

# **Mechanical Behavior of Al-SiC Composites Prepared By Stir Casting Method**

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**ABSTRACT:** The role of engineering materials in the development of modern technology like Metal Matrix Composites (MMCs) have evoked a keen interest in recent times for potential applications in aerospace and automotive industries owing to their superior strength to weight ratio and high temperature resistance. Aluminium (2024) and SiC (320-grit) has been chosen as matrix and reinforcement material respectively. In this present study an attempt is made to develop Aluminium based silicon carbide particulate MMCs. Stir casting is one of the most economical method of processing MMC and to obtain homogenous dispersion of ceramic material. Al-SiC composites containing different weight percentages 10% and 15% of SiC have been fabricated by liquid metallurgy method. Experiments are conducted by varying weight fraction of SiC (10%, 15%), while keeping all other parameters constant. The distribution of reinforcement and percentage of composition are tested by Energy-dispersive x-ray spectroscopy. Hardness of the MMCs are measured by Rockwell hardness method. Experiments are planned to conduct Friction and wear characteristics of Al-SiC composites have to be investigated under dry sliding conditions carried out using pin-on-disk wear test for rating normal loads and keeping all other parameters constant. Weight loss of samples has to be measured and the variation of cumulative wear loss with sliding distance has to be found for the composites. The best results would be observed at % weight fraction of 320 grit size SiC particles for minimum wear and the superior weight percentage of reinforcement is identified for tribological applications.

**KEYWORDS:** Metal Matrix Composites MMC's, Silicon Carbide SiC, Stir casting method

## **1. INTRODUCTION**

Aluminum matrix composites (AMC) are materials in which the ductile metal matrix is reinforced by hard fibers or particulates. Aluminium-based, particulate-reinforced MMCs added with SiC particles in the ductile matrix lead to the attractive properties. These properties include increased strength, higher elastic modulus, higher service temperature, improved wear resistance, decreased part weight, low thermal shock, high electrical and thermal conductivity. The superior properties of these materials have enabled them to replace the existing conventional alloys in most of the applications related to automobile and aerospace industries. The combination of properties and ease of fabrication make them attractive for many structural applications requiring high specific strength and stiffness. In addition to high strength and stiffness, short fiber reinforced composites also possess other attractive properties like high damping capacity, machinability, friction, wear and seizure resistance and low coefficient of thermal expansion. Because of these enhanced properties and lower cost, the short fiber reinforced composites are expected to find wide application in automotive industries. The property advantage of composite material varies largely with the manufacturing variation of matrix, reinforcement materials and also composite.

In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when S. Ray introduced alumina particles into aluminum melt by stirring molten aluminum alloys containing the ceramic powders. Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mold casting, or sand casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement.

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The cast composites are sometimes further extruded to reduce porosity, refine the microstructure, and homogenize the distribution of the reinforcement. A major concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes. The final distribution of the particles in the solid depends on material properties and process parameters such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification. The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added.

An interesting recent development in stir casting is a two-step mixing process. In this process, the matrix material is heated to above its liquids temperature so that the metal is totally melted. The melt is then cooled down to a temperature between the liquids and solidus points and kept in a semi-solid state. At this stage, the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. This two-step mixing process has been used in the fabrication of aluminum.

Among all the well-established metal matrix composite fabrication methods, stir casting is the most economical. For that reason, stir casting is currently the most popular commercial method of producing aluminum based composites. The solidification of the melt containing suspended SiC particles is done under selected conditions to obtain the desired distribution.

## Objectives for Development

The development objectives for light metal composite materials are:

- Increase in Young's modulus
- Increase in yield strength and tensile strength at room temperature and above while maintaining the minimum ductility or rather toughness
- Increase in creep resistance at higher temperatures compared to that of conventional alloys
- Increase in fatigue strength, especially at higher temperatures
- Improvement of thermal shock resistance
- Improvement of corrosion resistance
- Reduction of thermal elongation

## II. EXPERIMENTAL PROCEDURE

**2.1 Stir casting** Among the variety of manufacturing processes available for metal matrix composites (MMCs), stir casting process is generally accepted as a particularly promising route, currently practiced commercially. Its advantage lies in its simplicity, flexibility and applicability to large quantity production.

