M. ŁĄGIEWKA, C. KOLMASIAK

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COMPOSITE CENTRIFUGAL CASTINGS AFTER REMELTING

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The presented work presents the results of research on the content and distribution of SiC particles in metal composites after remelting. The research covered the AlMg10 alloy matrix composites produced by mechanical stirring. The castings were made using the centrifugal casting technology, on a machine with a vertical axis of rotation. The abrasive wear tests of the produced composites before and after the re-remelting were also carried out.

Keywords: centrifugal casting, AlMg10 matrix composites, silicon carbide, wear, recycling

INTRODUCTION

Recycling, i.e. remelting and even multiple remelting of waste from the production of composite castings, i.e. gating systems, scrap or worn castings, has been a big problem for some time in countries where cast composite materials are produced. Recycling of metal composite materials poses many problems, therefore there are no effective recycling methods in the world so far [1-4]. Companies producing composites on an industrial scale usually give their recipients only technological guidelines regarding a one-stage recycling process, without explaining in detail the physicochemical phenomena occurring in the remelting process. Factors that affect the quality of the composite after re-remelting are: remelting time, temperature of subsequent remelting, mixing speed during remelting, refining procedures used, scraping of elements, development (or inhibition) of possible reactions on the metal-ceramic contact surface, change of stress surface and interphase in adhesive connections, uniform particle distribution or their agglomeration, sedimentation or particle outflow [5-8].

Depending on the mechanism of connecting the particles with the matrix

present in the composite, the prolongation of the contact time of the particle surface with the liquid alloy during subsequent remelting may lead to growth or degradation of the possible transition layer [8-10]. In the case of a typically adhesive bond, this can affect the wettability (positively or negatively). Understanding the phenomena occurring at the boundary of the particle-matrix separation during remelting will allow to determine the conditions of maintaining (or increasing) the required properties and to develop the technology of recycling processes [11-13]. This will expand the possibilities of producing composites by casting and the use of secondary composite raw materials, which is of great economic and environmental importance. The increase in the production of metal composite materials requires the development of technologies for the re-use of production waste and used parts of machines and devices made of this type of materials [14].

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

METHODOLOGY AND RESEARCH MATERIAL

In the presented work, comparative tests of the content and distribution of ceramic particles in composite centrifugal castings were carried out, which were obtained immediately after the production of composites by mechanical mixing and after remelting them. In order to conduct the tests, a composite based on the AlMg10 alloy was produced, containing 10 % by weight of SiC particles with a grain size of 70 - 100 µm. For the production of centrifugal castings, a centrifugal casting station with a vertical axis of rotation with variable, continuously adjustable rotational speed was used, designed and manufactured in the Department of Foundry [2]. The rotating form mounted on the table of the stand allowed for obtaining castings with the dimensions of φ 120 x 30 / mm. Composite castings were obtained using the following parameters, determined as optimal in previous works:

- sample weight 230 g, allowing to obtain cylindrical castings with a wall thickness of 10 mm,
- pouring temperature - 700 °C,
- spin time - 180 s.
- mold rotational speed - 1500 min^{-1}
- mold temperature - 260 °C.

In the first stage of the test, composite castings were produced by mechanical mixing of the AlMg10 + 10 % SiC suspension with the parameters specified above. During the remelting of the composites, the same remelting technology was used as in the preparation of composites by mechanical mixing method, i.e. after melting, the composite was intensively mixed with a mechanical stirrer for 180 seconds and poured into a rotating mold. In order to check the effect of remelting composites on the functional properties, tests of abrasive wear were additionally carried out on selected surfaces of the produced centrifugal castings.

RESULTS OF RESEARCHES

Figure 1 shows a composite centrifugal casting from which a sample for structure testing has been cut.

The conducted observations of the structure of the obtained centrifugal castings (Figure 2 and 3) showed that the total content of SiC particles practically did not change, however, the distribution of these particles on the cross-section of the samples (in the radial direction) is not as unambiguous as in the primary casting of composites.

During remelting and intensive mixing, impurities were introduced into the melt, which partly adhered to the surface of the particles, and partly appear as separate clusters. The presence of particles with impurities on the sample made it very difficult to perform quantitative measurements on a computer image analyzer. The obtained results of the distribution (Figure 4) show the variable distribution of SiC particles on the cross-section of the centrifugal castings. Near the outer surface, a clear increase in the number of particles is observed, further deeper into the casting their concentration clearly decreases, in places on many samples a pure matrix alloy is practically observed. On the other hand, at the inner surface, we again observe a slight increase in particle concentration.

