

# Experimental Investigation of Fabricated SiC Reinforced Aluminium Based Metal Matrix Composite

## Thesis

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By

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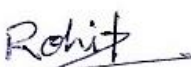
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Pantnagar  
November, 2021

  
**(Rohit Rawat)**  
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## CERTIFICATE - I

This is to certify that the thesis entitled “**Experimental Investigation of Fabricated SiC Reinforced Aluminium Based Metal Matrix Composite**” submitted in partial fulfillment of the requirements for the degree of **Master of Technology** in Mechanical Engineering with major in **Design and Production Engineering** of the College of Post-Graduate Studies, G. B. Pant University of Agriculture & Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Rohit Rawat**, Id. No. **55560** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation and source of literature have been duly acknowledged.

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## CERTIFICATE -II

We, the undersigned, members of the Advisory Committee of **Mr. Rohit Rawat** Id. No. **55560**, a candidate for the degree of **Master of Technology** in Mechanical Engineering with major in **Design and Production Engineering**, agree that the thesis entitled “**Experimental Investigation of Fabricated SiC Reinforced Aluminium Based Metal Matrix Composite**” may be submitted in partial fulfillment of the requirements for the degree.



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# CONTENTS

S. No.	Chapter	Page No.
	(a) List of Tables	
	(b) List of Figures	
	(c) List of Abbreviations	
<b>1.</b>	<b>INTRODUCTION</b>	<b>1-7</b>
	1.1 Literature Gaps	6
	1.2 Objectives	6
	1.3 Approach	7
<b>2.</b>	<b>REVIEW OF LITERATURE</b>	<b>8-15</b>
	2.1 Conclusion from the literature review	15
<b>3.</b>	<b>MATERIALS AND METHODS</b>	<b>16-36</b>
	3.1 Aluminium 1070	16
	3.2 Reinforcement	18
	3.2.1 Silicon Carbide (SiC)	19
	3.2.2 Magnesium (Mg)	20
	3.3 Casting Process	21
	3.3.1 Sand and Mould Preparation	23
	3.4 Fabrication Methodology	24
	3.4.1 Surface Finish of Casting	26
	3.5 Test Procedure	26
	3.5.1 Density	26
	3.5.1.1 Theoretical Density	26
	3.5.1.2 Experimental Density	27
	3.5.1.3 Porosity	27
	3.5.2 Hardness Test	27
	3.5.3 Tensile Test	29
	3.5.4 Sliding Wear Test	31
	3.5.4.1 Coefficient of Friction	32
	3.5.5 Dry Sand Abrasion Test	33
	3.5.6 Scanning Electron Microscopy (SEM)	35

<b>4.</b>	<b>RESULTS AND DISCUSSION</b>	<b>37-57</b>
4.1	Tensile Tests	37
4.2	Density	40
4.3	Hardness	43
4.5	Sliding Wear Test	44
4.6	Abrasive Wear Test	49
4.7	Micro Structural Analysis	51
<b>5.</b>	<b>SUMMARY AND CONCLUSIONS</b>	<b>58-59</b>
5.1	Recommendation for Future Work	59
	<b>Literature Cited</b>	
	<b>Appendix</b>	
	<b>Curriculum Vitae</b>	
	<b>Abstract (English)</b>	
	<b>Abstract (Hindi)</b>	

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## LIST OF TABLES

---

<b>Table No.</b>	<b>Title</b>	<b>Page</b>
<b>3.1 (a)</b>	Chemical composition of Aluminium 1070	17
<b>3.1 (b)</b>	Properties of Aluminium 1070	17
<b>3.2 (a)</b>	Chemical composition of Magnesium Metal Powder	21
<b>3.5 (a)</b>	Wear test parameters used for the experiments	32
<b>3.5 (b)</b>	Dry Sand Abrasion test parameters used for the experiments	34
<b>4.1</b>	Tensile properties of Al with different wt. % of SiC	40
<b>4.2</b>	Density and porosity of aluminum matrix with different wt. % of SiC	41
<b>4.3</b>	Hardness values of aluminum matrix composite with different wt. % of SiC	44
<b>4.4</b>	Wear rate with varying sliding distance	44
<b>4.5</b>	Coefficient of Friction with varying sliding distance	47
<b>4.6</b>	Mass abrasion rate of composites	50
<b>4.7</b>	Specific Mass abrasion rate of composites	50

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# LIST OF FIGURES

Figure No.	Title	Page
3.1 (a)	Aluminium 1070 Alloy Sheet	18
3.2 (a)	Magnesium Metal Powder	21
3.3 (a)	Stir Casting Setup	22
3.3 (b)	Mould	23
3.3 (c)	Preparation of sand and mould used in the cope and drag arrangement	24
3.4 (a)	Melting of Aluminium sheet and heated furnace	25
3.4 (b)	Stirring the mixture of Aluminium 1070 and SiC	25
3.4 (c)	Pouring the molten metal and solidification	25
3.5 (a)	Specimen for hardness test	28
3.5 (b)	Rockwell Hardness Testing Machine	29
3.5 (c)	Universal Testing Machine	30
3.5 (d)	UTM sample before and after test	31
3.5 (e)	Counter disc on apparatus	31
3.5 (f)	Pin on disc testing machine	33
3.5 (g)	Dry sand abrasion test setup	34
3.5 (h)	Sample before and after abrasion test	35
3.5 (i)	Scanning electron microscopy (SEM) setup	36
4.1	Stress-strain curve of Al and Al based composite with various wt. % of SiC	38
4.2	% increase in ultimate strength of various composites from base Al metal	38
4.3	Ultimate strength of Al and Al based composite with various wt % of SiC	39
4.4	% elongation of various compositions of SiC and Al matrix	39
4.5	Comparison of theoretical and experimental density with varying wt. % of SiC	42

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<b>4.6</b>	Comparison of porosity with varying wt. % of SiC	42
<b>4.7</b>	Variation in Hardness of the composites with wt % of SiC	43
<b>4.8</b>	Mass wear rate of different compositions with varying sliding distance	46
<b>4.9</b>	Specific Mass wear rate of different compositions with varying sliding distance	46
<b>4.10</b>	Coefficient of Friction of different compositions with varying sliding distance	47
<b>4.11</b>	Volume wear rate of different compositions with varying sliding distance	48
<b>4.12</b>	Specific Volume wear rate of different compositions with varying sliding distance	48
<b>4.13</b>	Mass abrasion rate of different compositions with varying wt % of reinforcement	49
<b>4.14</b>	Specific Mass abrasion rate of different compositions with varying wt % of reinforcement	50
<b>4.15</b>	Scanning micrograph of 21 wt % of SiC	51
<b>4.16</b>	Scanning micrograph of 21 wt % of SiC	52
<b>4.17</b>	Scanning micrograph of 26 wt % of SiC	52
<b>4.18</b>	Scanning micrograph of 21 wt % of SiC	53
<b>4.19</b>	Scanning micrograph of Clustering of SiC particles in 26 wt % of SiC	53
<b>4.20</b>	Scanning micrograph of Abrased surface in 16 wt % of SiC	54
<b>4.21</b>	Scanning micrograph of grain distribution in 16 wt. % of SiC	54
<b>4.22</b>	Scanning micrograph of grain distribution in 21 wt. % of SiC	55
<b>4.23</b>	Scanning micrograph of several delamination in 21 wt. % of SiC	55
<b>4.24</b>	Scanning micrograph of abrasion of surface in 6 wt. % of SiC	56
<b>4.25</b>	Scanning micrograph of porosities in 21 wt. % of SiC	56
<b>4.26</b>	Scanning micrograph of porosities in 26 wt. % of SiC	57

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## **LIST OF ABBREVIATIONS**

$\emptyset$	:	Porosity
%	:	Percentage
Al	:	Aluminium
AMC	:	Aluminium matrix composite
ASTM	:	American Society of Testing and Materials
cc	:	Cubic centimeter
cm	:	Centimeter
CTE	:	Coefficient of thermal expansion
E	:	Modulus of elasticity
FCC	:	Face Centered Cubic
g/min	:	gram/minute
gm	:	grams
gm/cm <sup>3</sup>	:	gram/cubic centimeter
GPa	:	Giga Pascal
Gr	:	Graphite
HRB	:	Hardness Rockwell B
K	:	Kelvin
Kg	:	Kilogram
kV	:	kilo Volt
m/s	:	meter/second
Mg	:	Magnesium
mg	:	milligram
min	:	minute
mm	:	millimeter
MMC	:	Metal matrix composite
MoS <sub>2</sub>	:	Molybdenum di Sulphide
MPa	:	Mega Pascal
N/m	:	Newton/meter
°C	:	Degree Celsius

