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# Mechanical Properties Of Metal Matrix Composite Of Aluminum (7075) And Silicon Carbide

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**Abstract**

The development of new metal matrix composites (MMC's) is ever increasing and development of aluminum based MMC's is essential because of its properties. Al and its MMC's have wider applications in automobile and aircraft industries due to their high strength to weight ratio. The objective of this work is to conduct a detailed assessment of the mechanical properties of A 7075-SiC composites. In this work a composite is developed by adding silicon carbide in Aluminum metal by mass ratio 2%, 4% and 6%. The composite is prepared by melt stir casting technique. Mechanical tests such as tensile strength, yield strength, % Elongation, impact test and hardness test are conducted. It is observed that the hardness of the composite is increased with increase of reinforced particle weight fraction. The tensile strength and impact strength both are increased with rising of reinforced weight fraction compared to pure metal. Different mechanical tests were conducted and presented by varying the weight fractions of SiC.

***Key Words:*** *Metal Matrix Composites (MMC's), Melt stir casting technique, Silicon Carbide (SiC).*

## 1. Introduction

Aluminum alloy materials are combinations of materials. They are made up of combining two or more materials in such a way that the resulting materials have certain design properties or improved properties. Aluminum Silicon carbide alloy composite materials are widely used for a many number of applications like engineering structures, industry and electronic applications, sporting goods and so on.

Metal Matrix Composite (MMC) is engineered combination of metal (Matrix) and hard particles (Reinforcement) to tailored properties. Metal Matrix Composites (MMC's) have very light weight, high strength, and stiffness and exhibit greater resistance to corrosion, oxidation and wear. Fatigue resistance is an especially important property of Al-MMC, which is essential for automotive application. These properties are not achievable with lightweight monolithic titanium, magnesium, and aluminum alloys. Particulate metal matrix composites have nearly isotropic properties when compared to long fibre reinforced composite. But the mechanical behavior of the composite depends on the matrix material composition, size, and weight fraction of the reinforcement and method utilized to manufacture the composite. The distribution of the reinforcement particles in the matrix alloy is influenced by several factors such as rheological behavior of the matrix melt, the particle incorporation method, interaction of particles and the matrix before, during, and after mixing [1].

Non homogeneous particle distribution is one of the greatest problems in casting of metal matrix composites [2]. Nai and Gupta [3] reported that the average coefficient of thermal expansion of the high SiCp end was reduced as compared to that of the low SiCp end. Hashim et al. [4] reported that the distribution of the reinforcement material in the matrix must be uniform and the wettability or bonding between these substances should be optimized. Aluminum-silicon carbide metal matrix composite has low density and light weight, high temperature strength, hardness and stiffness, high fatigue strength and wear resistance etc. in comparison to the monolithic materials [5].

However, aluminum alloy with discontinuous ceramic reinforced MMC is rapidly replacing conventional materials in various automotive, aerospace, and automobile industries [6]. Amongst various processing routes stir casting is one of the promising liquid metallurgy technique utilized to fabricate the composites. The process is simple, flexible, and applicable for large quantity production. The liquid metallurgy technique is the most economical of all the available technique in producing of MMC [7].

Aluminum alloy-based composites containing 10wt% alumina (size range: 150- 225 mm) were prepared by liquid metallurgy technique using the vortex method [8,9]. The ZnO whiskers 25 vol% reinforced with Al-matrix composites were fabricated by a squeeze casting process [10]. The quartz-silicon dioxide particulates reinforced LM6 alloy matrix composites were fabricated by carbon dioxide sand molding process [11]. Various researchers have utilized conventional stir casting technique for producing MMC [12,13,14,15] but still applied research is needed for successful utilization of the process for manufacturing of MMC.

In this study stir casting is accepted as a particularly promising route, currently can be practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production [16], and allows very large sized components to be fabricated. The cost of preparing composites material using a casting method is about one-third to half that of competitive methods, and for high volume production, it is projected that the cost will fall to one-tenth [17].

