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Effect of Chemical Composition of the Matrix on AlSi/SiC_p+C_p Composite Structure

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Abstract

The casting processes using mechanical stirring of composite suspension are considered for the most economical methods for manufacturing of metal matrix composites in the application and industrial practice. The most common problems during the composite suspensions production include: weak wetting between liquid Al alloy and ceramic particles and gassing of composite mixtures resulting with introducing the particles into aluminium alloy and long-term stirring process. The agglomerates and clusters of particles created among others as an effect of gas blisters absorption on the surface of ceramics causes discontinuity of composite structure and thereby they reduce properties of final products. The porosity has disadvantageous effect on mechanical properties of products, it reduces the corrosion and wear resistance, particularly under technically dry friction conditions. Therefore, to produced the casts composite possessed optimal properties, it is necessary their minimal porosity. To obtaining a good high-quality castings, the proper selection of components, particularly the chemical composition of the Al matrix and the kind of reinforcement are necessary.

In this paper, the effect of chemical composition of the matrix on AlSi/SiC_p+C_p composite structure were presented.

Keywords: Innovative Foundry Technologies and Materials, Castings Defects, Aluminium Composite Structure.

1. Introduction

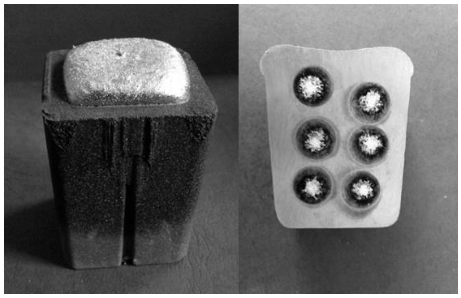
Many published articles showed that the aluminium alloy matrix composites reinforced with ceramic particles (i.e.: SiC, Al_2O_3) exhibit better mechanical properties in comparison with unreinforced Al alloys [1-3]. Due to their beneficial ratio of strength/density and better wear resistance have been used as tribological parts in some vehicles [4-6].

As described also in own previous articles, using of hybrid reinforcement (SiC_p+C_p) in aluminium matrix alloys gives stabilization of friction coefficient and, most of all, reduction of wear of the friction partner [7-12]. These properties may be used in a tribological systems, like piston-cylinder, which must characterized by dimensional stability, strength, and durability [10-12]. In order to produced the casts composite possessed optimal properties, it is necessary to obtain their minimal porosity [10]. To obtaining a good high-quality castings, the proper selection of components, particularly the chemical composition of the Al matrix and the kind of reinforcement are necessary [13-15].

Important aspects in the discussed components configurations (AlSi/SiC_p+C_p) are wettability of surface reinforcement by the liquid aluminium matrix alloy and interactions between molten aluminium alloy and glassy carbon or silicon carbide reinforcement [16,17]. Moreover, characterized high strength, possibility to heat treatment and good technological properties (high castability, good wettability on ceramic surface, low viscosity). Based on literature data and own researches, it was assumed that such properties provide the alloys containing miniumum 7% Si and also Cu, Mg and Ti additions [14,15,18]. One of the conditions for obtaining a stable suspension of the composite is modification of the chemical composition the matrix alloy, that provides wetting in the molten AlSi alloy and ceramics particles system. The procedure for the preparation of suspensions of composite in semi-technical scale was developed in project NR07 001106 [15]. It is assumed in the preparation of the EN AC-AlSi7Mg matrix alloy step of gas refining (Ar) and increasing the base rate weight fraction to 2% Mg and Sr to the weight proportion of 0.03%. PTA 200/PrG furnace stand to obtain suspension of composite allows to produce 50 kg per cycle. To obtain 10% volume fraction of the ceramic particles is required about hour introducing step. The aim of the research was carried out to determine the effect of time holding the modified matrix alloy on the concentration of Mg and Sr.

2. Experimental procedures

The EN AC-AlSi7Mg (AK7) alloy was applied as initial for designed to the next its modification. In the study was used castings made into Quick-Cup mould (Fig. 1). The analysis of chemical composition was performed on the of the ingot cross section at CCD Foundry Master arc-sparc spectrometer. The alloy composition was examined at following conditions: in the delivery of ingots (Fig. 2, Table 1), after remelting, after the modification process increasing the mass fraction of Mg and Sr, after hold at a temperature of 720ºC during 3h modified alloy (Figs. 3,4). The structure of AK7+2%Mg+0.03%Sr alloy after modification was presented on Figure 5.