PAMC	:	Particulate reinforced aluminium matrix composite
RPM	:	Revolution Per Minute
SEM	:	Scanning Electron Microscopy
SiC	:	Silicon Carbide
UTM	:	Universal Testing Machine
UTS	:	Universal Tensile Strength
wt. %	:	weight percentage
$\mu\text{m}$	:	micro meter
$\rho$	:	Density

# APPENDICES

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Appendix	Title	Page No.
1	Stress-strain curve of Al	
2	Stress-strain curve of Al composite with 6 wt. % of SiC	
3	Stress-strain curve of Al composite with 11 wt. % of SiC	
4	Stress-strain curve of Al composite with 16 wt. % of SiC	
5	Stress-strain curve of Al composite with 21 wt. % of SiC	
6	Stress-strain curve of Al composite with 26 wt. % of SiC	



# *Introduction*



Aluminum alloys are increasingly playing a vital role in low to heavy weight at low prices (compared to titanium alloys) associated with good resistance to corrosion. They are broadly used in aircraft parts, car parts, metal cases and electric motors. However, the major drawbacks of these alloys is their resistance to low wear. Al-Si base alloys are preferred over because of their attractive features for example their enhanced weight, good thermal conductivity, corrosion resistance and superior dispersion. The Al-Si alloy family is extensively used in wearable systems such as brakes, pistons, cylinder liners as well as motor casing. By improving the wear properties of these alloys, the performance of these alloys can be expanded and used in many more applications. The features of monolithic composite materials are constrained by the solution of one or more phases. Also, their range is small, relying on the growth of kinetics and balance conditions. Overcoming these shortcomings and satisfying the ever-increasing demand for modern technology, combinations have emerged as powerful opponents in wear related applications.

Composite materials, polymers, and ceramics have dominated new the choices of engineers for the previous thirty years. The volume and number of usages of composite materials have grown steadily, penetrating and conquering new markets tirelessly. Modern composite materials account for a large percentage of the engineered market globally, with uses ranging from ordinary items to sophisticated specialized applications.

Although compounds have already proven their value as low-weight materials, the current challenge is to make them less expensive. The composite industry is constantly upgrading their production technology to make economically attractive composite components. It is clear, especially in composites, that the development of production technology alone is insufficient to overcome the cost barrier. It is important that there is a mutually collaborated effort to design, equipment, process, tools, quality assurance, production, and system management so that compounds compete with metals.

Aluminum (Al) is a silvery white, ductile chemical compound that falls under the poor metal group. Al is versatile metal that is abundant, light, and strong. Aluminum-matrix composites, like other composites, are a group of elements with varying stiffness, electrical, strength, density, and thermal properties. The amalgam of matrix, reinforcement materials, volume and condition and location of reinforcement, and methodology can vary to attain the required structures (**Sijo and Jayadevan, 2016**). However, Al composites provide very good thermal conductivity, high shear strength, excellent abrasion resistance, high temperature performance, high coefficient of thermal expansion, non-combustion, least amount of damage by fuels and solvents, and the ability to form and treat on conventional equipment.

Silicon carbide is a tetrahedral carbon compound and silicon atoms with a strong bond to the crystal lattice thus, resulting in an extremely hard and strong material. Acids and alkalis have not any effect on SiC up-to 800 °C. In air, SiC forms protective silicon oxide at 1200 °C and can be used up to 1600 °C (**Praveen and Raghuraman, 2007**). This material possesses exceptional resistance against thermal shock owing to its high thermal conductivity, low thermal expansion, and high strength. SiC ceramics with few or no grain boundary imperfection may withstand temperature nearing 1600 °C without losing their strength. This material is particularly widely used as wafer tray supports and paddles in semiconductor furnaces because of its hardness, corrosion resistance, high melting point, chemical purity, chemical stability and strength retention at elevated temperature. The properties of SiC are low density, high strength, low thermal expansion, high hardness, and high elastic modulus. Reinforcement particle distribution, orientation, volume fraction, matrix microstructure and size are all parameters that alters the behavior of the composites.

Metal Matrix Composites (MMCs) are made by distributing a reinforcing material into a metal matrix. The majority of industrial MMC have a matrix of aluminium, magnesium, copper, or titanium alloys with reinforcements of SiC and aluminium oxide. Based on their reinforcement they are classified as fiber reinforced Metal Matrix Composite, Whisker reinforced Metal Matrix Composite and Particulate Reinforced Metal Matrix Composite. Aluminum Matrix Composites

(AMC) are generally applied MMCs in a wide range of industries including automotive, aerospace, electronics, equipment manufacturing, and sports products. Composites of metal matrix aren't as popular as their plastic equivalents right now, but they're generating a lot of attention in the scientific community. Metal matrices have a greater amount of strength, fracture toughness, and stiffness than their polymer equivalent. In corrosive environments, they can resist higher temperatures compared to polymer composites. Most metals and their alloys can be used as matrices, but they require reinforced materials that are both stable and non-reactive across a wide temperature range. However, the matrix material serves as the primary guiding factor in the choice. In addition to this they are also light metals provide the matrix for enhanced thermal application.

The composites of Metal matrixes have an increased specific modulus, better specific strength, superior characteristics at extreme temperatures, lower coefficients of thermal expansion, and enhanced wear resistance than monolithic metals. Metal matrix composites (MMCs) are now studied for a variety of range of applications due to these characteristics. However, their reduced toughness than the monolithic metals and they are currently affluent. MMCs have higher mechanical properties as compared to most polymer matrix composites, including increase in transverse strength and stiffness, higher shear and compressive strengths, and higher temperature capabilities. Certain physical properties of MMCs, such as absence of substantial moisture absorption properties, flammability, high thermal and electrical conductivities, and resistance against most radiations, are key benefits (**Dursun and Soutis, 2014**).

MMC is prepared by adding reinforcement particles into the matrix of any metal. These particles improve abrasion resistance, hardness, strength-to-weight ratio, stiffness, and a range of thermal properties. Al, Ti, Cu, Mg and their alloys are often used metallic matrices. In the fabrication of MMCs, these alloys are most commonly employed matrix materials. Fibres, whiskers, and particles are used as reinforcements. The formability of particulate-reinforced composites has a cost benefit over other materials. Further, they are inherent with heat and wear resistant properties **Bodunrin et al. (2015)**.

Metal matrix composites (MMCs), such as SiC particle reinforced Al, are amongst the most popular composites because of their excellent properties such as high strength, hardness, stiffness, wear and corrosion resistance. Due to their low cost of production, SiC particle reinforced Al based MMCs are among the more often and widely available MMCs. Electronic heat sinks, automotive drive shafts, and explosive engine components are just a few examples of what they can be used for in aerospace, automobiles, and industries. The primary concern in the preparation of Al-SiC composites is the physical and chemical compatibility of SiC particles with the Al matrix. As a result, particle reinforced metal matrix composites can be made using techniques like powder metallurgy and casting. The properties of different methods are different. In this study, the melt route method is used to produce SiC particle reinforced Al MMC. The influence of reinforced particle weight percentage on mechanical properties such as hardness and microstructure of composites can be studied. The disadvantage of casting is the uniform dispersion of ceramic particle reinforcements, whereas the liquid state process maximizes the reactions between the metal matrix and the ceramic reinforcement, reducing the bonding between reinforcement and matrix, non-wettability of ceramic particles by liquid aluminium, particle segregation, higher porosity level, and extensive interface reaction due to higher processing temperature (**Singh *et al.*, 2015**).

