# Mechanical Behaviour of Micro and Nano Scaled Silicon Carbide Reinforced Al 6063 Metal Matrix Composite

**Zishan Ahmad, Mukesh Kumar Pandey, Nadeem Faisal**

***Abstract*: In this research study Al 6063 is used as the base matrix element, due to less weight, high specific strength, impact strength and good mechanical properties. Further, SiC are reinforced in Al 6063 matrix for enhancing its properties. Stir casting process has been accomplished for fabricating the (Al 6063-SiC) composites. In this experiment two various size of reinforcement particle are utilized, one of them is micro sized and another one is nano sized. Micro sized reinforcement particle has dimensions of (25-40µ), while nano sized particle consists dimensions of 500nm. The weight fraction of the micro and nano sized SiC particle taken in this experiment are in order of 0%, 2%, 4%, 6%, 8%, and 10% respectively. Various mechanical tests such as hardness, tensile tests and impact tests were conducted for determining the effect of micro and nano sized SiC reinforced aluminum matrix composites. The comparative study related with impact strength, hardness and tensile strength of micro and nano sized silicon carbide reinforced with aluminum matrix composites were shown in this work. There is an enhancement of mechanical properties has been observed with enhancement in weight percentage of micro sized silicon carbide, on other hand there is also a decrease in mechanical properties has been found while increasing the weight percentage of nano sized silicon carbide. The main objective of this paper is to enhance the mechanical properties of the Al 6063 metal matrix with reinforcing silicon carbide particle.***

***Keywords: Al 6063, SiC, stir casting, metal matrix, composite, tensile, impact, hardness.***

## I. INTRODUCTION

Nowadays due to good mechanical properties like high strength to weight ratio, decomposable nature, wear & corrosion resistance, composite materials are overcoming conventional materials. Uzun [1] conducted an experiment in which powder metallurgy method were used to reinforced aluminium foams with silicon carbide and carbon nano tubes, in which matrix material are aluminium powder, foaming agent are titanium hydride and reinforcing elements are silicon carbide and carbon nano tubes. After the experiment he concluded that foamable presage materials have more than 94% relative density values, also by the addition of SiC and carbon nano tube the elastic plastic distortion behavior of the presage material is significantly affected. Further, there is an increment of average stress and young's modulus in composite foams have been observed while increment in the weight quantity of SiC particles and carbon nano tubes. Prasad Reddy et al., [2] shows the Al alloy silicon carbide particles based nano composite mechanical properties, and their fabrication methods, after the experiment they found that unreinforced alloy have weak mechanical properties as compared to reinforced silicon carbide Al matrix composite, also he concluded that particles in the matrix shows a good bonding among the surface, while microstructural evaluations shows that nano silicon carbide particles have uniform distribution in the matrix. Sulaiman et al., [3] presented their investigation to show the effect of mechanical properties of Al-12SiC (LM6) and Al-SiC composite and. They determined that by inclusion of 10 wt.% SiC and 0.5wt% Al-10Sr to Al by a process of vortex method give a best result, maximum amount of hardness was to be found 73.52 rock-well number, also they found that with the addition of SiC and Sr gives increment in the properties of tensile strength of composite material. Faisal and Kumar [4] has studied the effect of presence of nano scaled silicon carbide at 0, 0.5, 1, 1.5, 2 and 2.5 wt.% reinforced with aluminium matrix composites. They concluded that addition of SiC in aluminium metal matrix enhance the elastic modulus, brittle behavior and less failure strain. They also concluded that there is an enhancement of hardness up to 66% with addition of 2.5wt% nano SiC filler, tensile and flexural properties were also enhanced up to 20% by the addition of SiC particles. Prasad Reddy et al., [5] concluded that filler particles in composite material have capability to better up the properties of composite material at certain limit, also they concluded that matrix ruled properties together with matrix solidness, toughness and hardness, can be improve in future for laminar shear and plane. Meena et al., [6] presented the reinforced of Al 6063 with SiC particles by the fabrication of composites with melt stirring technique. After the experiment it was examined that as the wt.% of reinforced increase in composite material there is also an increment in tensile strength, impact strength and hardness of composite material. Ranjbaran [7] developed aluminium matrix composite (AMC) for high and low temperature applications. Fracture toughness testing was held by Ranjbaran, to study the presence of crack in composite material, it was examined that fracture in materials and flow properties both are control by matrix alloy. They also concluded that proper choice of constituents is necessary for toughness of composite material.

