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Structure and properties of aluminum cast composites strengthened by dispersion phases

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This paper presents a fragment of investigations on the use of chemically active and passive composite agglomerates for the production of composites reinforced with fine dispersed particles. In particular, the paper presents some of the results of strength tests with the intention to present the influence of composite agglomerates on selected mechanical properties and structure. The presented systems should be treated as model ones which allow showing the influence of the reinforcement on composites in a cast state.

1. ASSUMPTIONS AND SUBJECT OF RESEARCH

The methods of incorporating fine dispersed particles into a liquid metal applied up to now, make use of the in situ reaction [1] between a liquid metal (or a chemical element being a component of the alloy) and the incorporated reacting substance (most frequently gas, e.g. oxidation of Al by oxygen [2]), run-purge with CnHm gases, as a result of which dissociation and carbides formation occur [3]. The exchange reactions, which proceed between Al and the incorporated oxides of high dispersion (particles of a few dozen micrometers size), also can be used. An example of such a solution is the application of such oxides like CuO [4].

Another solution allowing incorporating fine dispersed particles into Al alloys is to apply a mechanical alloying (MA) process in which Al powder is combined with ceramic powder [5-7]. The application of appropriate grinding and agglomerating parameters leads to ceramic particles size-reduction to a size of about 1 μm and their incorporation into Al powder. Under MA conditions, it is possible to incorporate into the Al powder matrix up to 50 vol.-% of ceramic particles. Best results are obtained for Vp, of about 35%. Such powders are very easy to incorporate into a liquid aluminum alloy, distribute in it and homogenize. Figure 1 show.s examples of structure for Al/SiC and Al/Al_2O_3 composite powders using to metal reinforcing

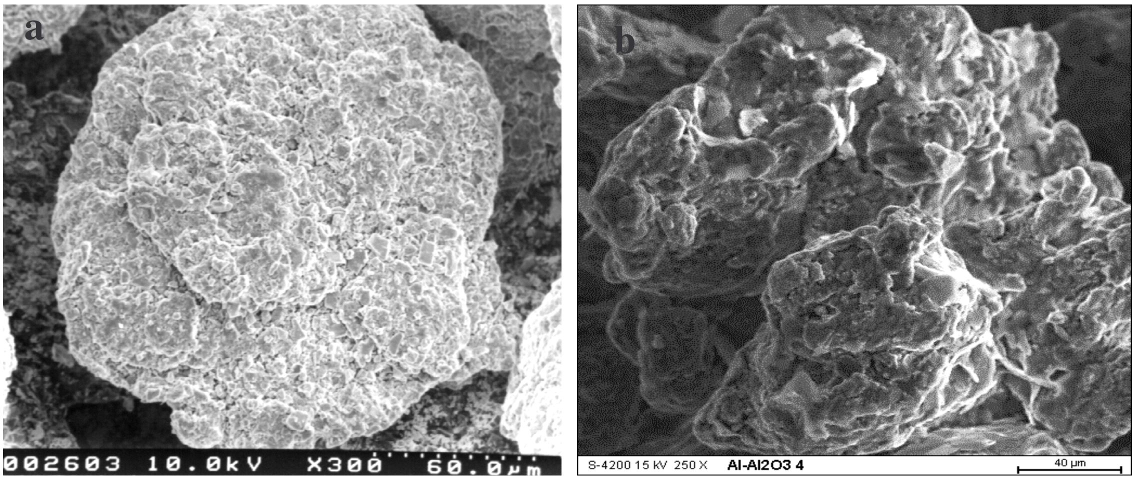

Fig. 1. Structure of Al./SiC (a) i Al./Al_2O_3 (b) composite powders obtained by mechanical alloying process.

Composites for the investigations were formed in two stages. Producing of composite powders by mechanic alloy process was at a first stage. At a second stage consist to introduced and incorporated composite powders into a liquid aluminum alloys in order to created composite suspension.

In case of SiC particles an alloy containing 12% of Si (AlSi12CuMg (AK12) was used, whereas in case of the remaining alloys aluminum was used (99.5%). For comparative purposes composites were also made containing SiC particles in a quantity of 15 vol.-% with particles size of about 10 µm and Al_2O_3 particles in a quantity of 10% of 30 µm size. Composition of composites with reinforced particles and composite powders were used for research are presented in Table 1.

Table 1
Composition of composites were used for research

Matrix	Reinforced Particles	Composites Powders
Al	10% Al_2O_3	
Al	10% Al_2O_3 (30 µm)	30% Al/Al_2O_3
Al		Al/(CuO,$FeTiO_3$,Ni)
Al		CuO
AK12		30%Al/SiC
AK12	15% SiC (10 µm)	

The composite particles before their incorporation into a liquid alloy were held for 2 hours at a temperature of 200^0C and then incorporated into a mechanically stirred liquid metal of 720^0C temperature. After the incorporation of powders, the alloy was homogenized by stirring it in an argon atmosphere for 2 hours and later on it was poured into a graphitoidal ingot mould. Some of the composites formed were again remelted (720^0C) and poured into a cast iron form, obtaining bars of a 12 mm diameter.