While fabricating an Al-SiC composite, Al does not react with SiC particles until it reaches its melting point, which is 660°C, but molten Al reacts quickly with SiC, producing a variety of products depending on the temperature range of 650°C to 920°C (**Saheb, 2011**). This compound improves material characteristics and wettability to an extent, however due to its brittleness, hydrophilic nature, and other detrimental properties, cracks spread along the compound interface without transferring load to the reinforcing particle. This gives idea to further work for better improvement. The vortex method, in which ceramic particles are introduced into liquid aluminium and then the liquid melt is stirred, is the most well-known method of producing composites through casting approach. The improvement of wettability is dependent on three parameters: raising the solid's surface energies, lowering the matrix alloy's surface tension, and lowering the solid/liquid interfacial energy (**Singh *et al.*, 2015**).

Aluminum matrix composites (AMCs) are gaining popularity as advanced engineering materials because of their strength, ductility, toughness, malleability, high conductivity, light weight, and abundant availability (8 percent of earth crust is aluminum). Aluminum alloys are still the focus of extensive research because of their low density, which provides significant benefits in a broad range of applications. In the manufacture of wear-resistant parts, these alloys have begun to substitute cast iron and bronze (**Krishna and Xavier, 2014**). Aluminum-based composites have increased strength, stiffness, lower density, temperature survival, wear and corrosion resistance, and improved damping characteristics.

Aluminum matrix composites are fabricating to have the toughness of the alloy matrix and the hardness, stiffness and strength of hard ceramic reinforcements. As a result, composite materials have a higher strength and toughness. Furthermore, composites have a high thermal conductivity and a low thermal expansion coefficient. This improves the thermal stability of the composite materials. The addition of ceramic reinforcements leads to strengthening of the alloy due to following facts:

- I. Due to the presence of thermal residual stress, there is a higher dislocation density (because of significant difference in thermal expansion coefficient between the matrix and reinforcement),
- II. Elastic and plastic incompatibility between the matrix and reinforcement resulting in interaction stress,
- III. Resistance to flow of the matrix material. These phenomena lead to enhanced high-temperature strength. As a result, compared to alloys, composites may be used at much higher temperatures.

Particulate reinforced Al matrix composites are gaining popularity these days due to their inexpensive and benefits such as isotropic characteristics. Strengthening of aluminium alloys with fine ceramic particulate composite materials was developed as an alternative to unreinforced alloys for getting materials with high stiffness, with a special focus in wear resistance and structural applications. PAMCs have a unique combination of mechanical and physical properties. These composites possess new mechanical, tribological, thermal, and electrical conductivity properties, as well as

resistance to harsh environments, impact resistance, erosion resistance, fatigue, and fracture properties. The change in properties is caused by a variety of factors, including enhanced wear resistance offered by particulates and a change in density. These properties differ from the base alloy from which it derives its name, and they must be an establishment for every composite developed. The properties of the composite depends on

- a. Alloy properties
- b. Particulate properties
- c. Type of manufacturing
- d. Manufacturing condition
- e. Reinforcement percentage
- f. Wetting of particulates
- g. Post heat treatment
- h. Particulate size
- i. Reaction of particulate with alloy

### **1.1 Literature Gaps**

Aluminium 1070 alloy uses limited as a matrix. The effect of SiC reinforcement on Al 1070 based MMCs' properties is not broadly evaluated. Effect of Magnesium as a wettability agent is not evaluated in case of SiC reinforced aluminium 1070 alloy based MMCs.

### **1.2 Objectives**

Aluminum metal matrix composites have a wide range of applications in aerospace and defense. However, it has a lower resistance, is ductile, has a low strength, and hardness. To overcome this problem, silicon carbide is used as a reinforcement particle in Al MMC to improve its mechanical properties. The experiment was carried out on SiC reinforcement particles with varying compositions of 6, 11, 16, 21, and wt. %. Further, we also know that the wettability of metal and ceramic particles are not good, so enhancing wettability by adding a wettability agent

is being considered. The present investigation focused on fabricating an aluminium matrix to produce the desired composite. Here, the reinforcing phase is silicon carbide, and magnesium is added to enhance the wettability. Different percentages of reinforcing phase are used to produce composites. The objectives of the current research work are fixed, which are outlined below:

- a. To fabricate Al-based metal matrix composites with the various wt. % of SiC.
- b. To investigate the mechanical properties of the fabricated composite.
- c. To study morphological behavior of the MMCs by Scanning Electron Microscopy (SEM).
- d. To investigate dry sand abrasion test and sliding wear test on fabricated MMCs.

### **1.3 Approach**

Material science, material testing, and microscopic investigation are the two main areas used in the current investigation. To develop the composite material and determine mechanical properties such as tensile strength and hardness, material science and testing are performed. The microstructure of the developed hybrid composite material is determined through scanning electron microscopy. It's also used to see how the filler material disperses and interacts within the matrix.



*Review  
of  
Literature*



In the last two decades, composites have sparked a lot of interest, and many academics are researching in this area. This becomes extremely important when discussing the most well-known research on MMCs and their properties. This chapter provides background information about the issues that will be addressed in the research work, as well as a focus on the importance of the current study.

**Alpas and Zhang (1992)** investigated the effect of reinforcement and found that at low loads, SiCp acted as load-bearing materials at stresses less than the particle fracture strength. The abrasive action of the steel counter face was also seen to cause the transfer of iron-rich layers onto the contact surfaces. Carbide particles on the contact surfaces cracked over a certain load defined by the size and volume percentage of SiCp. Wear was controlled by a subsurface delamination process caused by decohesion of SiC-matrix interfaces, resulting in wear rates comparable to those of the unreinforced matrix alloy. At a load of 95 N, the unreinforced aluminium-silicon alloy's wear rates increased dramatically (by a factor of 100). The use of SiC reinforcement to prevent the shift from a mild to a severe wear rate regime was found to be beneficial.

**Ravikiran and Surappa (1997)** the number of SiCp fractures in A356/SiC composites was found to decrease as the sliding speed was increased. With increased speed, the pin's wear rate decreased. The pin surface suffered considerable damage at lower speeds (less than 2 m/s), resulting in a high wear rate. With increasing speed, the area fraction of SiCp exposed on the pin surface increased. Due to the melting of a thin layer of matrix material at greater speeds, SiCp protrude above the matrix and bear almost the entire load. At high speeds, a stable iron oxide coating forms, which acts as a protective layer on both the pin and disc surfaces. As a result, as the matrix's speed increases, the damage it experiences decreases.

**Singh *et al.* (2002)** in Al-Si<sub>12</sub>Fe/SiC composites, the abrasive wear rate of the composite and matrix alloy increased as the applied load and abrasive size increased. For finer abrasives, the composite surpassed the matrix alloy in terms of wear

resistance, while the tendency was reversed for coarser abrasives. Wear rate for composites reduced as the sliding distance increased due to wear surface work hardening, clogging, attrition, and shelling of abrasive particles.

**Manna and Bhattacharaya (2003)** the machinability of Al/SiC-MMC has been observed. The effect of machining parameters such as feed, depth of cut, and speed on cutting force and surface roughness was studied. BUE and chip formation were investigated using SEM micrographs in several experiments. Because of the development of strong cutting force and the formation of BUE, the author has concluded that flank wear rate is inversely related to cutting speed.

**Das (2004)** the development of aluminium alloy composites for engineering purposes was discussed. The performance of prototype Al-SiC composite components such as brake drums, cylinder blocks for automobiles, and parts for the mineral processing industries was examined under real-world conditions. It was proved that composite components had the ability to replace conventionally manufactured components. Composites' improved mechanical qualities make them a viable alternative for a variety of engineering applications.

**Yu et al. (2004)** investigated a unique method for fabricating uniformly distributed  $\text{Al}_2\text{O}_3$  particles in a metal matrix composite made of aluminium. Sintering an Al-10 wt. % ZnO sample at  $1000^\circ\text{C}$  produced the composite. In comparison to the furnace cooled sample,  $\text{Al}_2\text{O}_3$  particles were observed to be dispersed more uniformly in the Al (Zn) solid solution matrix in the oil-quenched sample.

**Dobrzanski et al. (2008)** investigated the microstructure and corrosion resistance of Al-Si12 alloy composites using sintered  $\text{Al}_2\text{O}_3$  particles as reinforcements.

**Yalcin and Akbulut (2006)** with increasing SiCp concentration, both the wear rate and the friction coefficient of the A356 alloy decreased (5-20 vol. %). When tested at 5 N applied load, specimens reinforced with 15 and 20 vol. % SiCp showed an increase in the friction coefficient. Poor interfacial bonding between the matrix and SiCp was identified as the source of this increase. Particle transfer from the matrix to the Tungsten Carbide ball and disc contact can generate excessive vibration due to poor bonding and particle segregation.