From the review, it is found that number of research work on wear behaviour of MMCs have been published, but only few work related to the influence of weight fraction on mechanical properties like tensile strength, hardness, impact strength, percentage of elongation etc. have been reported. In this work, different weight fractions of Silicon Carbide particulates are added with aluminum matrix to fabricate the Al/SiC metal matrix composites. Different samples have been fabricated by melt-stirring casting and their hardness, tensile strength, and impact strength are carried out. In this study the influences of the reinforced particulate size (220mesh) and weight fraction (2%, 4% and 6%) on mechanical properties like Tensile strength ($N/mm^2$), Yield strength ($N/mm^2$), % Elongation, Hardness (HRB) and Impact Strength (J) is investigated.

## 2. Materials and Experiments

### 2.1 Fabrication of Al/SiC Metal Matrix Composites

Silicon Carbide (SiC) reinforced particles of average particle size 220 meshes, 300 meshes, 400 meshes is used for casting of Al / SiC-MMCs by melt-stir technique. Table 1 represents the chemical composition of commercially available Al-matrix used for manufacturing of MMC. Different dimensions of round bars with 2%, 4 % and 6% of reinforced particles of size 220 mesh respectively.

Experiments were carried out to study the effect of settling the reinforced particulates on the solidification of mechanical properties of the cast MMC's. In the present study, commercially available aluminum (7075) is used as matrix reinforced with Silicon Carbide (SiC) particulates. The melting was carried out in a clay-graphite crucible placed inside the resistance furnace. An induction resistance furnace with temperature regulator cum indicator is utilized for melting of Al/SiC-MMCs. A design and developed stirring setup is shown in fig 1. Aluminum alloy (Al 7075) was first preheated at 450°C for 2 hours before melting and SiC particulates were preheated at 1100°C for 1 hour 30minutes. to improve the wetness properties by removing the absorbed hydroxide and other gases. The furnace temperature was first raised above the melting temperature, that is, 750°C, to melt the matrix completely and then it was cooled down to just below the melting temperature to keep the slurry in a semi-solid state.

At this stage the preheated SiC particles were added and mixed mechanically. The composite slurry was then reheated to a fully liquid state and mechanical mixing was carried out for 20min at 200rpm average stirring speed. In the final stage of mixing, the furnace temperature was controlled within 760 ± 10°C and the temperature was controlled at 740°C. Mould (size 15mm diameter ×100mm long) made of IS-1079/3.15mm thick steel sheet was preheated to350°C for 2 hours before pouring the molten Al/SiC -MMC. Then fabrication of composite was followed by gravity casting. Similar process was adapted for preparing the composite specimens. The following table1 shows the chemical composition of matrix aluminum 7075.

Table 1: Chemical composition of matrix Al 7075 alloy

| Elements of Al 7075 | Si | Mn | Mg | Cu | Fe | Ti | Cr | Zn | Al |
|---|---|---|---|---|---|---|---|---|---|
| % | 0.4 | 0.3 | 2.5 | 1.6 | 0.5 | 0.2 | 0.15 | 5.5 | remaining |

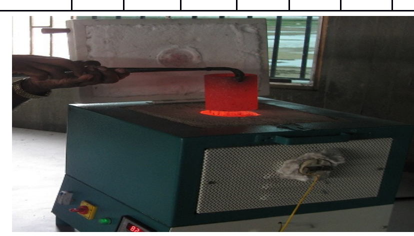

Fig. 1 Melt-stirring setup utilized for casting of composites

Fig. 2 Al – 7075 with Silicon Carbide composite material

## 2.2 Tensile Test

In any design work, it is important to consider practically realizable values of strength of the materials used in design. The tensile test is one of the basic tests to determine these practical values.

| Sample Identification | Observed Value | | |
|---|---|---|---|
| | Tensile Strength ($N/mm^2$) | Yield Strength ($N/mm^2$) | Elongation (%) |
| 2% of SiC | 202 | 150 | 33 |
| 4% of SiC | 255 | 224 | 27 |
| 6% of SiC | 265 | 242 | 25 |

The tensile test was conducted in accordance with ASTM D3039 on a universal testing machine (UTM MS OES – 2) at room temperature. The sample of dimensions 100 x 15 mm in cylindrical shape. The sample of 100mm length was clamped between the jaws of machine with each end covering 20mm of sample. The tensile load was applied over 60mm span length at a constant strain rate of 10mm per minute. The tensile load was applied till failure.

