Microstructure, Friction and Wear of Aluminum Matrix Composites

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Abstract. MMCs are made by dispersing a reinforcing material into a metal matrix. They are prepared by casting, although several technical challenges exist with casting technology. Achieving a homogeneous distribution of reinforcement within the matrix is one such challenge, and this affects directly on the properties and quality of composite. The aluminum alloy composite materials consist of high strength, high stiffness, more thermal stability, more corrosion and wear resistance, and more fatigue life. Aluminum alloy materials found to be the best alternative with its unique capacity of designing the materials to give required properties. In this work a composite is developed by adding silicon carbide in Aluminum metal matrix by mass ratio 5%, 10% and 15%. Mechanical tests such as hardness test and microstructure test are conducted.

1. Introduction

The “composite” term refers to a material system which is composed of a discontinuous constituent (reinforcement) distributed in a continuous phase (matrix), and which has distinguishing characteristics like the properties of its constituents, the geometry and architecture of the constituents, and the properties of the boundaries (interfaces) between different constituents [1-3]. This paper has the subject of metal matrix composites and more specifically on the aluminium matrix composites (AMCs). In AMCs one of the constituent is aluminium alloy, the matrix phase. The other constituent is embedded in this aluminium alloy matrix and serves as reinforcement, which is ceramic, SiC<sub>p</sub>. Properties of AMCs can be modified by varying the nature of constituents and their volume fraction.

The major advantages of AMCs compared to unreinforced materials are as follows [1, 4, 5]:

• Improved damping capabilities;
• Reduced density (weight);
• Greater strength;
• Thermal/heat management;
• Improved stiffness;
• Improved high temperature properties;
• Controlled thermal expansion coefficient;
• Control of mass (especially in reciprocating applications);
• Enhanced and tailored electrical performance;
• Improved abrasion and wear resistance.

The aim of this paper was the obtaining and the investigation of a metal matrix composite with three different percent of reinforcement.
2. Processing of AMCs

2.1. Liquid state processing
This involves incorporation of ceramic particle into liquid aluminium alloy. The crucial thing is to create good wetting between the particle reinforcement and the liquid aluminium alloy matrix. The simplest and most commercially used technique is known as Vortex technique or stir-casting technique.

The Vortex technique involves the incorporation of pre-heated ceramic particles into the vortex of molten alloy created by the rotating impeller. Lloyd [6] reports that vortex-mixing technique for the preparation of an aluminium matrix composites with ceramic particle dispersed was originally developed by Surappa & Rohatgi [7] at the Indian Institute of Science.

2.2. Preparation of Aluminium-Silicon Carbide Composite
Casting is one of the most ancient processes of manufacturing metallic materials. The metal matrix composite used in the present paper was prepared by the Vortex method. For the preparation of the Al/\text{SiC}_p, particles mass of 5%, 10% and 15% are taken. Figure 1 illustrates the schematic set up for Vortex technique. A three-phase electrical resistance furnace with temperature controlling device is used for melting. For each melting 500 g of alloy is used. The pre-heated molten metal is degassed at a temperature of 780 °C. SiC particles, preheated at 500 °C, are then added to the molten metal and mixed continuously by a mechanical stirrer at 720 °C.

The mixing time is between 5 and 8 minutes. During the mechanical agitation, Borax powder in small quantities was added to increase the wettability of SiC particles.

The metallic melt, with the reinforced particles, was poured into the cylindrical metallic mould. The pouring temperature was maintained at 680 °C. The melt was allowed to solidify in the mould in normal conditions.