**Muratoğlu and Aksoy (2006)** in the temperature range of 20–200°C, researchers evaluated the abrasive wear behavior of Al 2124/SiC composites as cast and aged. The weight loss of aged specimens was smaller than that of as cast specimens, according to wear test results. It was also discovered that wear resistance improved for both aged and non-aged specimens when evaluated at room temperature. Above 50°C, both aged and as cast specimens showed very little change in wear rate. At temperatures between 50–200°C, contact between SiCp in the composite material and abrasive paper resulted in broken or loosened hard SiC abrasives, which penetrated into the soft layer under the worn surface. As a result, the surface strength of the composite specimens increased, resulting in little change in wear rate.

**Xiao *et al.* (2007)** a study of the mechanical properties of Al matrix composites made using the squeeze casting technique by altering the particle size of SiC reinforcement. They investigated at the bending strength and fracture toughness of the composites and observed that bending strength increased as particle size decreased, while fracture toughness decreased.

**Altinkok and Koker (2004)** investigated mechanical parameters like as bending strength and hardness in Al<sub>2</sub>O<sub>3</sub>/SiC/A332 composites. The bending strength and hardness of the composites were found to increase as the SiCp size was decreased.

**Singla *et al.* (2009)** experimented with different weight fractions of SiC (5%, 10%, 15%, 20%, 25%, and 30%), while keeping all other parameters constant. The results show an increasing trend in hardness and impact strength as the weight percentage of SiC increases up to 25% of the total weight fraction. Beyond this weight fraction, the hardness trend began to decrease as SiC particles interacted with one another, causing particle clustering and, as a result, settling. The density of SiC particles in the melt started to decrease thereby lowering the hardness. The sample containing 25% SiC has the best hardness and toughness values, with 45.5 BHN (Hardness) and 36 N-m (Impact Strength). The hardness value increases until the weight fraction of SiC reaches 25%, after which the hardness trend began to decrease. In the hardness test, significant plastic flow was focused in the localized region

directly below the indentation, whereas the material behaved elastically elsewhere. When compared to regions away from the depression, the particle density increased directly below the indentation. Although plastic deformation does not cause volume change, the presence of extremely high hydrostatic pressure under the indentation can cause volumetric contraction of the metal matrix.

**Suresha and Sridhara (2010)** the effect of adding graphite particles to Al/SiC/Gr composites on wear behavior was investigated, and it was discovered that increasing speed reduced wear while increasing load and sliding distance increased wear.

**Rao and Das (2011)** in AA2024/SiC, the wear rate and interface temperature decreased as the SiC concentration increased, however the coefficient of friction reversed the trend. They also observed that as the load, speed, and sliding distance increased, the wear rate increased.

**Rahman *et al.* (2014)** the 20 % weight fraction of silicon carbide in the aluminium matrix provides the highest tensile strength, according to research. The grain refining effect is caused by tensile load transfer to the strongly bonded silicon carbide reinforcement, which increases the dislocation density and hence increases the tensile strength. Tensile tests on Al6061 reinforcement with silicon carbide and graphite particles showed that Al6061-graphite had a higher tensile strength than Al6061-silicon carbide. This is due to the high strength possess by the filler graphite. Due to poor graphite wetting, the tensile strength remained same at a 12 % weight fraction. They found that increasing the SiC content in composites reduced cumulative mass losses. In comparison to pure aluminium, the loss of mass for aluminium-silicon carbide was less. During wear testing, the softer Al is worn away, leaving behind the hard silicon carbide particles. These exposed silicon carbide particles protect the matrix from additional wear. At a 20% weight fraction of silicon carbide, the highest wear resistance was observed.

**Krishna and Xavior (2014)** the mechanical properties of Al6061/SiC composites and Al6061/SiC/Gr hybrid composites obtained by stirring were investigated. The density and tensile strength of the Al6061/SiC compound increase

as the SiC component increases due to its hardness. The extra graphite-reinforced hybrid composite has higher enduringness and lower density as the graphite percentage increases. SiC and graphite are uniformly dispersed within the Al6061 matrix, according to microstructure studies.

**Inegbenebor *et al.* (2016)** performed an experiment on conventional simple methods of synthesizing MMC with properties obtained through silicon carbide dispersion in the matrix. A two-step mixing procedure of stir casting technique was used to attain these goals. The matrix and reinforcement materials were chosen to be aluminium (99.66 % C.P) and SiC (320 and 1200 grits) respectively. Experiments were carried out with different weight fractions of SiC: 2.5 %, 5.0 %, 7.5 %, and 10 %. The results showed that the stir casting method was very successful in achieving uniform reinforcement dispersion in the matrix. The improved properties of composites over the base metal showed this. Reinforced Aluminium Silicon Carbide (ASC) indicated an improvement in Young's modulus (E) and hardness compared to the unreinforced case, as well as a marginal decrease in electrical conductivity. When compared to the silicon carbide 320 grit (29 m), the silicon carbide 1200 grits (3 m) showed increased Young's modulus (E) and hardness of 1517.6 MPa and 26.1 Hv values at 7.5 % volume fraction silicon carbide.

**Daniel *et al.* (2017)** they presented their research on the effect of SiC (5, 10%, and 15%) and particle size (10, 20, 40 m) on the reinforced aluminium matrix, as well as a constant 2% molybdenum disulfide (MoS<sub>2</sub>). Method to work out the wear and tear resistance of composite materials calculates the friction coefficient and wear resistance of composite materials. Under dry sliding conditions, the test is performed by varying the sliding speed (1, 5.25, and 3.5 m/s), with different sliding distances (500, 1000, and 1500 m), and loads (30.50 and 70 N). The effect of ceramic particle hardening results, sliding path, sliding speed, and applied load on the friction coefficient and wear rate is determined using the Taguchi experiment and the ANOVA method. The results show that the friction coefficient is mostly influenced by the applied weight and the sliding distance. Soft materials such as graphite and molybdenum disulfide are added as a secondary reinforcement to overcome the shortcomings of hard reinforcement and ensure wear and lubrication.

**Vanam *et al.* (2018)** the effect of Al5083-SiC composite on mechanical, microstructure, and wear properties was investigated. Stir casting is used to make AMC with SiC weight %s of 3, 5, and 7. Pin on disc wear tests were performed with standard loads of 10, 20, and 30 N. The tribological behaviour was examined with a sliding velocity of 3.14 m/s and a sliding distance of 942 m. The wear mechanisms of worn-out surfaces were studied using an optical microscope on worn-out specimens. The materials' micro hardness number and tensile strength were determined using micro hardness and tensile tests. The microstructures were observed using SEM and XRD analyses. Increased addition of SiC particles resulted in improved tribological properties.

**Sharma and Kumar (2019)** after the addition of cerium oxide, AA 6061 hybrid AMCs with (SiC + Al<sub>2</sub>O<sub>3</sub>) showed improved mechanical properties and decreased porosity (rare earth particles). The tensile strength increased from 30 to 123 MPa after the addition of 2.5 wt. % cerium oxide. After adding 2.5 wt. % CeO<sub>2</sub>, the micro hardness and Rockwell hardness of the AA 6061 base alloy increased by 17.02 % and 33.80 %, respectively. When cerium oxide was not added, the Rockwell hardness only improved by 16.31%. With the increase in UTS, the ductility of the hybrid composites was observed to increase. The use of rare earth powder (CeO<sub>2</sub>) oxides as an additive to Al<sub>2</sub>O<sub>3</sub> and SiC ceramics has been proven to be beneficial in the fabrication of high-performance and cost-effective AA 6061 hybrid composites. Under all test conditions, stir-cast AA 6061 hybrid composites with CeO<sub>2</sub> showed a lower level of wear.

**Suresh *et al.* (2019)** aluminum 7075 was used to produce a nano composite containing 50 nm SiC particles. Composite specimens are made with SiC particles in concentrations of 1, 2, 3, and 4 wt. %. Wear tests with 20, 30, and 40 N loads on a steel disc were performed, as well as a micro hardness test. On the worn-out surfaces, microstructures were studied. Nano composites were shown to have better wear and hardness properties than the base metal.