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Boopathi [8] performed an experiment to show that due to good mechanical characteristics reinforced materials are widely selected for structural applications. The main theme of study was to determine physical properties of aluminium 2024 with the occurrence of fly ash, SiC or both combinations, after fabricating the materials he found that hardness and tensile strength was increased. Mohanavel et al., [9] Their work shows the effect of SiC on the composites of AA6351 aluminium matrix, which were fabricated by stir casting process. Weight fraction from 0% to 20% has been taken for reinforcing SiC particle in AA6351 aluminium matrix. Various test has been examined in their experiment such as impact, hardness, density and yield strength. The outcome shows that there is an enhancement of mechanical properties in the composites as there is an increment in weight fraction of reinforcement particle, variation in density has been also observed in their investigation. Finally, it has been concluded that 20% weight fraction of SiC gives best result for mechanical properties. Khedera et al., [10] presented the experimental examination to yield a metal matrix composite (MMC) using base material as a aluminium which are further reinforced with one of the following ceramic additives each time (SiC, $Al_2O_3$, Alumina, & magnesium oxide MgO) with different volume fractions. Liquid state mixing techniques was employed for the different constituents. After the experiment they concluded that there is a betterment in composite sample properties like hardness, tensile strength, yield strength with the addition of particulates such as MgO, SiC and Al2O3 particulates into the matrix. They also concluded that SiC has a superior mechanical property than other ceramic which was used in the experiment. Reddy and Srinivas [11] They performed research analysis in which SiC and fly ash with weight ratio of 2.5%, 5%, and 7.5% with equal quantity are reinforced with Al 6082, they also compared the mechanical properties like tensile strength, hardness with unreinforced alloy. After the experimental investigation they found that there is an increment in mechanical properties of reinforced alloy as compared to unreinforced alloy. So, in this way they determined that with addition of SiC and fly ash in Al 6082 there is good improvement of mechanical properties in Al alloy. Kiran, Govindaraju and Jayaraju [12] In their investigation SiC and titanium dioxide as a filler with a glass fiber are used for production of polymer composites, and also titanium carbide and alumina were reinforced along with glass fibers as fillers. The fillers are taken as a range of zero to six volume% in the composites. After the investigations it was observed that fillers having alumina and SiC reinforced composites shows enhancement of mechanical properties. Tensile strength, flexural strength and impact strength of composites are significantly enhanced with the addition of SiC and Al2o3 fillers. David et al. [13] carried an experiment by stir casting process in which they manufacture aluminium composite with various wt.% of SiC and fly ash. The microstructure and mechanical properties of the manufacture aluminium composites sample were analyzed. Poovazhagan et al., [14] Their investigation shows that SiC with 1.0 percentage volume and B4C with 0.5 percentage volume gives the optimum tensile strength for aluminium alloy composites. Through the investigation they also found that there is an increment in hardness value as the increment in hybrid ratio. The aim of our paper is to study the effect on mechanical properties with the addition of the various percentages of micro and nano scaled SiC in Al matrix composites. Also, to investigated the outcome of tensile strength, hardness, impact strength. The study has been done to find out the best percentage mixture for micro and nano SiC on mechanical properties.

## II. MATERIALS AND METHODS

### A. Materials Used

*Aluminium:* In this examination, aluminium alloy (Al6063) were used as a base alloy. Al alloy 6063 was obtain from Sigma Aldrich Ltd. Bangalore. The compositions of Al 6063 aluminium alloy along with their features are tabulated in Table 1 & Table 2.

