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SOME ISSUES ON TAILORING POSSIBILITIES FOR MECHANICAL PROPERTIES OF PARTICULATE REINFORCED METAL MATRIX COMPOSITES[*]

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The evolution of mechanical properties, for some aluminium matrix composites, as a function of the variation of particulate nature and content is reported. The composites were made by Vortex casting and based on a commercial aluminium alloy, with either single-phase or two-phase (hybrid) reinforcement. The reinforcing particles are graphite and silicon carbide, in volume fraction concentrations up to 10%. The mechanical properties were evaluated by hardness measurement and tensile tests, made according to the corresponding standards for metals, at room temperature. On the other hand, an investigation is made on the evolution of mechanical properties and wear resistance of the studied composites, in different conditions of heat treatments. The study suggests that the heat treatment has potential to produce a desired combination of properties in aluminium graphitic composites, by varying the treatment parameters (temperature and duration). By rigorously choosing the balance of the reinforcing phases, together with some technological parameters of the manufacturing process, it is possible to optimize the properties of metal matrix composites.

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1. Introduction

The impressive widspread of the use of composite materials at present could be explained, among other arguments, by the possibility to predict the composite's properties, on the basis of the volumic content and the corresponding properties of the matrix and the reinforcement [1]. In fact, the user can get a new material that is tailored by his demands.

In recent years there was a great deal of interest in particulate-reinforced metal-matrix composites (MMCs), and in particular those based on existing aluminium alloys. Among them, graphitic aluminium alloys have been found to be potential engineering materials for a variety of antifriction and antiwear applications [2]. In such cases, the presence of graphite in the base alloy ensures smooth functioning in service under the conditions of boundary lubrication which are encountered sometimes due to a temporary scarcity of the lubricant.

Some recent studies [3-4] have indicated that there is a wide scope for improving the friction and wear properties of the graphitic aluminium alloys by heat treatment. In addition to this, it is also possible to compensate, to some extent, for the deterioration in their properties such as hardness, strength etc., by the heat treatment, having in view that the deterioration in those properties occurs due to the presence of the weaker graphite particles. This requires the selection of a heat-treatable variety of aluminium alloy matrix for dispersing the graphite particles. Elements like copper, nickel, magnesium etc., when present in the Al alloys, make the latter heat treatable.

On the other hand, the improvement of mechanical properties for the about cited MMCs could be achieved by using, as a second reinforcement, another non-metallic phase (of ceramic nature, in

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principle), having good stiffness and hardness. Such composites are named “hybrid” and their use is now largely in progress, together with their study.

It is very interesting to emphasize the influence that the reinforcing particle volume fraction have to exert on the mechanical properties of MMCs [5]. This fact is important as well in the hybrid particulate composites because, in this case, the balance of the two phases plays as a supplementary parameter in order to control the studied properties.

2. Experimental

This paper focus on the mechanical properties (in connection with some tribological characteristics) of some particulate reinforced composites, based on a commercial aluminium alloy of type ATSi7Cu3Mg, with a nominal composition of 2.93% Cu, 6.6% Si, 0.51% Fe, 0.36% Mg, 0.15% Ti and the balance aluminium. The composites are meant for improving the tribological properties of the base alloy, and are made by Vortex casting, in laboratory conditions, at the Material Science and Engineering Faculty, in Technical University Iasi [6].

Firstly, graphite particles (63μm in size, 3.5% maximum volumic content) are used as a reinforcement. Such composites are recommended for tribological applications, because of graphite self-lubricating properties. This effect is obtained at the cost of decreasing the composite mechanical properties. In a previous study [7], a decrease of about 30% was observed, in terms of elastic modulus and tensile strength for those composites, by comparison with the base alloy. As a consequence, it is observed a high loss-weight for the studied composites, in sliding friction against steel or cast iron [8].

2.1. Heat Treatments

In order to attenuate the above cited negative effect of the soft particles, a heat treatment could be applied on the composite specimens. Optimisation of the temperature and duration of the treatment plays an important role towards obtaining a good combination of the matrix microstructure and certain properties of the composite.

The present investigation was carried out to determine the response of the studied composites, over a range of solutionizing times, in terms of changes in mechanical and tribological properties. In view of this, the composite samples were submitted to a solution hardening treatment, by heating at 520-530 ^{0}C deg., for a range of times situated between 4 and 8 hours, quenching in hot water, followed by ageing for 8 hours at 160-170 ^{0}C deg.