**Rouhi *et al.* (2019)** aluminum-based composites reinforced with varied proportions of SiC, MoS<sub>2</sub>, and SiC/MoS<sub>2</sub> particles were synthesized by pressing and

sintering the appropriate powder mixes to improve dry sliding wear resistance of pure aluminium against steel. The microstructural analyses revealed a dense microstructure, which was satisfactory with the density and hardness results. Pin on disc wear tests performed against an AISI 52100 steel pin at constant load and sliding velocity showed that there was a critical content for both types of reinforcements at which the lowest wear rate was obtained, i.e. 10% and 2% for Al/SiC and Al/MoS<sub>2</sub> composites, respectively. The Al/10SiC/2MoS<sub>2</sub> hybrid composite, on the other hand, had the lowest wear rate and coefficient of friction. When MoS<sub>2</sub> particles were introduced into pure aluminium, the major wear mechanism changed from adhesion to abrasion, according to scanning electron microscopy observations. The main wear mechanism for Al/SiC and Al/SiC/MoS<sub>2</sub> composites has been found as mild delamination. The frictional traces and worn surfaces of Al/SiC/MoS<sub>2</sub> composites were similar to those of Al/SiC composites, showing that SiC particles play a dominating role in the hybrid composites' tribological behavior.

**Narendranath and Chakradhar (2020)** in a matrix of AMCs, fly ash and SiC particles were evenly dispersed. Between the matrix and the reinforcements, there was a clear interface and perfect bonding. The addition of up to 7.5 wt. % fly ash improved the UTS and microhardness. There was a decrease in UTS and microhardness when the weight fraction of fly ash was 10%, which could be attributed to improper mixing of reinforcement particles and matrix material at a higher percentage of fly ash.

**Devanathan *et al.* (2020)** microstructure revealed a rationally uniform distribution of reinforcements, while the matrix revealed discontinuities. The composite with 10 % SiC, 20 % fly ash, and 10 % coconut shell ash had the best hardness and strength. The presence and distribution of a higher amount of coconut shell fines within the matrix is the reason for this.

**Bhowmik *et al.* (2021)** the wear behaviour of an Al7075 composite reinforced with SiC particles was investigated. Stir casting is used to fabricate components with SiC particles with a grain size of 20 m and concentrations of 0, 3, 6, and 9%. Using the X-Ray Diffraction method, uniform particle mixing was detected. All samples

were subjected to wear testing with a constant load of 30 N, a stable sliding distance of 2000 m, and sliding velocity variations of 1, 2, 3, and 4 m/s. Friction between the disc and the pin resulted in a lower COF and a higher wear rate. In a worn-out surface Al7075 composite pin with 9% SiC, minimal material removal was obtained.

**Bhushan (2021)** to make AMC, researchers employed the stir casting process and delivered 5, 10, and 15 wt. % SiC with particle sizes ranging from 10 to 40 m to AA 7075. For inspecting the samples and studying the interaction and dispersion of SiC particles with the matrix, scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDAX) tests were used. The hardness of the samples increased as the SiC reinforcement was increased from 5% to 15%. The composite sample with 10% SiC had the best tensile properties.

## 2.1 Conclusion from the literature review

After this elaborate literature review, the conclusions drawn are summarized as:

- a. Hardness shows the best results when the silicon carbide is employed at 25% weight %.
- b. Hardness increases as silicon carbide content increase, but lowers as graphite content increases. As a result, both the reinforced material and the necessary number can be utilized in suitable proportions to achieve the desired hardness.
- c. The addition of silicon carbide continuously produces noticeable improvements in wear resistance.
- d. Apart from mechanical and tribological properties, thermal is one such area where the further research can be concentrated upon.



*Materials  
and  
Methods*



This chapter focuses at the material's characteristics as well as how to evaluate the properties and effects of adding reinforcement to an aluminium metal matrix composite. The requirements and the experimental setup are included. This chapter covers the materials and systems used in composites handling, as well as the outcomes of physical, mechanical, and wear testing conducted on the proposed composite materials under various conditions. The chemical composition, tribological properties, specimen geometry, and procedure parameters are all discussed in detail.

### **3.1 Aluminium 1070**

Aluminium is the most common matrix material used in metal-matrix composites because of its low melting temperature, and low density. Aluminium with a purity of 99.70 percent or higher is soft, ductile, and corrosion-resistant, as well as having a high electrical conductivity and being one of the lightest engineering metals, with a strength-to-weight ratio superior to steel. Aluminium has a density of only  $2.7 \text{ g/cm}^3$ , approximately one-third as much as steel ( $7.83 \text{ g/cm}^3$ ). As a result, it's a key structural element for the transportation industry, allowing for increased payloads or fuel savings. It is commonly used for foil and conductor cables and has many applications, particularly in the electrical and chemical areas. While strain hardening can provide moderate increases in strength, alloying with other elements is required to produce the higher strengths required for other applications. However, alloying elements such as manganese, silicon, copper, and magnesium can be added to aluminium to increase its strength and form an alloy with properties tailored to particular applications. The main impurities in Aluminium 1070 alloy are iron and silicon. Aluminium has a thermal conductivity that is around three times that of steel. Aluminium is therefore a valuable material for both cooling and heating applications, such as heat exchangers. Aluminium is widely used in cooking appliances and kitchenware due to its nontoxic properties. Rolling, extruding, drawing, machining, and other mechanical techniques can now be used to produce aluminium. It can also be cast with a greater precision.

Aluminium's properties can be tailored through alloying, cold working, and heat treatment. When aluminium is exposed to the air, a layer of aluminium oxide

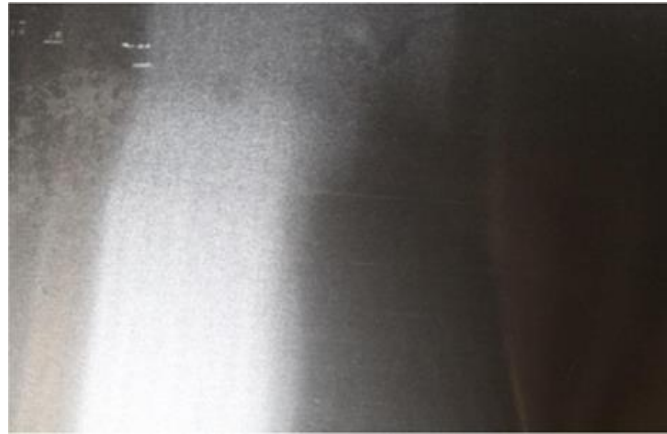
accumulates on the surface relatively quickly. This layer has excellent corrosion resistance. The heat conductivity of aluminium is around three times that of steel. As a result, aluminium is an excellent choice for cooling and heating applications like heat exchangers. Aluminium is commonly used in cooking tools and kitchenware because to this feature, as well as the fact that it is non-toxic. Aluminium can then be formed via rolling, extruding, drawing, machining, and other mechanical operations. It's also possible to cast it with a high degree of precision. Aluminium's properties can be improved through alloying, cold working, and heat treatment. Aluminium is non-ferromagnetic, which is a desirable feature in the electrical and electronic industries. It is non-pyrophoric, which is significant in applications involving the handling or exposure of flammable or explosive materials. Aluminium is also non-toxic and is commonly used in food and beverage containers. Its natural finish, which can be soft and lustrous or bright and shining, has an appealing appearance. It can be virtually any color or texture. The Aluminium 1070 procured from Balaji Aluminium Store, New Delhi.