First of all stirring system has been developed by coupling motor with gearbox and a mild steel stirrer. All the melting was carried out in a graphite crucible in an oil-fired furnace. Bars of aluminium were preheated at 1000°C for 3 to 4 hours before melting and mixing the SiC particles were preheated at 800°C for 1 to 3 hours to make their surfaces oxidized.

The furnace temperature was first raised above the liquidus to melt the alloy scraps completely and was then cooled down just below the liquidus to keep the slurry in a semi-solid state. At this stage the preheated SiC particles were added and mixed by means of stir casting setup. After sufficient manual mixing was done, the composite slurry was reheated to a fully liquid state and then automatic mechanical mixing was carried out for about 10 minutes at a normal stirring rate of 600 rpm. In the final mixing process, the furnace temperature was controlled within 760°C. Pouring of the composite slurry has been carried out in the die mould prepared according to the pin dimensions.

The important experimental setup used here is stir casting and squeeze casting set up. Stir casting method is a relatively low cost liquid processing present to produce MMC and hence, this processing technique had been utilized in this study. Figure1 shows Stir casting setup used in this study. Besides being simple, flexible, and attractive, as compared with other techniques, it also allows very large size components to be fabricated and is also applicable to large quantity production. Stir casting route also ensures that undamaged reinforcement materials are attained.

**2.2 EDX Test** (Energy-dispersive x-ray spectroscopy) is an analytical technique used for the elemental analysis or

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chemical characterization of a sample. It relies on an interaction of some source of X-ray excitation and a sample. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing unique set of peaks on its X-ray emission spectrum.

To stimulate the emission of characteristic X-rays from a specimen, a high-energy beam of charged particles such as electrons or protons, or a beam of X-rays, is focused into the sample being studied. At rest, an atom within the sample contains ground state electrons in discrete energy levels or electron shells bound to the nucleus. The incident beam may excite an electron in an inner shell, ejecting it from the shell while creating an electron hole where was the electron.

An electron from an outer, higher-energy shell then fills the hole, and the difference in energy between the higher-energy shell and the lower energy shell may be released in the form of an X-ray. The number and energy of the X-rays emitted from a specimen can be measured by an energy-dispersive spectrometer. As the energy of the X-rays are characteristic of the difference in energy between the two shells, and of the atomic structure of the element from which they were emitted, this allows the elemental composition of the specimen to be measured.

**2.3 Hardness** is a measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied. Some materials, such as metal, are harder than others. Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behaviour of solid materials under force is complex. Therefore, there are different measurements of hardness like scratch hardness, indentation hardness, and rebound hardness. It is dependent on ductility, elastic stiffness, plasticity, strain, strength, toughness, viscoelasticity, and viscosity.

The Rockwell scale is a hardness scale based on indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. There are different scales, denoted by a single letter, that use different loads or indenters. The result is a dimensionless number noted as HRA, where A is the scale letter. Rockwell hardness test is carried out under ASTM A370-12a, HRA method. Testing was done with a load of 60 kg-f and dwell time of 15 seconds was given. The cylindrical specimens of 20 mm diameter and length 200 mm were used for the test. Before testing the specimen surface was polished in metcobain polishing machine using diamond paste abrasives.

## III. RESULTS AND DISCUSSION

### 3.1 Stir casting Specimen

The standard stir casting samples Fig. 1 (pins – cylindrical shape) have been prepared ( $\varnothing 20\text{mm} \times 200\text{ mm}$ ) out of castings (Fig. 1) having different wt. % of SiC.



