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MECHANICAL PROPERTIES OF DIE-CAST COMPOSITES REINFORCED WITH NATURAL AND SYNTHETIC GRAPHITE

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Preliminary Note – Prethodno priopćenje

This paper presents the results of mechanical tests on AlSi10Mg alloy matrix composites reinforced with natural and synthetic graphite particles. The natural graphite used as reinforcement in the composite was flake graphite of very high purity, chemically refined, while the synthetic graphite came from recycled graphite electrodes used in electric arc furnaces. Composite slurries containing 5, 10 and 15 % graphite particles were die-cast on a cold chamber die casting machine. Samples of pure AlSi10Mg alloy were also cast.

Keywords: die-casting, composites, graphite, mechanical properties, aluminium alloy

INTRODUCTION

The manufacture of castings from metal composite materials is very complicated, primarily due to the lack of wetting of the reinforcing particles with the liquid alloy [1, 2]. When producing such castings, it is necessary to create a slurry of the particles in the liquid alloy in a first step and then cast such a slurry, which, once the particles are introduced, has much worse casting properties than the matrix alloy itself. Thus, making a metal composite casting with uniformly distributed reinforcement by gravity casting is challenging [3 – 5]. The introduction of the composite slurry into the casting mould under high pressure greatly facilitates the production of the composite casting, as the forced filling of the cavity of the casting mould does not require as much flowing power as in the case of gravity casting [6, 7]. In addition, using die casting technology, higher proportions of reinforcing particles can be used in composites than in gravity casting. Aluminium alloy matrix composites reinforced with graphite particles are primarily produced for machine and equipment parts that require high wear resistance and a low coefficient of friction.

However, one should bear in mind that these materials are often also subjected to loads even during abrasion. Therefore, it is also important to know the effect of reinforcing particles on the mechanical properties of such materials [8, 9].

Graphite used as reinforcement for metal matrix composites is a very valuable material, so recycling graphite electrodes and reusing synthetic graphite is purely beneficial. Firstly, the recovery of valuable material from waste provides cost savings and secondly, the reduction of such waste has a beneficial impact on the environment and sustainability [10]. The recycling of graphite electrodes therefore allows for the recovery of raw materials but also has the effect of reducing the acquisition of new raw materials resulting in a reduction in the negative environmental impact of the metallurgical industry [11 – 13].

METHODOLOGY AND RESEARCH MATERIAL

To test the mechanical properties, a die-cast multi-cavity mould was used, which allowed 4 specimens to be made for strength tests with a single pour of the mould. The castings were made in one of the die casting shops cooperating with the Częstochowa University of Technology. Before making the die castings, a composite slurry had to be made. To this end, AlSi10Mg alloy was melted in a crucible of a resistance furnace and a corresponding amount of natural or synthetic graphite particles was introduced. The particle size of both natural and synthetic graphite was in the range 70-100 μm. Composites containing 5, 10 and 15 % particles were produced. Natural graphite was chemically refined flake graphite, while synthetic graphite was recycled graphite from graphite electrodes used in electric arc furnaces. Both types of graphite particles were previously annealed at 250 °C to remove moisture from the graphite particles. During the introduction of the graphite particles into the liquid melt, the slurry was stirred and then introduced into the pressing chamber of a 160 T horizontal cold-chamber die-cast machine with a slurry injection speed of 60 m/s and a filler thickness of 1 mm.

Tests of the mechanical properties of the composites included measurements of: yield strength R_{02}, tensile

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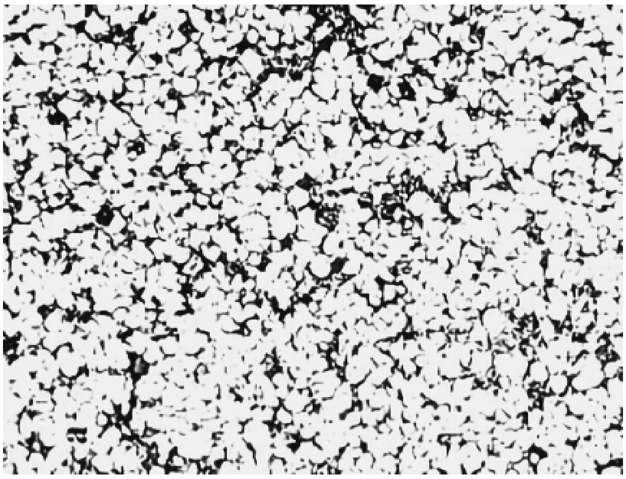

Figure 1 Microstructure of a die-cast AlSi10Mg alloy, magn.100 x.