## 2.3 Impact Test

The notched izod impact strength test was conducted at room temperature in accordance with ASTM D 256 on a impact test machine (ITM MS OES-2). The specimen of dimensions 63.5 x 10 x 3.5 mm where used for impact strength analysis. Before testing a notch was developed on each specimen at an angle of 450 and 2 – 2.5mm depth. The specimen was clamped in a square support was struck at a central point by hemispherical bolt of diameter 5mm.

## 2.4 Hardness Test

Hardness tests were performed on metal matrix composite specimens. The hardness values of the specimen were measured using Brinell hardness testing (BHTM OES-2) system with 10mm diameter at a load of 500 kg. The detention time was 30 seconds. Three tests were taken on each specimen to eliminate possibility of segregation and mean value was considered.

# 3. Results and Discussion

Various Experiments were conducted on fabricated MMCs samples by varying weight fraction of SiC (2%, 4% and6 %) and size of SiC particles (220 mesh) to analyze the casting performance characteristics of Al/SiC-MMCs.

## 3.1 Tensile Strength

The table 2 shows the effect of aluminum and SiC reinforcement content on the Ultimate Tensile Strength, Yield strength and elongation of the metal matrix composites specimen.

Table 2: Results Obtained on Composite Specimen

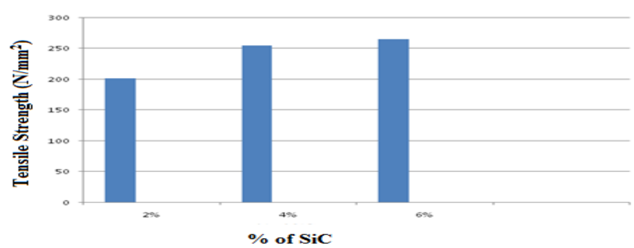


Fig. 3 Tensile strength of SiC reinforced AMCs

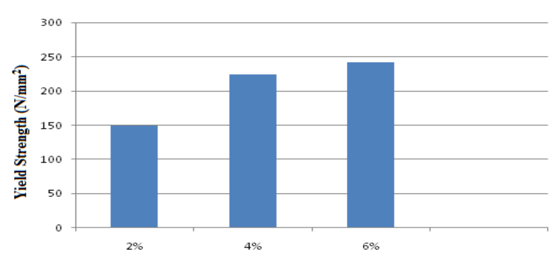

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Table 3: Result of Impact Test

| Weight Fraction of SiC | Energy Observed Vale in J |
|---|---|
| 2% of SiC | 0.72 |
| 4% of SiC | 0.82 |
| 6% of SiC | 0.85 |

Fig. 4 Yield Strength of SiC reinforced AMCs

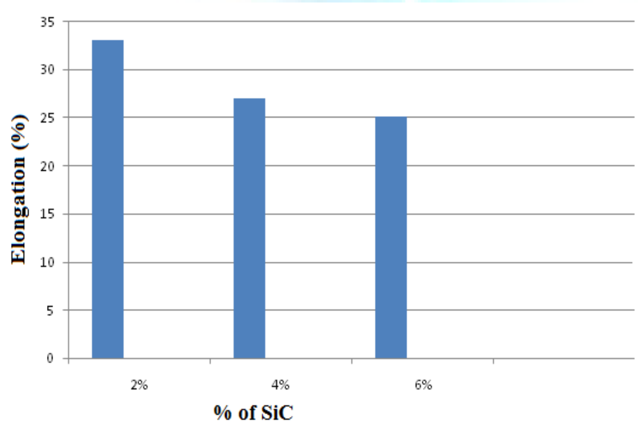



Fig. 5 Elongation of SiC reinforced AMCs

The Tensile properties of the Al 7075 and SiC MMCs for three different volume fractions at ambient temperature expose an increase in Ultimate Tensile Strength, Yield strength with increase in reinforcement content in the aluminum alloy matrix.

