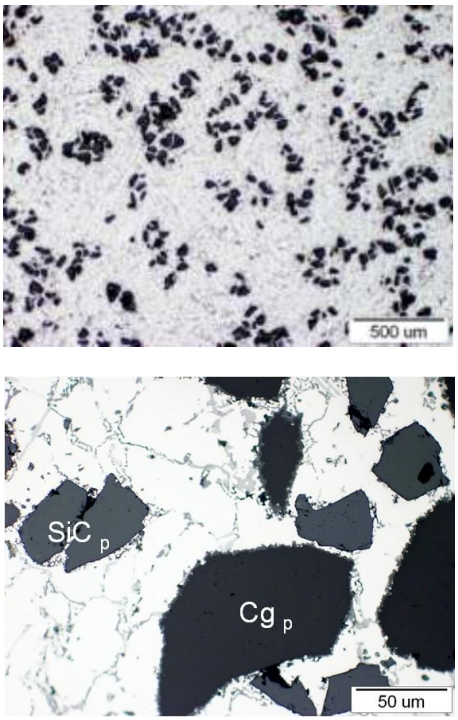


Fig.4. Structure of heterophase composite

Number of obtained semi-finished composite pistons is sufficient to the next stage of the research, which are attempting to machining of piston surface. Hard ceramic SiC particles improve the tribological properties of the composite, but their presence complicates the machining of the cast. Application of glassy carbon should allows to reduce these negative effects. Preliminary tests at recessing the ring grooving confirmed the possibility of shaping the working surface of piston (fig. 5). Obtaining the proper shaping of piston require to select appropriate cutting tools and optimization of process parameters.

Fig.5. Heterophase composite piston after preliminary machining

## 4 Summary

The repeatability of the shape of the materials at permanent mould machine casting significantly affect the ability of machining in CNC centers. Obtained composite suspension with particles of SiC reinforcement and a mixture of SiC and glassy carbon were characterized by good casting properties. Carried out technological tests confirmed the possibility of forming semi-finished composite pistons using permanent mould technology. Casting made in the industrial conditions characterized by a high repeatability. The produced a series of trial batch is sufficient to machining on automatic lathes. Currently, are carried out studies on the selection of appropriate cutting tools and machining conditions.

*Acknowledgements*

*Scientific work carried out under the funding of the National Centre for Research and Development as part of the 6th competition of development projects , Project No. N RO7 001106.*

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