Figure1. Pictorial view casting of sample containing different % SiC by weight

### 3.2 EDAX result of 10% SiC composite

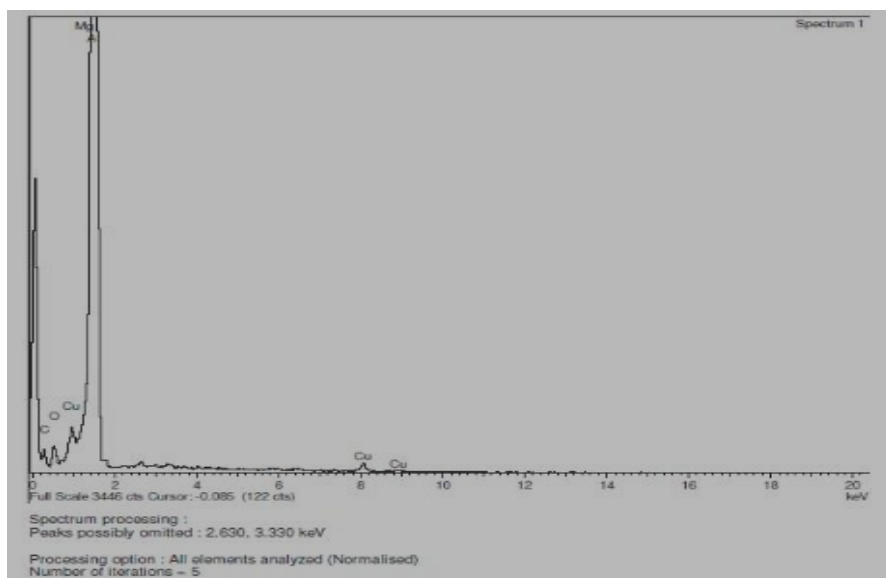
Chemical composition of the composite of 10 %wt Al-SiC was found to be as follows

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S.No	Element	Weight %
1	Caco3	24.19
2	SiO2	7.67
3	MgO	0.87
4	Al	64.79
5	Cu	2.47



## 3.3 EDAX result of 15% SiC composite

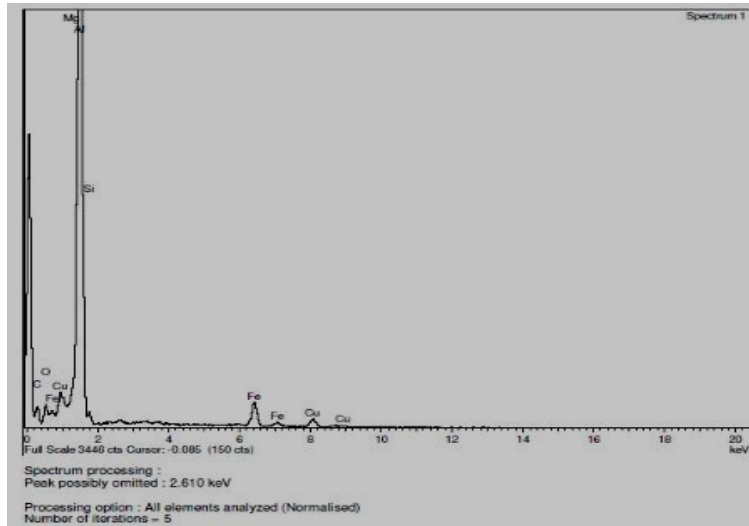
Chemical composition of the composite of 15 %wt Al-SiC was found to be as follows

S.No	Element	Weight %
1	Caco3	28.11
2	SiO2	10.05
3	MgO	0.61
4	Al	51.82
5	Cu	3.38
6	Fe	6.03

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## 3.4 Hardness test result

Hardness test was performed on the specimens of both 10 and 15 %wt Al-SiC composites under a load of 60 kg-f and the average hardness of 10 and 15 %wt Al-SiC composites are found to be 48 and 54 HRA respectively.