**Table 1. Aluminium (Al 6063) alloy physical composition along with the weight percentage**

| | |
|---|---|
| Tensile Strength | Max. 130 MPa |
| Hardness | 25 BHN |
| Impact strength | 9.81 joules |
| Elongation | 2.3% |
| Density | 2.7 g/cm$^3$ |

**Table 2. Aluminium (Al 6063) alloy properties**

| Elements | Fe | Cu | Cr | Ti | Mg | Mn | Zn | Al |
|---|---|---|---|---|---|---|---|---|
| % | 0.163 | 0.004 | 0.002 | 0.007 | 0.538 | 0.0131 | 0.001 | 98.478 |

**Table 3. Properties of Micro Sized Silicon Carbide**

| | |
|---|---|
| Density | 3.1 g/cm3 |
| Hardness | 9.60 mohs |
| Specific Heat | 750 J/kg/k |
| Flexural Strength | 550 Mpa |
| Melting Point | 2730°C |

*Silicon Carbide (SiC):* In this research work two scaled sized of SiC has been utilized which is micro and nano particles. As per the analysis micro sized silicon carbide particles size are in the range of 25-45 microns. The composite reinforced micro SiC particles are purchased from Hindustan traders Chennai. The properties of micro sized silicon carbide are presented in Table 3. High energy ball mill refinement process was carried out for obtaining nano particles from micro particles. Gray SiC micro powder of 40µm are purchased from Sigma Aldrich, Hyderabad, India. The nano powder of 500 nm was obtained by machining 40µm SiC powder in high energy planetary ball mill.

**B. Composite Preparation**

Stir casting method where used for preparation of composite material. Aluminium Scrap were melted at temperature of 800°C with the help of electric furnace, they are put in a graphite crucible under a flux layer. Solid dry hexa-chloroethane degasser were used to degassed the aluminium melt at 800°C. The molten metal is being added by preheated silicon carbide particulates, and after that the molten metal are stirred continuously around 10 min with a impeller speed of 605 rpm. Electronic weighing machine were used for weighing aluminium and silicon carbide particles. The molten metal further poured into a permanent mould of metallic cylinder having a length 120mm and radius of 29mm. Further the molten sample of mould were put in rest for 3.5 minutes into the mould for solidification of molten metal, after the solidification of sample the mould were obtain from the permanent mould of metallic cylinder. Composite sample consisting of various wt.% of silicon carbide in aluminum are depicted in Figure 1.


**Figure 1: Al-SiC Composite Specimens for Various Wt.%**

## III. EXPERIMENTATION AND TESTING OF MECHANICAL PROPERTIES

**A. Hardness Testing**

Matrix consisting of aluminium alloy and SiC particles; hardness tests was carried out for finding the outcome of hardness in prepared sample. The sample were operated in a Brinell hardness tester for determining the hardness value, standard Brinell hardness tester (FIE make, range 500-3000 kg-f, B3000 (H) model) are shown in Figure 2. which are also held in this experimentation. The 10mm diameter ball indenter with an applied load of 510 kg where held in a sample for 35 sec. Microscope were used for determining the indenter diameter which are present in the composite surface after applied load. Four different area in the composite sample surface were used to determining the hardness value, and after the determination of hardness the mean value were obtained for further calculation.


**Figure 2: Brinell Hardness Testing Machine**

**B. Tensile Testing**

Silicon carbide particles reinforced with Al alloy tensile test were carried out for determining the tensile strength in composite (Figure 3). Al 6063 alloy composite sample were machined as per standards ASTM E-8 and further carried out for tensile test to know the effect of silicon carbide in the composite. The sample was applied with a load between two adjustable grips of 205KN, computerized universal testing machine along with an electronic extensometer (TUE-C model, fine particle) as given in Figure 4. At ambient temperature with the help of electronic means a constantly increase force was established in the sample. Each test was held at three time and the mean value was determined to calculate the composite tensile strength using formulae I.