**Table 3.1(a) Chemical composition of Al 1070**

Element	Al	Fe	Si	Zn	V	Cu	Ti	Mg	Mn	Other
Content (%)	≥ 99.7	≤ 0.25	≤ 0.20	≤ 0.040	≤ 0.050	≤ 0.040	≤ 0.030	≤ 0.030	≤ 0.030	≤ 0.030

**Table 3.1 (b) Properties of Al 1070**

Atomic number	13
Atomic weight	26.97
Crystal structure	FCC
Colour	Tin-white
Specific gravity	2.7
Density	2.7 gm/cm <sup>2</sup>
Melting point	680 °C
Young's modulus of elasticity	68 GPa
Tensile strength	94.68 N/mm <sup>2</sup>
Hardness	41 HRB



**Figure 3.1(a) Aluminium 1070 Alloy Sheet**

The aluminium alloy 1070 is most commonly used in the following applications:

- a. Components for general industrial use
- b. Construction and structure
- c. Transporting electrical equipment
- d. Cables for communication, Cabinets for refrigerators and freezers
- e. For joining two pieces of aluminium together

### **3.2 Reinforcement**

Soft and hard reinforcements are added into the matrix to improve the mechanical and wear properties of aluminium alloy. Low friction, chemical inertness, lack of inherent abrasiveness, film forming ability on metal surfaces, and relatively inoffensive to nature are all properties of soft reinforcement. However, there was a decrease in hardness and flexural strength. This problem can be solved by combining strong ceramic reinforcements with soft reinforcements to increase mechanical and tribological properties. Reinforcement material can be continuous or discontinuous when embedded in the matrix. Whiskers, small fibres, or particles are used in discontinuous reinforcement, and one such reinforcement is silicon carbide. The formability of particulate-reinforced composites has a cost advantage over other materials. Furthermore, they have heat and wear resistance properties.

### 3.2.1 Silicon Carbide (SiC)

Soft and hard reinforcements are added into the matrix to enhance the mechanical and wear properties of aluminium alloy. Low friction, chemical inertness, lack of inherent abrasiveness, film forming ability on metal surfaces, and relatively inoffensive to nature are all properties of soft reinforcement. However, there was a decrease in hardness and flexural strength. This problem can be solved by combining hard ceramic reinforcements with soft reinforcements to increase mechanical and tribological properties. Silicon carbide (SiC) crystallizes in a number of different structures, each with its own set of electrical, optical, thermal, and mechanical properties. Physical properties of SiC are major academic areas as well as important parameters for accurate device simulations. SiC is a compound semiconductor, which means that it can only have a rigid stoichiometry of 50% silicon (Si) and 50% carbon (C). Tetravalent elements, such as Si and C, have four valence electrons in their outermost shells. To form a SiC crystal, Si and C atoms are tetrahedral connected by covalent bonds by sharing electron pairs in orbitals. Each Si atom has exactly four C atom neighbors, and vice versa. The Si–C bond energy is extremely high (4.6 eV), giving SiC a wide range of unique features. The physical properties of Silicon Carbide (SiC) offers excellent wear resistance and mechanical properties, such as high temperature strength and thermal shock resistance. As a technical ceramic, silicon carbide (SiC) is made in two ways. Infiltrating compacts consisting of mixtures of Silicon Carbide (SiC) and Carbon with liquid Silicon produces reaction bonded SiC. Silicon Carbide is formed when silicon interacts with carbon. The SiC particles are bonded together by the reaction product. Sintered SiC is made with non-oxide sintering aids and is produced from pure SiC powder. The material is sintered in an inert atmosphere at temperatures of up to 2000°C or higher, using conventional ceramic forming procedures. In temperatures as high as 1400°C, silicon carbide (SiC) maintains its excellent mechanical strength. It resists chemical corrosion better than other ceramics. Silicon Carbide is a refractory material with a high melting point, high thermal conductivity, and lesser thermal expansion, giving it superior thermal shock resistance. Aside from that, the high hardness, corrosion resistance, and stiffness make it suitable for a wide range of applications where wear and corrosion resistance are essential.

As a technological ceramic, silicon carbide (SiC) can be made in two different ways. Infiltrating compacts of Silicon Carbide (SiC) and Carbon with liquid Silicon results in reaction bonded SiC. Silicon Carbide is produced when silicon interacts with carbon (SiC). The SiC particles are linked together by the reaction product. Sintered SiC is made using non-oxide sintering aids and pure SiC powder. The material is sintered in an inert atmosphere at temperatures of up to 2000°C or higher, using conventional ceramic forming techniques. Silicon Carbide (SiC) can withstand temperatures up to 1,400 °C and still keep its excellent mechanical strength. It outperforms other ceramics in terms of chemical resistance. Silicon Carbide is a refractory material with a high melting point, high thermal conductivity, and low thermal expansion, resulting in good thermal shock resistance.

### 3.2.2 Magnesium (Mg)

Magnesium has higher work hardening properties and extremely high strength without significantly reducing aluminium's ductility. It also has a high level of wettability and resistance to corrosion. Silicon reacts with magnesium to produce  $Mg_2Si$ , a hardening phase that provides strength. In the solidification procedure of MMCs, the wettability of the reinforcement by the molten metal that will create the composite matrix is extremely important to establish a strong and adequate interface to allow efficient load transfer and distribution from matrix to reinforcements. To improve particle wetting by liquid metal, methods such as increasing the temperature of the metal liquid, pretreatment of the particles, coating or oxidizing the ceramic particles, and adding some surface-active elements such as magnesium and lithium to the matrix have all been recommended.

Because Mg is a strong surfactant, it aids in the scavenging of oxygen from dispersoids surfaces by generating MgO and  $MgAl_2O_4$  in accordance to Mg content, thus enhancing the solid's surface energy. Non-wetting of the reinforcement with molten metal is caused by the existence of oxide layers on the molten metal surface and the adsorbed contaminant on the reinforcement surface. At 660°C, the surface tension of Mg (0.577 N/m) is lower than that of Al (0.871 N/m), hence adding Mg lowers the molten Al surface tension. The presence of interfacial reaction ensures a

decrease in interfacial energy. The recovery of the particles into the melt without the addition of Mg is quite low. For appropriate result, the amount of Mg must be controlled; too high a concentration will cause particle agglomeration since Mg addition to Al affects casting fluidity.



**Figure 3.2 (a) Magnesium Metal Powder**

**Table 3.2 (a) Chemical composition of Magnesium Metal Powder**

Element	Mg	Fe	HCl
Content (%)	≥ 99	≤ 0.05	≤ 0.05

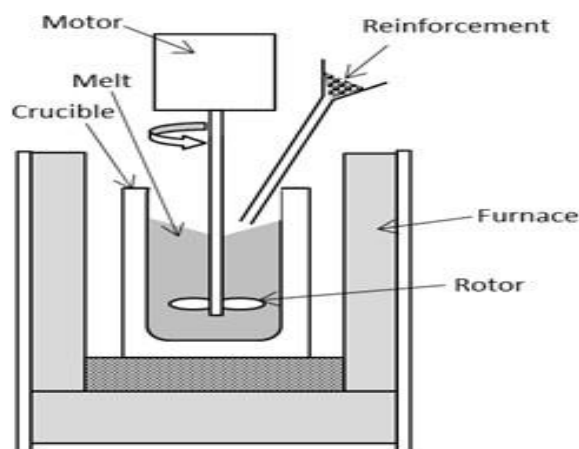
### 3.3 Casting Process

Mechanical stirring is used to give reinforcement to molten metal in the stir casting procedure. S. Ray invented this technique in 1968, when he developed the stir casting technique and for the first time synthesized Al-Al<sub>2</sub>O<sub>3</sub> particle reinforced composites. Stirring helps in two ways during stir casting for composites synthesis: it helps to transfer particles into the liquid metal and it helps to keep the particles in suspension (**Ray, 1995**). Magnesium has been identified as an additive that helps molten aluminium wettability of alumina particles.

Stir casting is a suitable processing technique for fabricating aluminium matrix composites and hybrid aluminium matrix composites because of its cost-effectiveness, simplicity, flexibility, and applicability to large-scale production. It also allows for the fabrication of very large-scale components. However, the following factors should be considered when generating AMMCs using stir casting. Between the reinforcement material and the matrix alloy, there must be no unfavorable chemical reactions. The

reinforcements degrade or disappear as a result of the reaction (Sijo and Jayadevan, 2016). If this reaction occurs, the composite will not have the expected qualities. As a result, special techniques are necessary to generate metal matrix composites with desirable properties. There is no or very little porosity in the cast AMMCs. Wettability between the two major phases and a homogenous distribution of the reinforcement material are crucial when producing AMMCs via stir casting. Wettability and reactivity are indicators of the quality of constituent bonding and, as a result, have a significant impact on the composite material's final qualities.