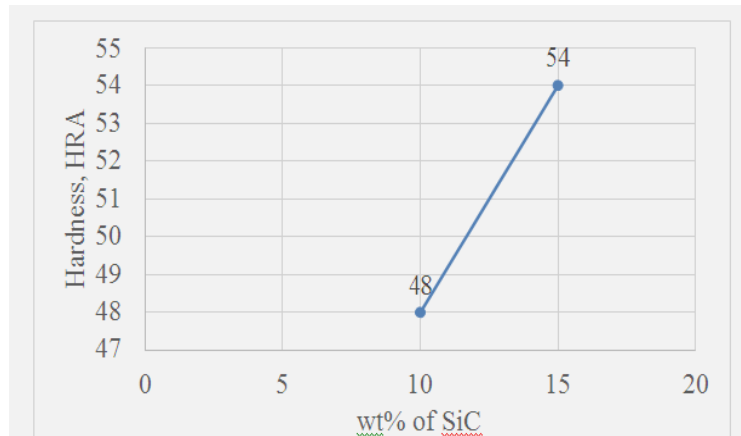


Figure3. Percentage of SiC Vs Hardness

Trail No	10% of SiC	Average	15% of SiC	Average
1	43	48	53	54
2	49		54	
3	47		53	
4	50		55	
5	46		54	

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The above result shows that increase of wt% of SiC in Al-SiC composite leads to hardness improvement.

## 3.5 Tensile test result

The following table shows the tensile test results

Description	10 %wt SiC	15 %wt SiC
Diameter	15.28 mm	15.35 mm
Area	183.4 mm <sup>2</sup>	185.1 mm <sup>2</sup>
Maximum force	49680 N	42310 N
Tensile strength	270.9 N/mm <sup>2</sup>	228.6 N/mm <sup>2</sup>
Elongation	2.9%	2.24%

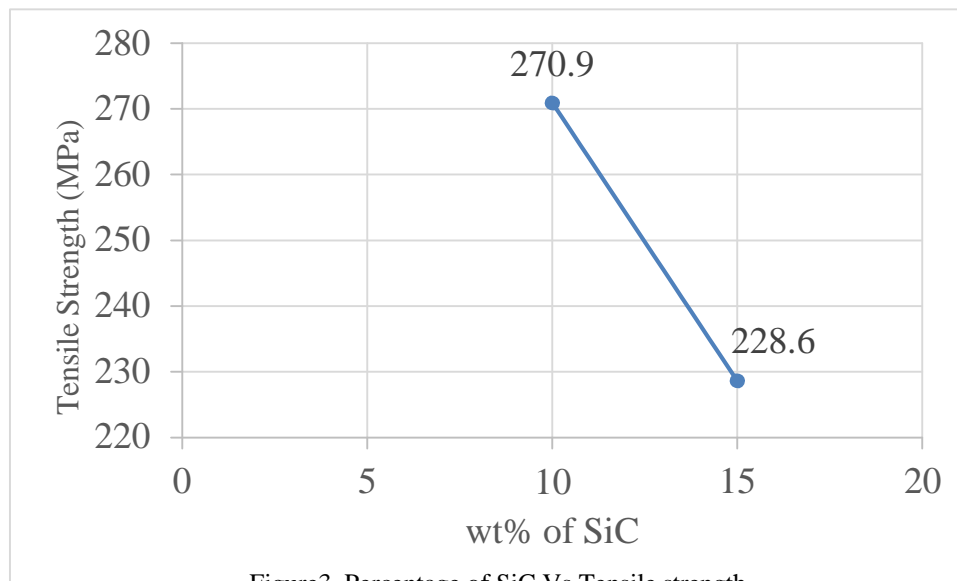


Figure3. Percentage of SiC Vs Tensile strength

The above result shows that addition of SiC in Aluminium metal matrix above 10% leads to decrease in tensile strength and elongation i.e., Addition of SiC above 10% increases the brittleness.

## IV. CONCLUSIONS

In the present study the Aluminum Metal-matrix Composite and SiC are prepared with the help of stir casting method.

- For uniform dispersion of material the number of blades should be 4 and blade angle should be 45° or 60°.
- Preheating of mould helps in reducing porosity as well as increases mechanical properties.
- Addition of SiC in Aluminium metal matrix above 10% decrease to increase in hardness.
- Addition of SiC in Aluminium metal matrix above 10% leads to decrease in tensile strength and elongation.
- The scope of this work can be extended to investigate the wear rate of Al-SiC by varying weight fraction of SiC (10%, 15%) under normal conditions.

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