$$Tensile\ Strength = F/A \quad (1)$$

Where,
F = Force in Newton (N) and A = Area ($mm^2$)

**Figure 3: Casted Tensile Specimen**

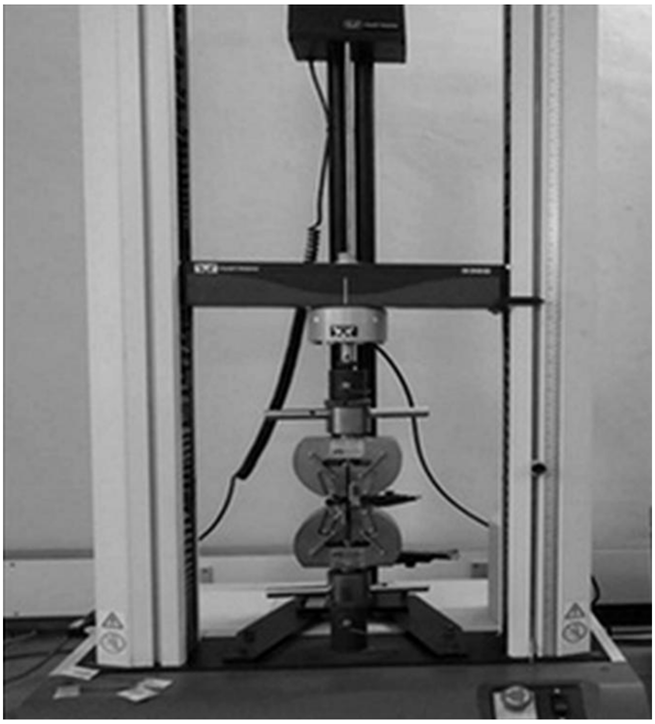

**Figure 4: Tensile Testing Machine (UTM)**

### C. Impact Testing

Standard impact pendulum type testing machine (ASI make, capacity 184 j AMT-8 model) (Figure 5) as per ASTMD 256 standard were used to test the impact strength of a composite material. Sample of 75mm long with (10×10 mm2) cross section, 2 mm deep and having a standard 45° notch were applied for the test. Each test was conducted for three times.

**Figure 5: Impact Testing Machine**

## IV. RESULTS AND DISCUSSIONS

Micro and nano sized silicon carbide reinforced with aluminium metal matrix composite comparative study has been carried out on the basis of experimental investigation such as tensile test, compression test, impact strength and and hardness.

### A.Effect of nano & micro sized silicon carbide percentage on hardness.

Pure aluminium matrix have a hardness value of 25BHN. Micro sized silicon carbide particles reinforced with a composite at 2% weight fraction shows the lowest hardness value (26 BHN) while composites reinforced with micro size particles at 10 wt.% shows the highest hardness (87.8 BHN). On another side composite reinforced with nano sized silicon carbide particles at 2 wt.% shows the highest hardness value (85.8 BHN) while composite reinforced with particles at 10wt% shows the lowest hardness (14.9 BHN). Figure 6. represents the variation of hardness between micro and nano SiC reinforced AMC graphically.


**Figure 6: Effect of Micro & Nano Sized Silicon Carbide on Hardness**

### B. Effect of Micro & Nano sized silicon carbide percentage on tensile strength.

Composite reinforced with (25-40) micron particles at 2wt% micro sized silicon –carbide has the lowest tensile strength value (69 MPa), and the highest tensile strength of 146MPa was found in 10 wt.% micro sized silicon carbide composite reinforced with aluminium 6063. The maximum tensile strength value (107MPa) was found in 2 wt.% nano sized silicon carbide composite reinforced with nano SiC particles, while the lowest tensile strength of 19MPa was found in 10wt% nano sized silicon carbide composite reinforced with nano SiC particles. Figure 7 represents the variation of tensile strength between nano and micro SiC reinforced AMC graphically.