The first step in the stir casting process is to melt aluminium. During melting, aluminium melt reacts with the atmosphere and moisture to form an aluminium oxide layer ( $\text{Al}_2\text{O}_3$ ). The melt's surface is protected from further atmospheric reactions by this layer. Particle reinforced metal matrix composites are typically made using the stir casting method (PMMC). The reinforcement constituent material is mixed into molten metal in this basic composite manufacturing technique. Stir casting of metal matrix composites begins with a melt of the matrix material of chosen, followed by the addition of a reinforcement material to the melt. The melt should be degassed with a selective medium before adding the reinforcement material, as the molten metal combines with air oxides and undergoes oxidation, which degrades the properties of the base material. The next step is to solidify the melt with embedded dispersoids under particular conditions to achieve the desired dispersed phase distribution in the cast matrix.



**Figure 3.3(a) Stir Casting Setup**

### 3.3.1 Sand and Mould Preparation

Die casting, permanent mould casting, or sand casting can all be done with the molten alloy and reinforcing particles. Sand casting is one of the oldest types of casting due to the simplicity of the materials required. It is still one of the most affordable metal casting processes due to its simplicity. The type of sand used has a significant impact on the quality of the casting. Two of the most major advantages of using sand are its ability to keep its shape and resist damage, such as cracking from the heat of the molten metal. The sand can also be reused to make more moulds in the future. The sand that is used in sand casting is called green sand and it has good refractoriness, permeability, flow ability and collapsibility. Refractoriness is the ability of the moulding sand to withstand high temperature of liquid metal without fusion. Permeability is the ability of the moulding sand to allow the gases to escape. Flow ability is the ability of moulding sand to flow to all the corners of the mould box due to ramming force. The sieve was filled with sand, and the mould was turned upside down to make room for the sand in the drag. After that, unsieved sand was poured in the mould and parting powder was applied to the setup. The lamper was used to compress the sand into the drag, and ramming was done to improve compaction. The drag base was flattened with a straight edge. A pin was used to locate the cope once it was placed on top of it. The cope and drag were then separated, and the mould was removed from the cope and drag. The green sand mould, illustrated in figure 3.3(b), was 210 mm long, 150 mm broad, and 18 mm thick. Figure 3.3(c) illustrates sand preparation using a sieve, dividing sand to separate cope and drag, and the required shaped mould for the cope and drag arrangement.



**Figure 3.3(b) Mould**



**Figure 3.3(c) Preparation of sand and mould used in the cope and drag arrangement**

### **3.4 Fabrication Methodology**

The composites were fabricated using the traditional stir casting technique. Aluminium sheet was melted in a crucible by heating it to 700°C in a coal furnace. With the help of a mild steel stirrer, swirled constantly for 5 to 10 minutes at a speed of 270 rpm. The stirrer was preheated before being immersed in the molten metal, and it was placed at a depth of about 2/3 of the melt's height from the bottom. The furnace temperature was raised above the liquidous temperature of aluminium, 760°C, in order to totally melt the aluminium, which was subsequently cooled to keep the slurry semi-solid. The powder form of reinforcement (SiC) was then added to the molten metal in weight % of 6, 11, 16, 21, and 26 for each composite. Magnesium was also added to the melt in a small amount (1 wt. %) to reduce floating of reinforcement particles on the molten surface and to enhance wettability of the contact surface. For mixing in the semi-solid condition, 10 minutes of manual mixing were used. The slurry was heated to a fully liquid state after manual mixing, and then mechanical mixing was done for additional 10 minutes. After a suitable amount of mixing, the mixture was poured into the mould. The casted composite was 200 mm long, 150 mm wide, and 16 mm thick, and when the process was completed, the produced sample was air cooled. Figure 3.4(a) shows the melting of aluminium sheets in a hot furnace.

This was followed by the addition of melting reinforcement and stirring, as indicated in figure 3.4(b). The molten metal and SiC combination was then poured into the mould to get the desired shape, as shown in figure 3.4(c).



**Figure 3.4(a) Melting of aluminium sheet and heated furnace**



**Figure 3.4(b) Stirring the mixture of Aluminium 1070 and SiC**



**Figure 3.4(c) Pouring the molten metal and solidification**

### 3.4.1 Surface finish of Casting

After the casting has solidified, the surface texture is rough. A faultless surface finish is the most important consideration when creating the needed specimens from the casted plate. The plate casting is finished with a milling machine and a manual grinder. The plate's final dimensions are 200 mm x 150 mm x 16 mm.

### 3.5 Test procedure

1. Density
2. Hardness (ROCKWELL)
3. Tensile test
4. Sliding wear test
5. Dry sand abrasion test
6. Scanning electron microscopy (SEM)

#### 3.5.1 Density

The density of an object is the mass of the object compared to its volume. There are two types of density measurement for MMCs.

- (i) Theoretical density
- (ii) Experimental density

##### 3.5.1.1 Theoretical density

The theoretical density was evaluated by using the rule of mixtures. The theoretical density of composites was calculated using the formula given in equation (3.1).

$$\rho_t = w_m \rho_m + w_r \rho_r \quad \text{equation (3.1)}$$

Where,

$w_m$  = weight percentage of matrix

$\rho_m$  = density of matrix

$w_r$  = weight percentage of reinforcement

$\rho_r$  = density of reinforcement

### 3.5.1.2 Experimental density

Actual Density define as actual mass per volume. In general, it expressed in terms of gm/cm<sup>3</sup>. The following Formula used to obtain actual density of Metal Matrix Composites given in equation (3.2).

$$\rho_a = \frac{m}{v} \quad \text{equation (3.2)}$$

$\rho_a$  = Actual Density of Metal Matrix Composite

$m$  = Actual Mass of Metal Matrix Composite

$V$  = Volume of Metal Matrix Composite

### 3.5.1.3 Porosity

From theoretical density that was calculated with the help of rule of mixture and experimental density that we calculated after fabricating the composite, porosity can be calculated using equation (3.3).

$$\emptyset = \frac{\rho_{ex} - \rho_{th}}{\rho_{ex}} \quad \text{equation (3.3)}$$

Where,

$\emptyset$  = porosity in the composite

$\rho_{ex}$  = experimental density of composite

$\rho_{th}$  = theoretical density of composite

### 3.5.2 Hardness test

Hardness is a characteristic of a material, not a physical property. It is determined by measuring the permanent depth of the indentation and is defined as resistance to indentation. The most widely used hardness test method is the Rockwell hardness test method, as defined in ASTM E-18. Other forms of hardness testing procedures are more difficult to perform and less accurate than the Rockwell test. The Rockwell test method is used on all metals, except the test metal structure or surface conditions would introduce too many variations, the indentations would be too large for the application; or the sample size or shape

would prevent its usage. The Rockwell method is used to determine the permanent depth of indentation caused by a force/load on an indenter. To provide a preliminary test force to a sample, a diamond or ball indenter is utilized. This preload breaks through the surface to minimize the effect of the surface finish. After holding the preliminary test force for a predetermined dwell time, the baseline depth of indentation is measured. To reach the total required test load, an extra load, referred to as the main load, is added after the preload. To allow for elastic recovery, this force is held for a predetermined amount of time. The major load is subsequently released, and the preliminary load is returned. The ultimate depth of indentation is measured after holding the preliminary test force for a predetermined dwell time. The difference between the baseline and final depth measurements yields the Rockwell hardness value. This distance is converted to a number of hardness. The preliminary test force is removed and the indenter is removed from the test specimen. The hardness number will be followed by HR (Hardness Rockwell) and the scale letter in the hardness value recorded from a Rockwell testing equipment. In the case of soft materials such as copper alloys, aluminium alloys, and soft steel, the B scale is used. The specimen used for hardness test are shown in Figure 3.5(a) and Figure 3.5(b) shows the Rockwell machine used for the test and the specimen under the indenter ball.



**Figure 3.5(a) specimen for hardness test**



**Figure 3.5(b) Rockwell Hardness Testing Machine**

### 3.5.3 Tensile test

The tensile test is one of the most basic mechanical tests that can be done on a material. Tensile tests are used to determine how materials will respond when subjected to tension. A sample is typically stretched to its breaking point in a simple tensile test to determine the material's ultimate tensile strength. Throughout the test, the amount of force applied to the sample and its elongation are measured. Stress (resisting force per unit area) and strain (percent change in length) are commonly used to describe material properties. The force measurements are divided by the sample's cross sectional area to obtain stress. The change in length is divided by the sample's initial length to obtain strain measurements. These numbers are then displayed on a stress-strain curve, which is an XY plot. Depending on the material being tested and its intended application, several testing and measuring processes are used.