(a) (b)

Fig. 1. Aluminium alloy casting made into Quick-Cup mould: a) ingot; b) cross-section

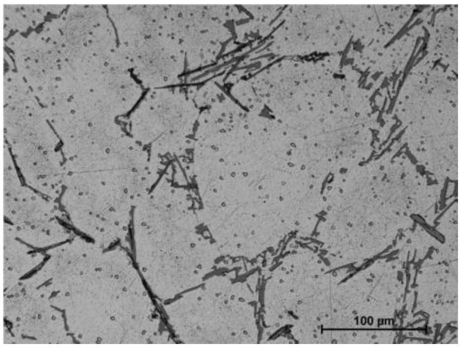


Fig. 2. The microstructure of AK7 alloy in initial state

The AK7+2%Mg+0.03%Sr/SiC$_p$+C$_p$ composite was prepared according to the procedure described in the patent [13] .

Table 1.
The chemical composition of initial Al alloy.

	Si	Fe	Cu	Mn	Mg	Ti	Sr	B
EN AC-AlSi7Mg (AK7)	6,3	0,462	0,0184	0,126	0,385	0,0412	0,0025	0,0064

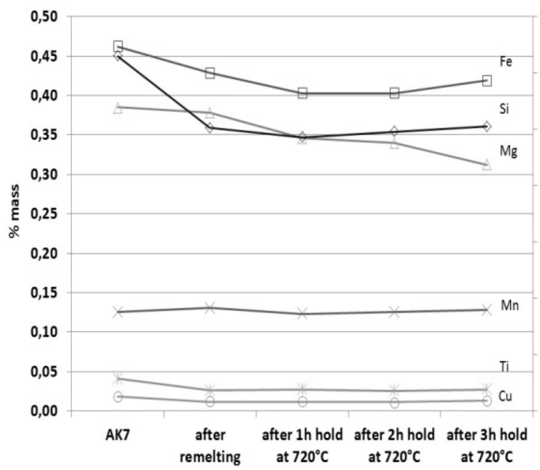


Fig. 3. The chemical composition of AK7 alloy in initial state, after remelting and after hold at a temperature of 720ºC

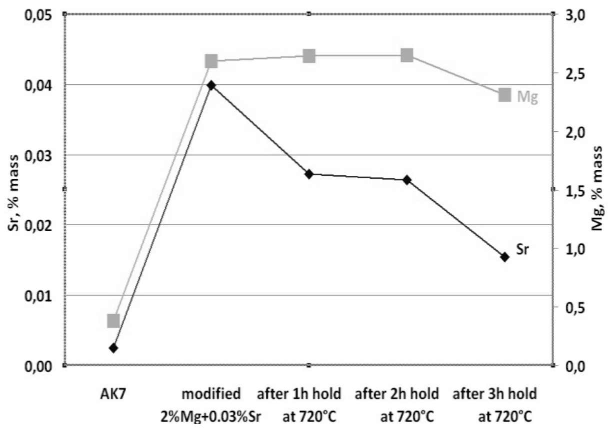
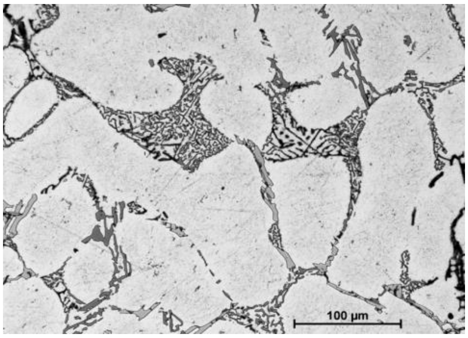
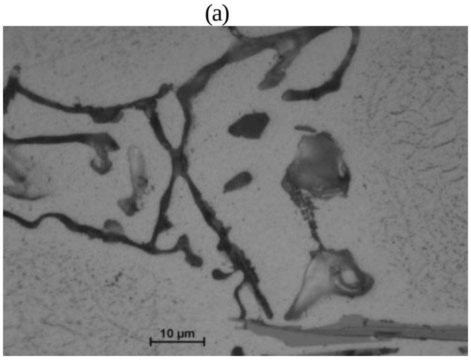


Fig. 4. The mass fraction of magnesium (Mg) and strontium (Sr) in AK7 alloy after modification and after hold at a temperature of 720ºC during 3h

The metallographic examination was carried out in collaboration with the Institute of Non-Ferrous Metals in Skawina. The analysis of hybrid composite microstructure were performed by light microscopy (Olympus GX 71), and scanning electron microscopy (Philips XL30). Analyses of chemical composition and surface distributions of elements (mapping) was performed by using the EDX (EDAX) for chemical analysis in micro-areas.