2.2. Test Methods

The suitable heat treatment parameters were established, for the studied composites, by analysing their influence on the ultimate tensile strength (UTS), elastic modulus (E) and Brinell hardness (HBS) values. The mechanical tests were made according to the corresponding standards for metals, and were conducted in laboratory atmosphere, at room temperature.

The tribological behaviour of the investigated materials was evaluated in tests using MMC shoes sliding, in dry conditions, against a hard steel roll, by measuring the weight-loss of the shoes in dependence with sliding distance.

2.3. Hybrid composites

Afterwards, having in view the strengthening of the composites, silicon carbide particles (40 μm in size, 2-9 % volume fraction) are introduced into the base alloy structure, simultaneously with the graphite particles (and maintaining the above cited characteristics), as a second reinforcement. The evolution of hybrid composite mechanical properties, as a function of particle volume content, was also estimated by Brinell hardness measurement and by tensile tests.

3. Results and discussion

The results of the above mentioned experiments will be presented and also discussed into the next paragraphs, giving emphasis to the influence of the experimental parameters on the variation of mechanical and tribological properties of MMCs. It will result the possibility of using those parameters in order to control some physical characteristics of composite materials.

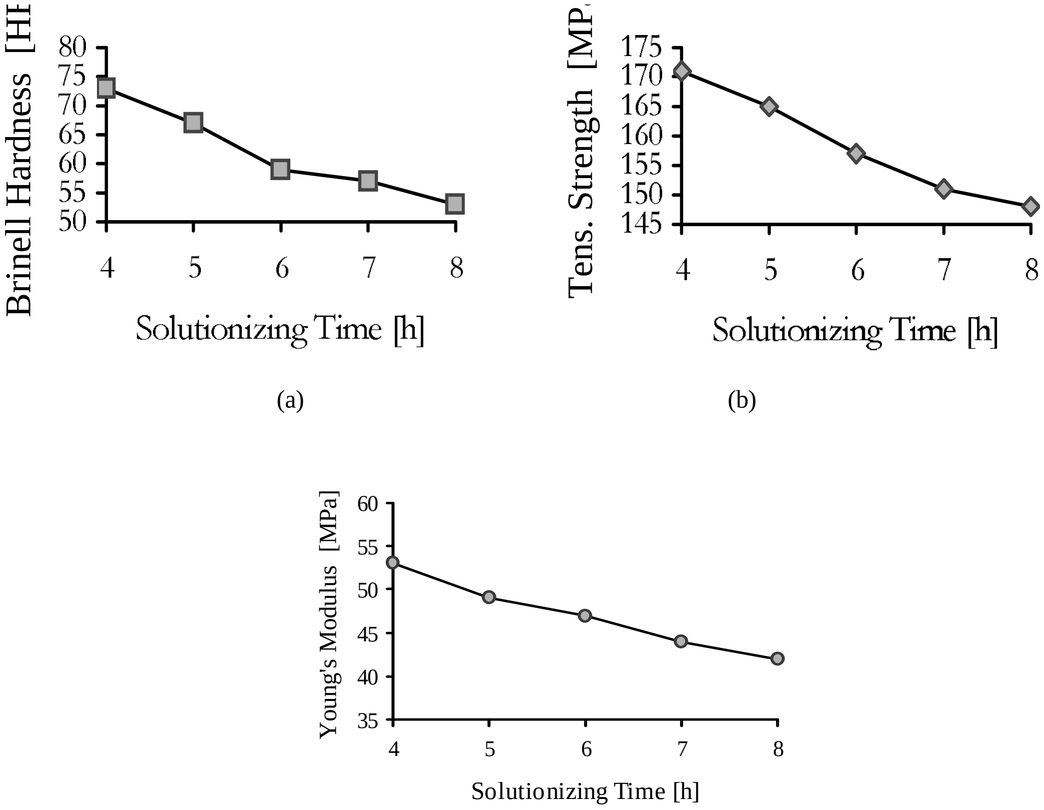
3.1. Heat treatment influence

The evaluated mechanical properties (including Brinell hardness, ultimate tensile strength and Young modulus, in average values) of the studied materials are briefly presented in Table 1 and Fig. 1, together with the indication of the maintaining time during the solutionizing treatment.