The fig 3 reveals that the Ultimate Tensile Strength of the composite increases about 50 percent with the addition of 6 percent of SiC. The fig. 4 exposes increase in yield strength of the composite about 40 percent by the addition of SiC the reinforcement. The fig 5 discloses decrease in elongation of the composite with the increase in weight fraction (2%, 4% and 6%) of SiC particles.

## 3.2 Impact strength

Impact Test was carried out on Izod Impact testing machine and results were recorded in table 2. According to size and weight fraction of SiC particles.

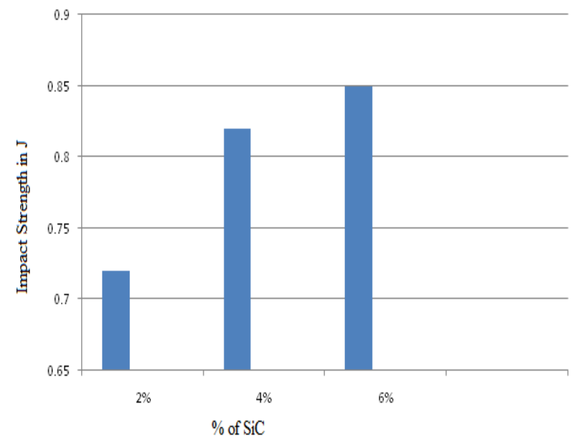



Fig 6 Impact strength of SiC reinforced AMCs

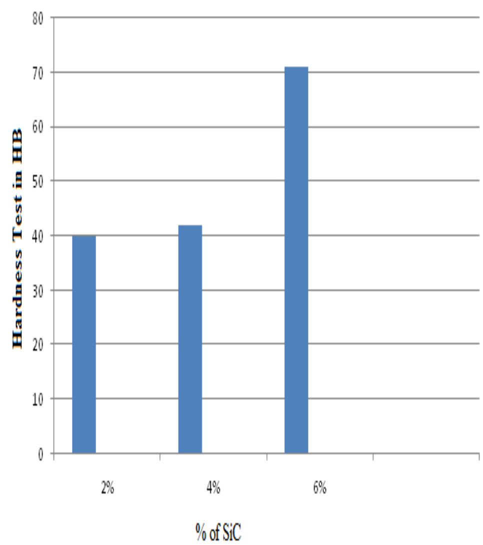
From the graph it becomes clear that impact strength of specimen is higher for 6% of SiC. Hence it is suggested that more the percentage of SiC more the impact strength. The graph shows a constant increase in impact strength for increase in percentage of SiC. Hence for areas requiring more impact strength more percentage of SiC can be added to make the metal matrix composite most suitable for our desired application.

## 3.3 Hardness Strength

Bulk hardness measurements are carried out on the metal matrix composite samples by using the standard Brinell hardness results were recorded in table 4. The Brinell hardness measurements are carried out in order to investigate the influence of SiC particulate weight fractions on the matrix hardness.

Table 4: Result of Hardness Test

| Sample ID | Observed Value (In HB) |
|---|---|
| 2% of SiC | 40 |
| 4% of SiC | 42 |
| 6% of SiC | 71 |




The fig 7 shows the effect of particulate reinforcement on the Brinell Hardness Number (BHN). The hardness of the composite increases about 60 percent as the reinforcement content of the silicon carbide is increased from 0 to 6 percent. The hardness of the composite specimen is increased with increase in the percentage of particulate reinforcement.

## 4. Conclusions

The investigation reveals the following conclusions:

**(a) Tensile Strength**: From the result graphs Proportionality ($N/mm^2$) limit, Tensile strength, yield strength increases with the increase in weight fraction (2%, 4% and 6%) of SiC particles. % Elongation decrease with the increase in weight fraction (2%, 4% and 6%) of SiC particles.

**(b) Impact Strength (J)** increases with the increase in weight fraction (2%, 4% and 6%) of SiC particles. Maximum Impact Strength = 0.85 J has been obtained at 6 % weight fraction of SiC particles.

**(c) Hardness (HB)** increases with the increase in weight fraction (2%, 4% and 6%) of SiC particles. Maximum Hardness = 71 HB and has been obtained at 6 % weight fraction of SiC particles.

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