2.2. Mechanical properties and structure of composites

Strength tests of composites were performed on an Instron 4468 machine, determining tensile strength and total strain. Impact test was performed by means of Charpy method on an instrumented Resil 50 pendulum machine (with 50 J energy), recording the course of the specimen destruction process. For all shares, measurement of hardness was also made by means of Brinell method. Table 2 presents of all the results research of mechanical properties for aluminum alloy composites obtained with the application of composite powders and mechanical stirring (mixing) of liquid alloy.

Table 2
Mechanical properties.

Composites composition matrix-particles; matrix-composites powder	Tensile strength	Elongation	Brinell hardnes		Impact [J/cm^2]	
	[MPa]	[%]	after casting	after remelting	after casting	after remelting
Al-10% Al_2O_3	84,3	10,5	46,8	45,8	14,2	15,7
Al-10% Al_2O_3 (30 μm) +30%Al/Al_2O_3	84,5	5,7	50,4	51,1	7,3	7,7
Al-Al/(CuO, FeTiO3,Ni)	188,6	7,3	80,4	102,7	28,8	9,7
Al-CuO	133,5	15,4	57,7	56,6	29,8	23,6
AK12-30%Al/SiC	100,9	3,8	-	117,1	-	10,1
AK12-15%SiC (10μm)	222,0	8,3	-	93,2	-	1,45

For composites study was performed metallographic examinations by the Richert MeF2 microscope. These investigations was premised evaluation cast quality and distribution of reinforcement in the matrix alloy (Figure 2).

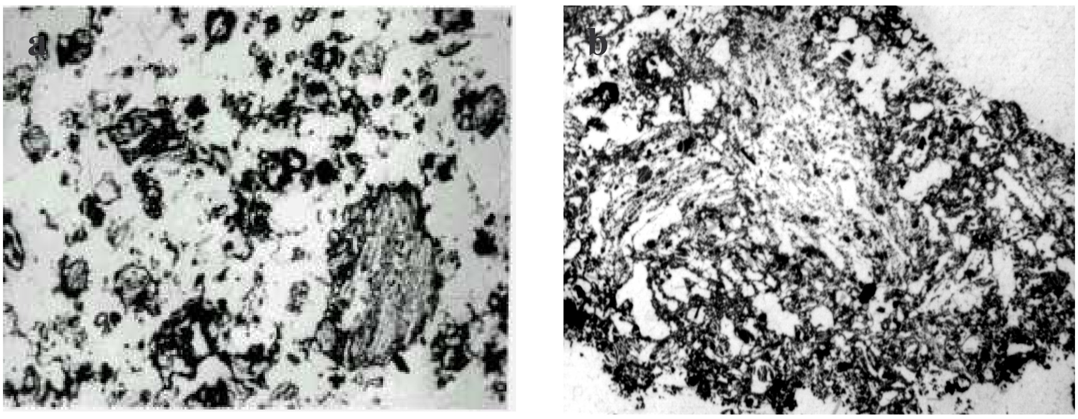

Figure 2. Structure of AlCu2Mg1NiFe1 - Al_2O_3 (a), AlCu4- Al_2O_3 (b) cast composites after casting

Examinations of fractures' structure after tension and after an impact strength test were carried out, as well. Selected fractures and characteristic curves force-displacement for composites obtained in the Charpy impact test are presented in Figures 3 and 4.