It is observed a trend to decrease in the mechanical properties of the composite, at the extension of the solutionizing time. One can note that some reduction of composites hardness and rigidity could be able to make them acceptable to certain antiwear applications, but it appears that the extension of solutionizing time over 5 or 6 hours could determine an unacceptable decreasing of those properties.

Table 1. Room temperature hardness and tensile properties of the investigated materials.

	Solutionizing time [h]	HBS	UTS [MPa]	E [GPa]
1.	4	73	171	53
2.	5	67	165	49
3.	6	59	157	47
4.	7	57	151	44
5.	8	53	148	42



(a) (b)

(c)

Fig. 1. Variation of composite hardness (a), tensile strength (b) and elastic modulus (c) as a function of solutionizing time.

The evaluation of tribologic behaviour of the investigated materials is illustrated in Figure 2, which contains the image of the interdependence between the loss-weight of MMCs sliding shoes and the sliding distance.

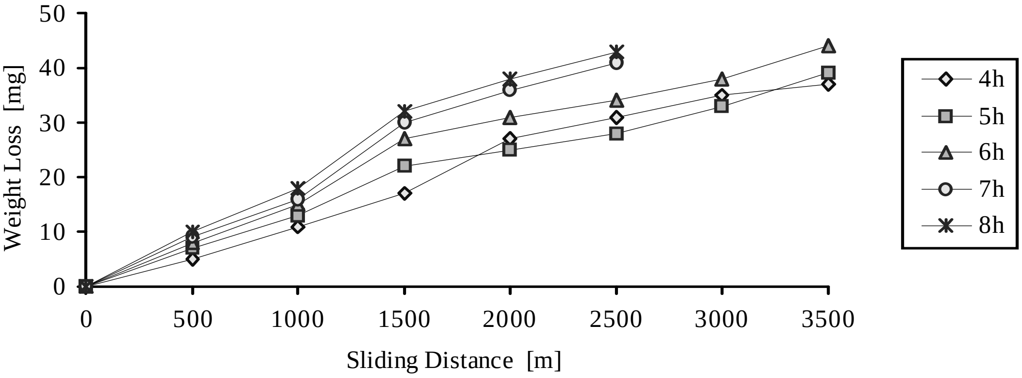


Fig. 2. The variation of weight loss, as a function of sliding distance, in shoe-on-roll tribologic experiment, for MMCs with different solutionizing time.

It was observed a similar trend into the sliding process, for all the composite samples: the initial increasing of loss-weight was followed by a reduction in wear rate, at a level that seems to be dependent on the mechanical properties of the composite material.