![Figure 1. Schematic set up for Vortex technique [8]: 1. Motor; 2. Shaft; 3. Molten aluminium; 4. Thermocouple; 5. Particle injection chamber; 6. Insulation hard board; 7. Furnace; 8. Graphite crucible.](image)

3. Investigation of Al/SiC_p

3.1. Microstructure Test
Metallographic samples were sectioned from the obtained composites. A 0.5 % HF solution was used to etch the samples. To observe the difference of SiC_p distribution in the aluminium matrix, microstructure of samples were taken on Optical type Metallurgical Microscope (Make: Nikon, Range-X50 to X1500).
All three samples were obtained by using Vortex technique by taking varying weight fractions of SiC<sub>p</sub>. The various weight fractions were (5%, 10% and 15%) of SiC particles. Figures 2a, 2b and 2c shows micrograph’s of samples containing 5%, 10% and 15% SiC by weight. It is clearly showed the resulting homogeneous distribution of particles in the samples.

![Micrographs of samples containing different SiC weight fractions](image1)

**Figure 2.** Microstructure of Al/SiC<sub>p</sub> samples for different % of SiC: (a) 5%; (b) 10% and (c) 15%.

### 3.2. Hardness Test

The hardness test were conducted on Automatic Optical Brinell Hardness Tester Model OPFB. Bulk hardness measurements were carried out on the aluminium alloy and composite samples using the standard Brinel hardness test. The Brinel hardness measurements were carried out in order to investigate the influence of SiC<sub>p</sub> weight fractions on the composite hardness. The applied load was 250N, and the indenter was a steel ball of 5 mm in diameter. Hardness values obtained are given in Table 1.

| Sample No. | % SiC<sub>p</sub> by weight | Hardness in BH |
|------------|----------------------------|----------------|
| 2.         | 5                          | 41             |
| 3.         | 10                         | 47             |
| 4.         | 15                         | 60             |

Table 1. Hardness values of obtained sample with different SiC contents.
3.3. Friction and wear

The investigations were performed with a composite block sliding on cylinder surface made of hardened ground steel. The parameters of the tests are presented in Figure 3.

In some cases, the composites proved applicable, as sliding bearings infiltrated by oil (porous sliding bearing) or as a high-speed sliding bearing lubricated by oil. Are also useful as a material for pistons and cylinders of small engines running at very high rotation speed [9].

![Figure 3. Coefficient of friction of different aluminium composites in function of SiC<sub>p</sub> content.](image)

Also, it was investigated the wear behavior of the pure Al alloy and of the metal matrix composites reinforced with SiC<sub>p</sub> using a ball-on-disc test at room temperature under low loads and dry conditions. It was found that SiC particles increased the macro hardness (Figure 4).

![Figure 4. Variation of macro hardness of Al/SiC<sub>p</sub> function of SiC content.](image)
Metallographic investigations have revealed that hardened layers were developed on the sliding surfaces, in which fragmented Si phase was redistributed and aligned parallel to the sliding direction (Figure 5 and 6). It can be seen that the thickness of the hardened layer formed on the obtained composites was reduced by the incorporated SiC\textsubscript{p}. The fragmentation of Si phase was found to be lesser magnitude in the Al/SiC\textsubscript{p} leading to lower wear rate.

![Figure 5](image1.png)

**Figure 5.** Subsurface layer of Al matrix after wear test with fragmented Si.

![Figure 6](image2.png)

**Figure 6.** Subsurface layer of Al/SiC\textsubscript{p} containing 15% SiC particles after wear test.

4. Conclusions

Silicon carbide particle reinforced aluminium matrix composite (Al/SiC\textsubscript{p}) were prepared by Vortex technique casting with different particle weight (5\%, 10\%, and 15\%) and the following conclusions can be drawn:

- Metallographic samples show a homogeneous distribution of particles in the metal matrix;
- Hardness of Al-SiC\textsubscript{p} is much better than the aluminum metal. In case of increased silicon carbide content, the hardness, and material toughness are enhanced and highest value is obtained at 15\% SiC content;
- SiC\textsubscript{p} increase the macro hardness;
- Obtained composites proved applicable, as sliding bearings infiltrated by oil (porous sliding bearing) or as a high-speed sliding bearing lubricated by oil. Are also useful as a material for pistons and cylinders of small engines running at very high rotation speed.
5. References

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