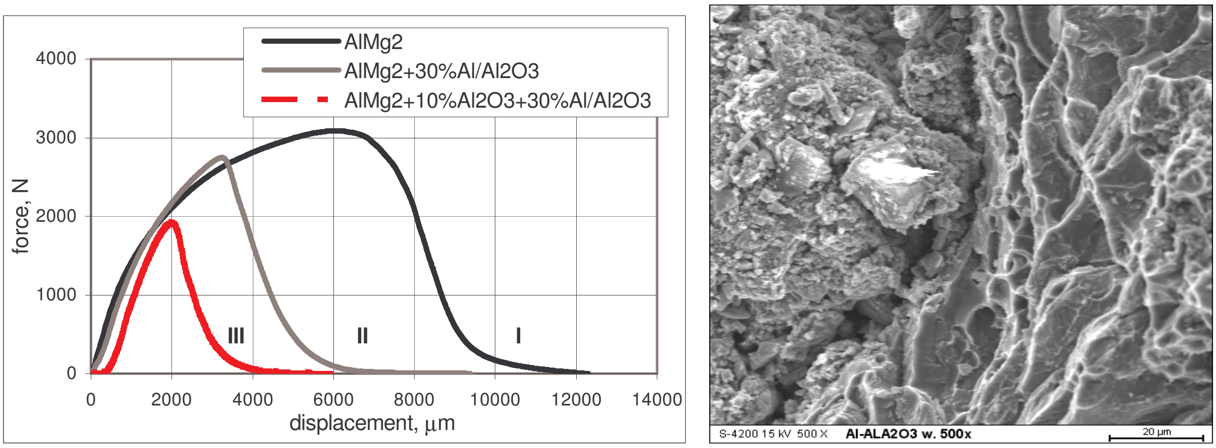

Figure 3. Charpy impact test diagrams for AlMg2 matrix alloy (I), with 30%Al./Al_2O_3 composite powders (II) and 10%Al_2O_3 ceramic particles+30%Al./Al_2O_3 composite powders (III) (a); impact fracture of Al-Al/Al_2O_3 composite (b).

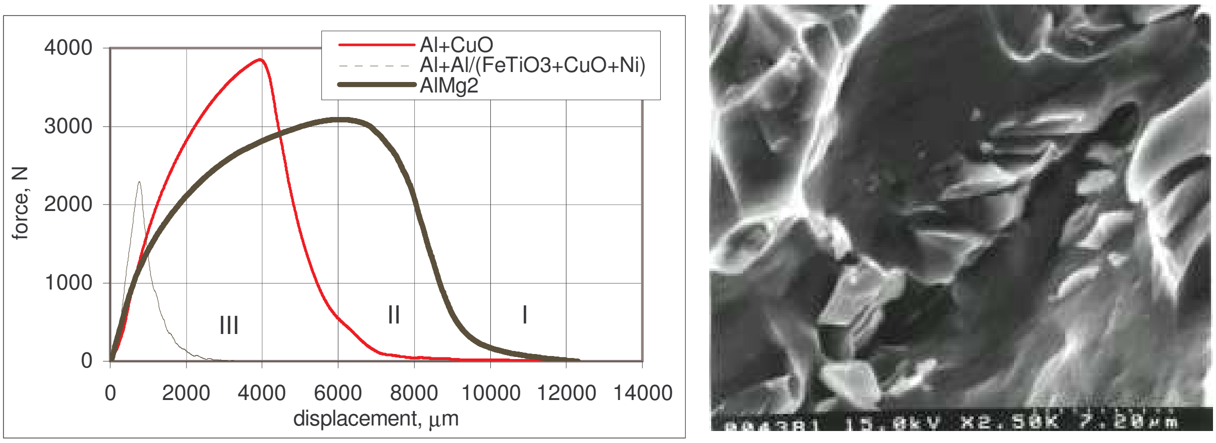

Figure 4. Charpy impact test diagrams for AlMg2 matrix alloy (I) with CuO (II) and Al/($FeTiO_3$,CuO,Ni) composite powders (III) (a); impact fracture of Al-CuO composite (b)

3. ANALYSIS OF RESEARCH RESULTS

As shown in Table 2, the highest tensile strength was obtained in case of using very complex reactive composite powders for the reinforcement. After its formation, a composite with composition 3 is characterized by strength 188.6 MPa. The composition of the composite powder was calculated so as to obtain, after a chemical reaction, an alloy with AlCu2Mg1NiFe1 (PA30) alloy matrix. Likewise, in case of incorporating agglomerates which contain CuO particles, the composition was determined so that after the reaction the matrix alloy should contain up to 3.6% Cu. This composite in a cast state is characterized by tensile strength equal 135 MPa and maintains considerable plasticity (ε =15.4%). In the structure of this group of in situ composites, presence of fine dispersed Al_2O_3 particles was found (Figures 2a, 2b, 4b) of a size of about 1 μm. In case of those two composites, in the state after casting, very high impact strength was obtained amounting to 30 J/cm^2, whereas after remelting, the impact strength of composite with composition 3 clearly fell down to 9.7J/cm^2. This may indicate that in the remelting process a reaction of brittle intermetallic compounds of Fe_xAl_y type takes place, since the composite hardness increases considerably from 80 HB to102 HB.

This kind of a change of properties was not found in composites reinforced by Al_2O_3 and SiC particles, since both after casting and remelting the composites are characterized by a permanents set of properties (Table 2). A long process of homogenization of a composite alloy, which lasted 2 hours, did not improve the properties of those materials. The cause of such a set of properties lies in the phenomenon of maintaining the original structure of composite powder (Figure 5), which after homogenization did not undergo fragmentation. An essential factor which influences the level of properties of this group of composites is casting porosity, which can be removed in the remelting process, as well as the porosity in composite agglomerates which is very difficult to remove.