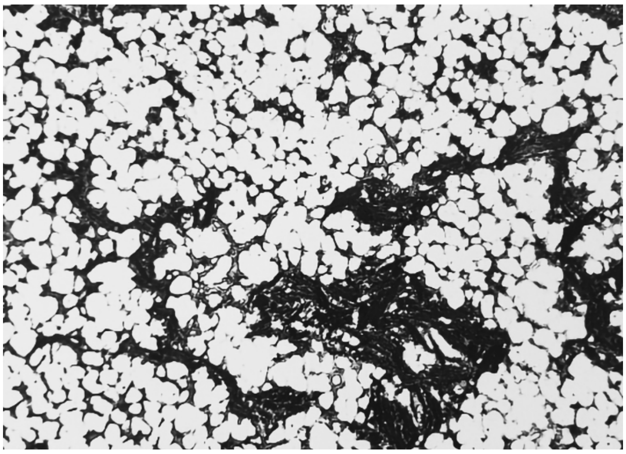

Figure 2 Microstructure of a die-cast AlSi10Mg + 5 % GN composite, magn.100 x.

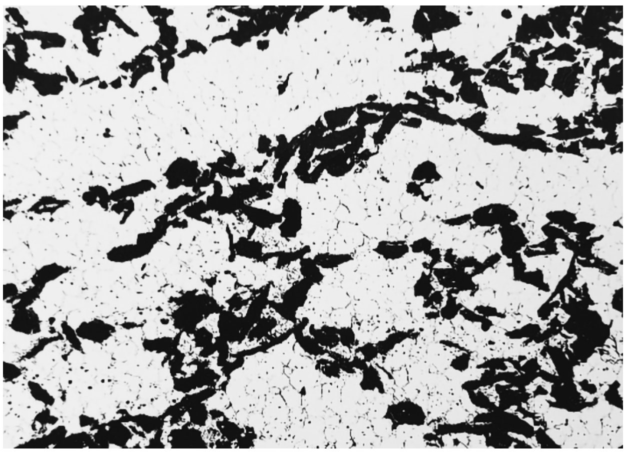

Figure 3 Microstructure of a die-cast AlSi10Mg + 5 % GS composite, magn.100 x.

strength R_m, Young's modulus E and relative elongation A. For comparison purposes, specimens were cast and the mechanical properties of pure AlSi10Mg alloy were tested.

After the mechanical tests were carried out, metallographic microsection were taken from the remaining specimens to observe the microstructure of the castings produced.

RESULTS OF RESEARCHES

Figures 1, 2 and 3 show the microstructures of the die castings. Figure 1 shows the microstructure of a die-cast AlSi10Mg alloy, Figure 2 the microstructure of a composite containing natural graphite and Figure 3 the microstructure of a composite containing synthetic graphite.

The structure of the matrix alloy is very typical for rapidly solidifying castings. Mixing the melt produces favourable globular crystals of the primary phase. The composite castings were distinguished by a relatively uniform distribution of reinforcement in the matrix, indicating that the slurry formation parameters were correctly chosen.

Figures 4, 5, 6, 7 show the results of the mechanical properties: yield strength, tensile strength, Young's modulus, and relative elongation for AlSi10Mg alloy and metal composites. These results represent the average values for each material of the four tests.

In general, it can be concluded that the introduction of reinforcement in the form of graphite particles, whether natural or synthetic, in most cases does not significantly impair the mechanical properties of the matrix alloy.

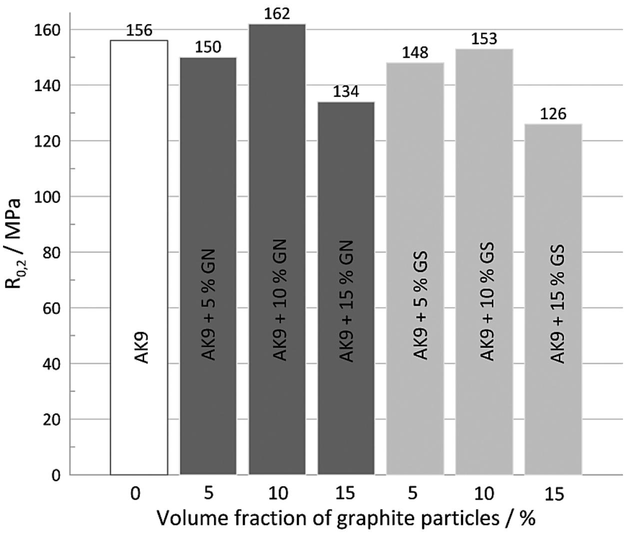

Figure 4 Yield strength of the tested materials.