(a)



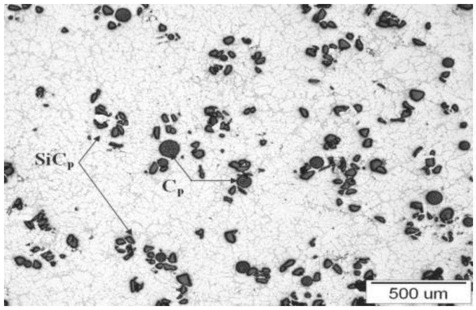
(b)

Fig. 5. The structure of AK7 +2%Mg + 0.03%Sr modified alloy, LM: a) intermetallic phases enriched in Cu, Mn, Si, Fe and Mg are visible; b) phase Al-Mg-Si

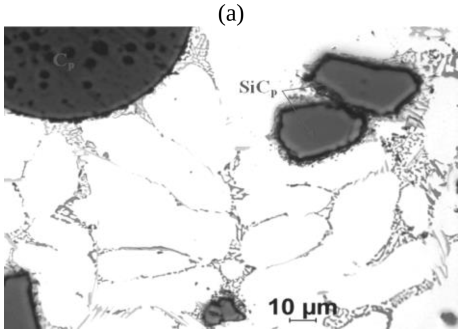
3. Results and discussion

As the analysis of the data, illustrated on Figure 4, after the one hour holding at 720°C temperature the strontium content in the alloy decreases to a value of 0.027%, and after 2 hours, to 0.026% mass fraction. Whereas the mass fraction of magnesium remained at 2.6%. As the microstructure researches showed such participation modifying elements is sufficient to obtain a beneficial at the matrix-particle interface.

Detailed observation the microstructure at the interface between Al alloy matrix with silicon carbide and glassy carbon particles showed increase in the concentration of such elements as: Si, Mg and Sr (Figs. 7, 8). The observed areas of interface between modified matrix alloy and reinforcement particles were clear, sharply outlined with no visible impurities. In the boundary areas the zone of interaction products of the components were no observed (Fig. 3b, 4a). Thus, the increase of Mg concentration in the particle-matrix connection area confirmed beneficial effects its role as modifying element of chemical composition the matrix alloy. Addition of 2% Mg provides good wetting the surface of particles by a liquid alloy. The applied modification provides the proper conditions for the introduction and a uniform distribution of ceramic particles in the liquid aluminum during stir casting process.



(a)



(b)

Fig. 6. The structure of AK7+2%Mg+0.03%Sr/SiC_p+C_p composite, LM: a) uniform distribution of reinforced particles is visible; b) the dark and large glassy carbon particle (C_p) and grey silicon carbide particles (SiC_p) are visible.

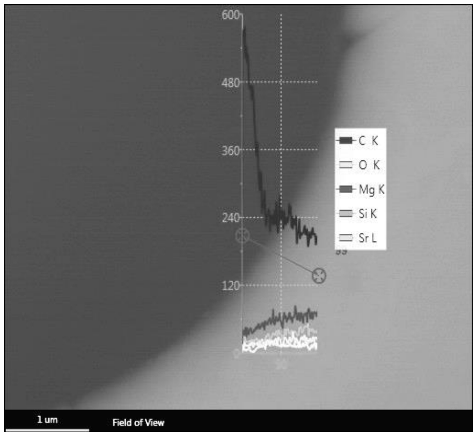


Fig. 7. SEM micrograph of AK7+2%Mg+0.03%Sr/SiC_p+C_p composite showing the chemical distribution on the interface between Al matrix and glassy carbon particles.

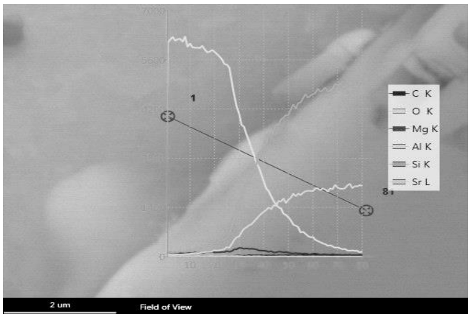


Fig. 8. SEM micrograph of AK7 +2%Mg + 0.03%Sr/SiC_p+C_p composite showing the chemical distribution on the interface between Al matrix and silicon carbide particles.

4. Conclusions

The presented studies have confirmed that the use of known modifiers for aluminum alloys is also suitable for the preparation of composite suspensions. As shown the tested composite was characterized by a uniform distribution of reinforcing particles in the matrix (Fig. 6a). Based on conducted observations and analysis of the microstructure using the techniques of light and electron microscopy was proved getting a good connection between the components and the desirability of modifying additives used (Mg, Sr). The observed change in the concentration of modifiers at the holding time (Fig. 4) does not effect on the manufacturing process of the composite suspension.

Acknowledgements

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