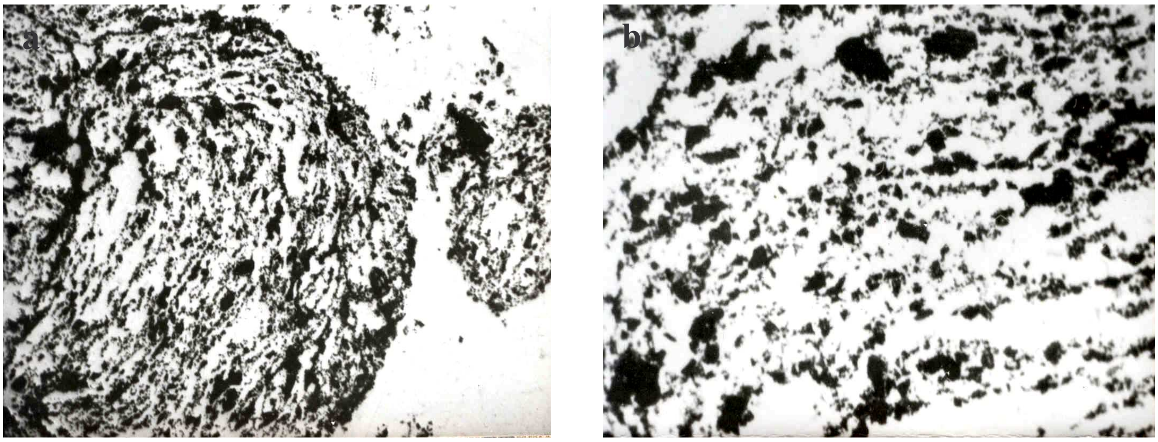

Figure 5. Structure of A-Al/Al_2O_3 composites after 2h homogenization (a) 100 mag, b) 250 mag.

An interesting case is reinforcing the AK12 alloy with SiC particles included in the (Al/SiC) agglomerate, which as opposed to the reinforcement with SiC of 10μm size only, ensures an increase of resistance, hardness as well as impact strength. This effect is probably connected with a decrease of silicon content in the alloy and the presence of plastic composite zones (island structure, Figure 6).

On the basis of the obtained research results, one can claim that from the point of view of strength properties it is more advantageous to apply complex oxides, which lead to obtaining composites of high strength properties in a cast state. It is also advantageous to use composite agglomerates for the reinforcement of casting alloys, especially silumins, since this ensures obtaining high strength properties and good plastic properties.

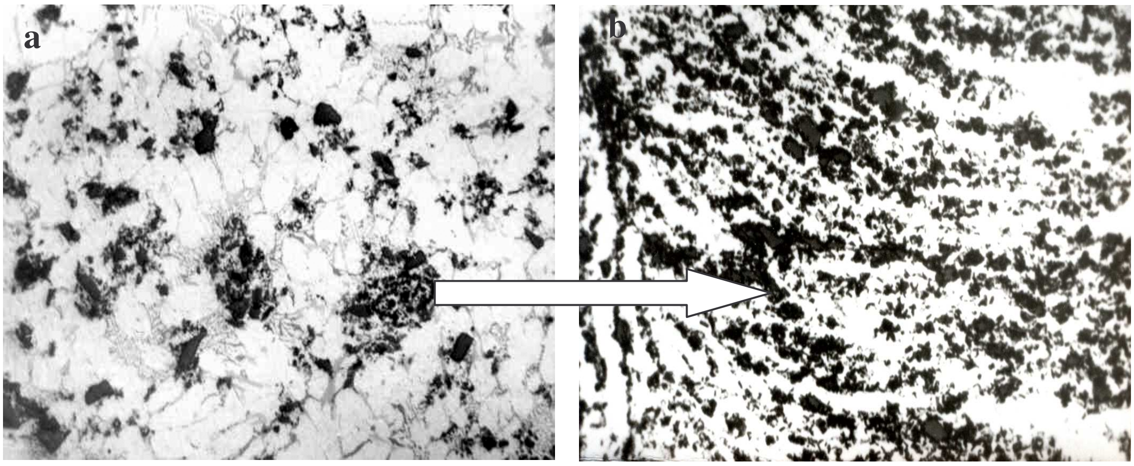

Figure 6. Island structure in AK12-Al./SiC composites after remelting (a); structure of composites powder in the matrix alloy (b)

4. CONCLUSION

Composites reinforced by Al_2O_3 ceramic particles obtained in the in situ process are characterized by high strength properties. Improvement of these properties is possible as a result of optimization of the technological process. Incorporation of composite powders in the systems Al/SiC and Al/Al_2O_3, into casting alloys of silumin type increases their strength and plastic properties in a cast state.

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