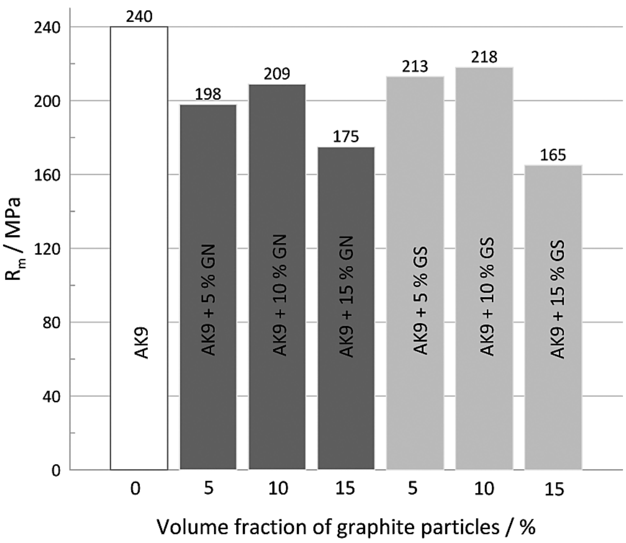

Figure 5 Tensile strength of the tested materials.

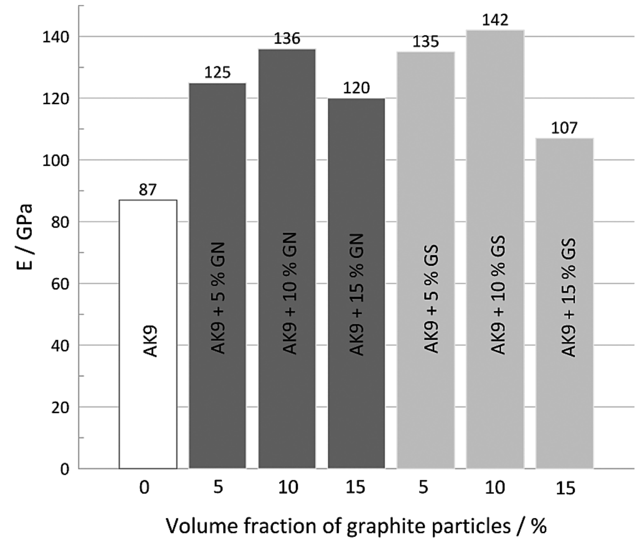

Figure 6 Young's modulus of the tested materials.

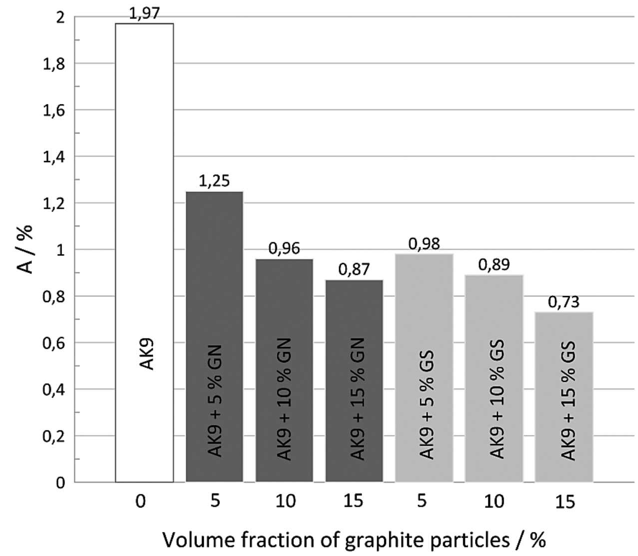

Figure 7 Relative elongation of the tested materials.

SUMMARY

The correct preparation of the composite slurry, the correctly selected mixing parameters of such a slurry and high-pressure die casting make it possible to obtain metal composite castings of excellent quality. This quality is influenced in the composites primarily by the uniformly distributed reinforcement in the matrix volume, but also by the matrix structure of the composite. Die casting of these materials has made it possible to obtain a globular shape and fragmentation of the crystals of the primary phase of the AlSi10Mg alloy, instead of the dendritic structure that occurs in gravity castings, which has a fundamental effect on improving the mechanical properties of the alloy. The introduction of graphite particles into the AlSi10Mg alloy resulted in a decrease in tensile strength, which occurred regardless of the type of graphite particles. The graphite particles slightly affected the yield strength for the content of 5 and 10 %, only the addition of 15 % graphite resulted in a decrease in yield strength. However, the presence of graphite particles significantly improved the Young's modulus of the tested materials, and this was the case for both natural and synthetic graphite. This indicates a strong bonding of the particles to the matrix material, which is indicative of well-chosen composite manufacturing parameters. The greatest negative effect of graphite particles was observed for relative elongation. Reinforcement of the composite with graphite particles caused a significant decrease in the aforementioned property. The results presented in this study did not highlight a significant effect of the type of graphite used to make the composite castings on the mechanical properties. Samples of composites containing natural graphite showed very similar mechanical properties to those containing synthetic graphite from recycled graphite electrodes. This means that it is justified to use synthetic graphite due to the lower price of this material and, above all, due to the possibility of reusing waste electrodes, which has a positive impact on the environment and sustainability.

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