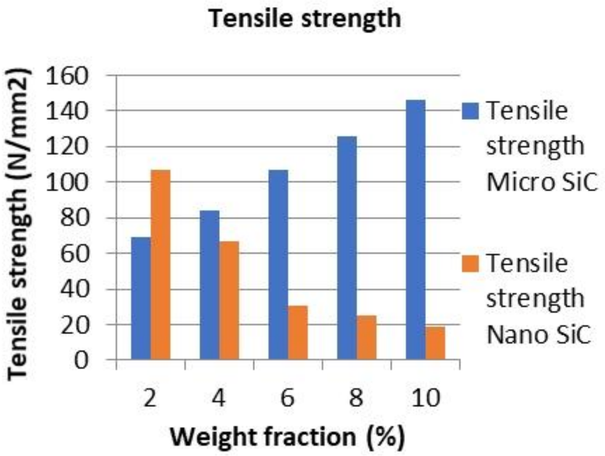


**Figure 7: Effect of Micro & Nano Sized Silicon Carbide on Hardness**

### C. Effect of micro & nano sized silicon carbide percentage on impact strength

Composites with micro sized silicon carbide particle at 2wt% showed highest impact strength (8.02N-m) and the composites reinforced with particles at 10wt% showed the minimum impact values (6.87N-m). Impact strength of composites enhanced with increment in weight fraction of nano sized silicon carbide up to 4%. The highest impact strength value (9.23Nm) was observed in 4wt% nano sized silicon carbide composites reinforced with nano SiC particles, while the lowest impact strength of 7.2Nm was observed in 10 wt.% nano sized SiC carbide composites reinforced with nano SiC particles. Figure 8 represents the variation of impact strength between micro and nano SiC reinforced AMC graphically.

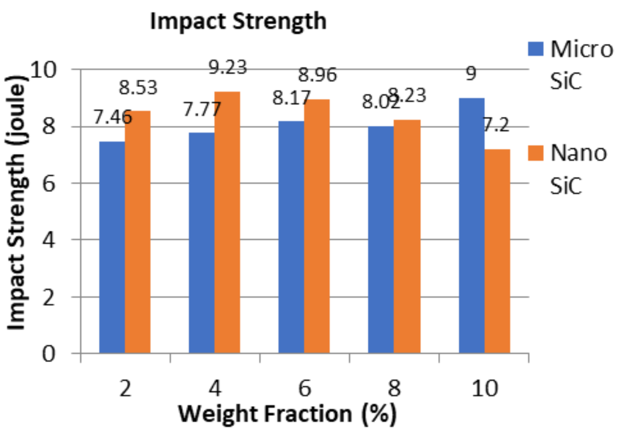


**Figure 8: Effect of Micro & Nano Sized Silicon Carbide on Impact Strength**

## V. CONCLUSION

The following conclusion can be drawn from the experimentation, results and discussions:

1) There is an increment in hardness, tensile strength up to 44% and 28.47% respectively. With the addition of SiC on aluminium matrix composite.

2) Impact strength of micro silicon carbide composites with micro sized silicon carbide reduced from 8.07nm to 6.07nm from 2 to 10% weight fraction.

3) The optimum outcome has been observed at 5% of 320 grain range SiC particles. The density of the composite materials also enhanced with increment in weight fraction of the reinforcement material.

4) From the result it was found that the hardness of the composite enhanced suddenly on 2% weight fraction of nano SiC with aluminium 6063, and decreases with increase in weight% above 2%.

5) Aluminium metal matrix composite containing 2, 4 and 10wt.% SiC particulates are best for manufacturing aluminium metal matrix composite.

## VI. FUTURE SCOPE

Composite, mechanical properties can be tested by increasing the weight fraction of SiC beyond 10%. This work can be extended to other liquid and solid-state fabrication techniques like squeeze casting, powder metallurgy etc. Experiments can be conducted to study the influence of particle size on different aluminium alloys reinforced with particles like fly ash along with SiC to increase the density.

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