The observation of microstructures at high magnifications showed that the particles present in the inner regions of the casting are not wetted by the matrix alloy, most of them are surrounded by oxide impurities, and the impurities are also concentrated in these regions. This particle distribution in the secondary casting results from the force distribution in the liquid alloy subjected to the centrifugal force. The „clean" (well-wetted) particles as heavier are thrown towards the outer surface, while the particles surrounded by light impurities and the impurities themselves as lighter are forced by the liquid alloy into the rotating system. Due to the relatively high contamination of the alloy with intensive mixing, the tests were repeated using the same parameters, but after the composite had been melted and kept for 180 seconds, it was mixed at a much lower speed. As a result, a good quality of the composite was obtained (trace amounts of impurities), but the total content of particles decreased compared to the original composite by an average of 10 %. During remelting and casting, particle flow was observed as well as adherence to the crucible walls. Measurements of the particle distribution on the cross-section of the obtained samples remelted with a lower mixing speed showed much smaller differences in SiC concentration in the casting (Figure 5). There are no pure matrix alloy areas in the samples, the particles are distributed more evenly.

Metal composite materials with gradient particle distribution are materials developed for operation in

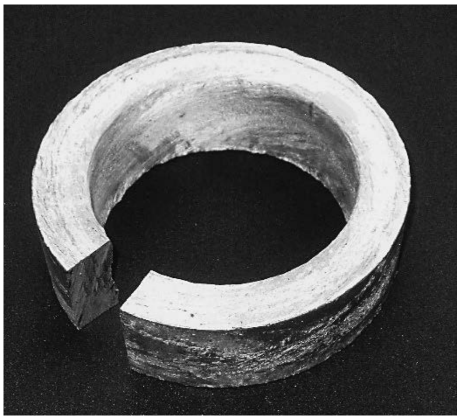

Figure 1 Composite centrifugal casting

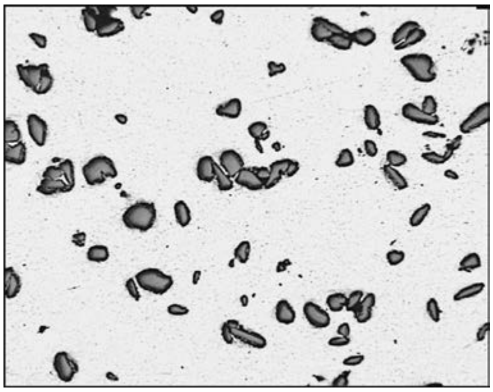

Figure 2 The microstructure of AlMg10 +10 % SiC composite, magn.100 x.

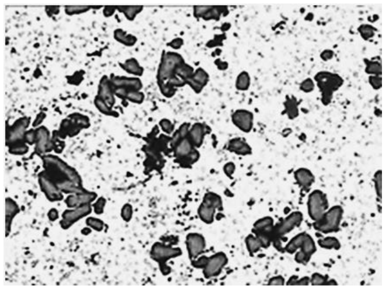

Figure 3 The microstructure of AlMg10 +10 % SiC composite after remelting, magn.100 x.

frictional conditions, and abrasive wear tests of these materials have also been carried out.

Abrasive wear measurements were carried out on the samples obtained from the materials described above. The tests were carried out using the T-05 tribological tester with the abrasion parameters determined on the basis of previous tests: total abrasion distance – 2 000 m; pressure on the sample - 50 N; rotational speed of the counter-sample - 300 min^{-1}. The test specimens were prepared in such a way that it was possible to measure the wear of both the outer and inner surfaces of the centrifugal castings. The results of the tests carried out are shown in Figure 6.

The outer surface of the primary composite with the highest concentration of SiC particles is characterized by the highest wear resistance. The wear resistance of the internal surfaces of these castings corresponds practically to

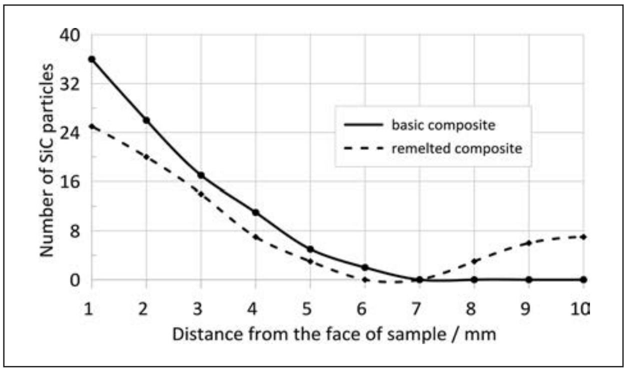

Figure 4 Particle distribution on the cross-section of a centrifugal casting

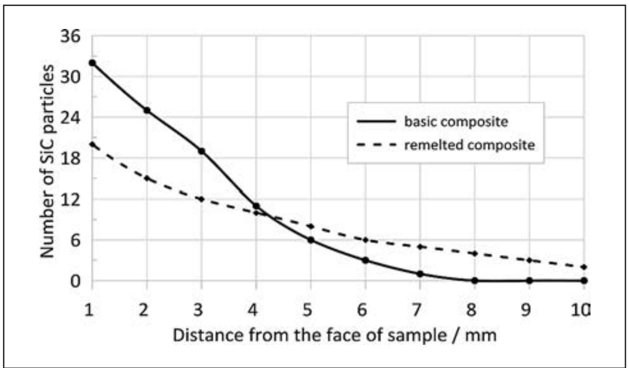

Figure 5 Particle distribution on the cross-section of the centrifugal casting (without intensive mixing of the suspension)