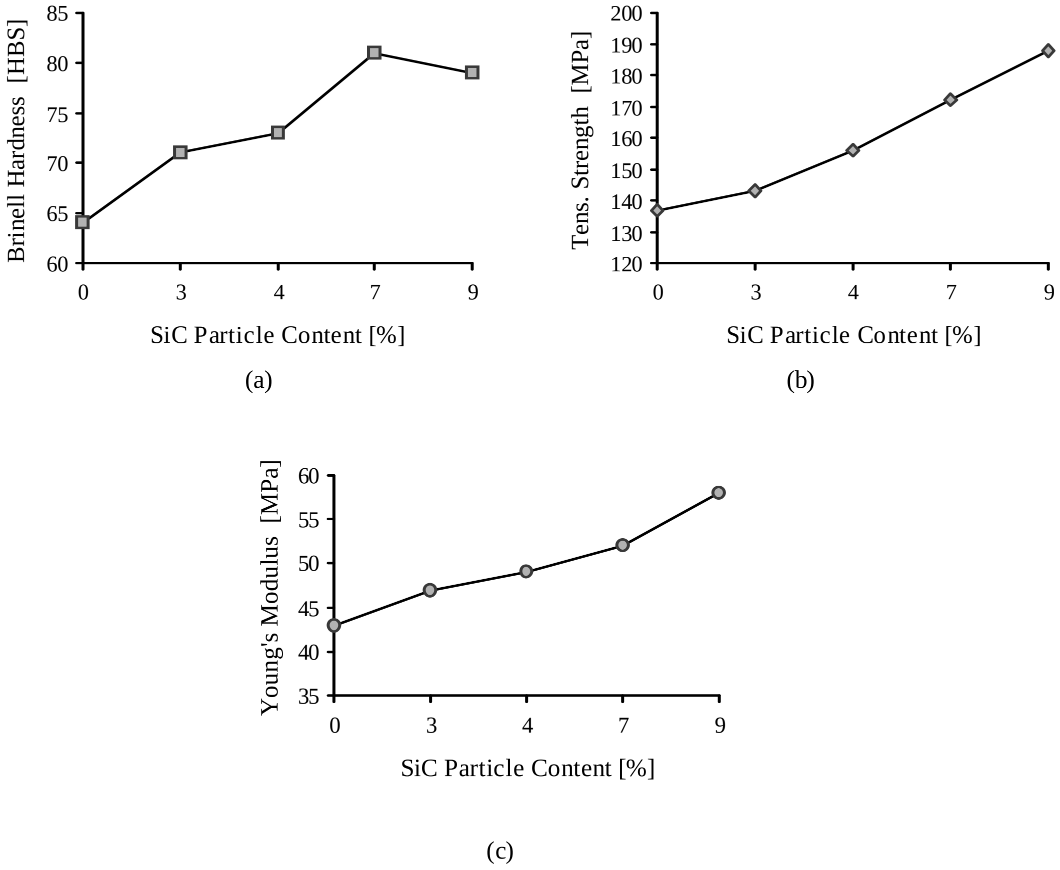
As a consequence, it appears that the samples with a solutionizing time of 4 and 5 hours have the most favourable wear resistance. It must be mentioned that the samples with 7 h and 8 h solutionizing time showed a premature scuffing tendency, in his slide against the hard steel roll. This fact seems to confirm the disadvantage of increasing the solutionizing time over the level of 5 or 6 hours.

3.2. Influence of SiC volume fraction

The mechanical properties (including HBS, UTS and E, as averages of the corresponding experimental values) of the materials that were analyzed are briefly presented in Table 2 and in Fig. 3. One can observe that the influence of SiC particle content was studied by using 5 groups of material samples, with 3.5 Wt. % particle content and different SiC particle volume fractions.

Table 2. Influence of SiC particle volume fraction on the mechanical properties of hybrid composite.

Sample type	SiC [%]	Wt [%]	HBS	UTS [MPa]	E [GPa]
1.	-	3.5	65	137	43
2.	3.0	3.5	71	143	47
3.	5.0	3.5	73	156	49
4.	7.0	3.5	81	172	52
5.	9.0	3.5	79	188	58



(a) (b)

(c)

Fig. 3. Variation of composite hardness (a), tensile strength (b) and elastic modulus (c) as a function of ceramic particles content.

The addition of an incremental content of SiC particles has various effects on the composite properties:

- the Brinell hardness is little influenced, and an increase over 7% of ceramic particles content seems to be inefficient (see Fig. 3a);
- the tensile strength has a permanent enlargement, which is quasi-proportional with the SiC content (see Fig.3b);
- the elastic modulus has a non-linear, but continuous increase in dependence of SiC particle volume fraction (see Fig. 3c).

It is important to note the conclusion of a previous investigation [9] of the present author: the tribological properties (wear rate and friction coefficient, in sliding lubricated contacts) of hybrid particulate aluminium matrix composites are also influenced by the nature and the volumic content of reinforcing particles. Therefore, those properties could be controlled, too, by a suitable choice of the above mentioned parameters.

4. Conclusions

The results that are presented in this paper lead to the following conclusions, in connection with the initial purposes of the study:

The mechanical properties of aluminium based hybrid particulate composites can be controlled by modifying the nature and the volumic content of reinforcement.

The parameters of heat treatments could also be used in order to modify the mechanical and tribological properties of the investigated composite.

The increase of solutionizing time leads to unfavourable effects both in mechanical and tribological properties, including the expansion of weight-loss in material, on an imposed sliding distance. It can be considered inadvisable, for the investigated aluminium matrix composite, a solutionizing duration over 4 or 5 hours.

One can conclude that by rigorously choosing the volumic content of reinforcing particles, together with suitable casting and heat treating conditions, it is possible to optimise the mechanical properties of the hybrid metal matrix composites. As a consequence, one can control some other physical properties (tribological, for example) of these materials, corresponding to their possible beforehand selected applications.

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