that of a pure matrix alloy, as these surfaces are free from particles and the contamination content is minimal. Abrasive wear increases with a decrease in the concentration of particles in the tested surface layers, and the increase is particularly rapid in the case of impurities and non-wetted particles in the analyzed areas. This is especially evident in the case of the inner surface of the secondary composite intensively mixed during remelting. Intensive particle chipping was observed, which resulted in a rapid acceleration of the surface destruction processes.

RESULTS OF RESEARCHES SUMMARY

The obtained results confirm the possibility of reprocessing of cast composites, but one should take into account a decrease in the content of reinforcing particles in the matrix of 5 to 10 %. It is very important to properly conduct the technological process and select its parameters. Incorrectly selected remelting parameters may lead to the introduction of significant amounts of impurities (it is practically impossible to clean such alloys), degradation of the possible transition layer, the occurrence of unfavorable chemical reactions and, as a result, the loss of wettability of the particles with the matrix alloy.

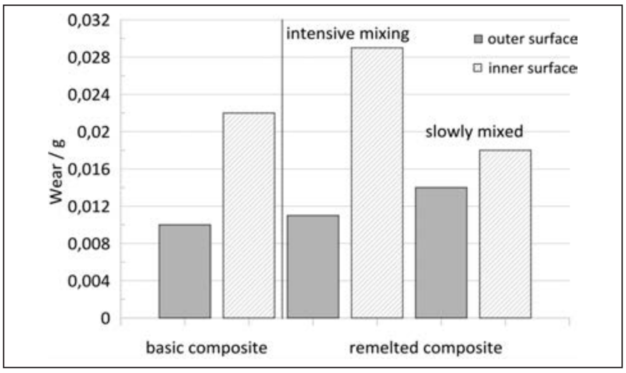

Figure 6 Abrasive wear of the tested materials

REFERENCES

[1] J. Śleziona, Development of properties of Al alloy composites - ceramic particles produced by casting methods, Gliwice (1994).

[2] J. Sobczyk, Metal composite materials - composites seminar P.Cz. (1996).

[3] L.A. Dobrzański, Fundamentals of materials science. Metallography. Engineering materials, Warsaw (2002).

[4] J. Nowacki, Composite materials, Ed. of the Lodz University of Technology, Lodz (1993).

[5] J. Jackowski, A. Modrzyńska, M. Szwaycer, Selected problems of recycling in foundries, Scientific Papers of the Poznan University of Technology 6 (2007), 59-68.

[6] Sz. Tomczyński, M. Mitko, Properties of AK7-SiC composites after remelting, Composites 2 (2002/4), 217-219.

[7] M. Mitko, Sz. Tomczyński, Recycling of composites AK20-synthetic graphite, Composites, 1, (2001/2), 188-190.

[8] M. Łągiewka, Z. Konopka, A. Zyska, M. Nadolski, Preliminary studies on the recycling of metal composites reinforced with ceramic particles, Sbornik vedeckych praci Vysoke skoly Banskie - Technicke Univerzity Ostrava 52 (2009/2), 171-176.

[9] J. Jackowski, D. Nagolska, M. Szweycer, P. Szymański, Recycling possibilities of metal composite castings, Composites 7 (2007/1), 37-40.

[10] M. Łągiewka, Z. Konopka, A. Zyska, R. Balawejder, Distribution of ceramic particles in composites on the AlMg10 matrix, Archives of Foundry 18 (2006/6), 273-278.

[11] M. Łągiewka, Mechanical and Tribological Properties of Metal Matrix Composites Reinforced with Short Carbon Fibre. Archives of Metallurgy and Materials 58 (2014/2), 707-711.

[12] A. Kurzawa, K. Naplocha, J. Kaczmar, Properties of composite materials based on the matrix of EN AW-2024 aluminum alloy and copper, Scientific Papers of the Rzeszów University of Technology 18 (2018/3), 335-344.

[13] J. Jackowski, P. Szymański, Recycling of small metal wastes of composite materials. ATMiA 27 (2007/1), 57-64.

[14] M. Łągiewka, Abrasive wear of composites based on CuPb30 alloy reinforced with graphite particles, Metalurgija 59 (2020) 3, 302-304.

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