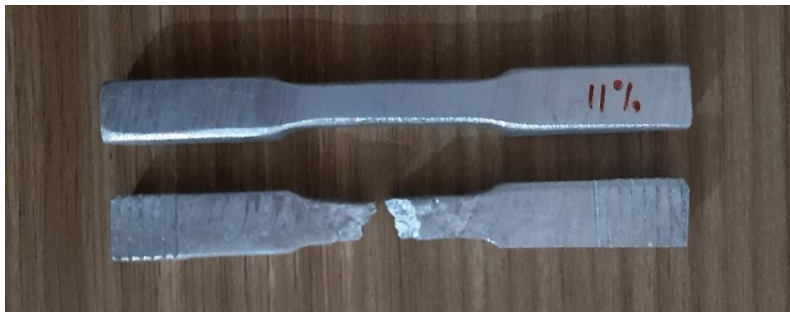
A tensile test involves placing a sample into a tensile test equipment and putting it under controlled tension until it breaks. A tensile test measures ultimate

tensile strength, breaking strength, maximum elongation, Young's modulus, yield strength, and strain hardening properties. The tensile testing was conducted on the AMT- SC made servo controlled Universal Tensile Machine (UTM) setup at MED COT Pantnagar. The tests conducted on environmental conditions. The rate of displacement is set to 0.005 mm/sec. The dimensions of the specimen are as per ASTM E8 standard. The dimensions of the testing specimen are given below:

- a. Gauge length – 25 mm
- b. Overall length – 100 mm
- c. Width of grip section – 10 mm
- d. Length of grip section – 30 mm
- e. Thickness – 6 mm
- f. Length of reduced section- 32 mm
- g. Width of reduced section – 6 mm
- h. Radius of fillet – 5 mm



**Figure 3.5(c) Universal Testing Machine**



**Figure 3.5(d) UTM sample before and after test**

### 3.5.4 Sliding wear test

Different types of Tribometer are used to characterize friction and wear in materials, with the pin on disc test being one of the most frequent. The method's popularity comes from its relative simplicity and abundance of tribological contacts, which may be well characterized by a simple pin on disc motion ranging from dry bolt screw connections to rail wheels to rail contact and lubricated biological implant contact. Several motion modes, such as unidirectional, fretting modes, and, more recently, any other complex motion patterns, are often tested in this test.



**Figure 3.5(e): Counter disc on apparatus**

A pin on disc Tribometer was used to perform the wear test. A stationary pin is generally loaded against a rotating disc in a pin on disc Tribometer. To simulate a specific contact, the pin can be any form, but spherical tips are often used to simplify the contact geometry. The ratio of frictional force to loading force on the pin determines the coefficient of friction. The experimentation performed on DUCOM (Wear and Friction Testing Machine) and ASTM G99 is followed. The wear test conditions of samples shown in the table 3.5(a) below.

**Table 3.5 (a) Wear test parameters used for the experiments**

<b>Pin material</b>	Al+SiC composites
<b>Disc material</b>	EN31 steel disc
<b>Sliding speeds</b>	2.5 m/s
<b>Track diameter</b>	50 mm to 80mm
<b>Loads</b>	20 N
<b>Temperature</b>	Room temperature (not constant)
<b>Sliding distance</b>	250m, 500m, 750m, 1000m, 1250m, 1500m.

Wear rate for the composites were calculated based on the difference in weights of the specimen using the equation (3.4) for varying sliding distance.

$$\text{Wear rate (WR)} = \frac{W}{\rho D} \quad \text{equation (3.4)}$$

Where

W = Weight loss (kg)

$\rho$  = Density of the material (kg/mm<sup>3</sup>)

D = sliding distance (m)

#### 3.5.4.1 Coefficient of friction

The ratio of friction force to normal load is known as the coefficient of friction. It is denoted by the symbol  $\mu$ . The Coefficient of Friction was calculated using equation (3.5).

$$\text{Coefficient of friction } (\mu) = \frac{f}{N} \quad \text{equation (3.5)}$$

Where,

$f$  = Friction force (N)

$N$  = Normal load (N)



**Figure 3.5(f): Pin on disc testing machine**

### **3.5.5 Dry sand abrasion test**

A standard test specimen is abraded with a grit of controlled size and composition in the dry sand abrasion test. The abrasive test is performed by introducing the test specimen between a rotating wheel and a hardened chloro butyl rubber tier or rim. A lever arm presses this test specimen against the rotating wheel at a specific force, while a regulated flow of grit abrades the test surface. The wheel rotates in such a way that its contact face moves in the same direction as the sand flow. Weights of specimens are taken before and after the test, and the mass loss is calculated. Due to the significant differences in material density, it is important to convert mass loss to volume loss in cubic millimeters. Dry sand abrasion test was performed at Department of Farm Machinery and Power Engineering, G.B. Pant University of Agriculture and Technology, Pantnagar. The test parameters are shown in table 3.5 (b).

**Table 3.5 (b) Dry sand abrasion test parameters used for the experiments**

Disc Material	ST37
Rubber Wheel Material	Chlorobutyl
Abrasive	Ottawa sand
Abrasive Flow	Medium (130 g/min)
Load	20N + Dead Weight
Rotation	1350
Rotational Speed	135 rpm

Mass abrasion rate was calculated by ratio of mass loss and sliding distance, as shown in equation (3.6)

$$\text{Mass abrasion rate} = \frac{m_l}{D} \quad \text{equation (3.6)}$$

**Figure 3.5(g): Dry sand abrasion test setup**



**Figure 3.4(h): Sample before and after abrasion test**

### **3.5.6 Scanning electron microscopy (SEM)**

SEM is utilized for deep analysis of material failure, microanalysis, mechanism of fracture, particle dispersion, and voids etc. It can be used at high magnification, generate extremely high-resolution images, and measure objects with extreme precision. The SEM generates a variety of signals at the surface of solid specimens using a focused beam of high energy electrons. The signals generated by electron sample interactions disclose information on the sample's external morphology, chemical composition, crystalline structure, and orientation of the materials that make it up. In most applications, data are collected over a selected area of the surface of the sample, and a 2-dimensional image is generated that displays spatial variations in these properties. SEM was performed at College of Veterinary and Animal Sciences, G.B. Pant University of Agriculture and Technology (Model no. JEOL JSM-6610LV).



**Figure 3.6(i): Scanning electron microscopy (SEM) setup**



*Results  
and  
Discussion*



**4.1 Tensile tests**

The mechanical properties of the aluminum silicon carbide were determined by 25 KN universal testing machine. The dog bone shape for the test was designed according to ASTM E8-04.

Figure 4.1 shows the tensile stress-strain curves for aluminium and aluminum-based silicon carbide composites containing 6, 11, 16, 21, and 26 wt. % silicon carbide. The ultimate tensile strength of aluminium composites increases with the addition of SiC reinforcement particles due to dispersion hardening, but after 21 wt. % SiC, the strength decreases due to reinforcing particle clustering. We found that the ultimate strength of Al base metal is 95 MPa, which is increased to 185.18 MPa at 21 wt. % SiC in the investigation. After then, the strength of the material decreases because SiC combines with molten aluminium to form  $Al_4C_3$  (aluminium carbide), which is more brittle than SiC and forms a layer of  $Al_4C_3$  on the SiC particles, decreasing the material's strength.

When stress is applied, particles of silicon carbide in the composite obstruct dislocation motion, which is not present in pure material, resulting in an increase in strength. Dislocation lines tear and migrate through the gap between two reinforcing particles as stress levels increase to a certain degree. As a result, the more SiC particles present, the greater the stress required to rupture the dislocation line. Clustering of SiC particles occurs after 21 wt. %, and hence dislocation experienced no obstacle.

The percent increase in ultimate tensile strength of various composites compared to parent Al metal is shown in Figure 4.2. The highest tensile strength of pure Al is 95 MPa, while the ultimate tensile strength of SiC at 6 wt. % is 118 MPa, which is about 124 percent increase in strength. The best results come from using 21 wt. % SiC, which increases strength by 194 percent over the base Al used. The ultimate tensile strength of Al and Al-based composites with varying wt. % SiC is shown in Figure 4.3. Particle pull out and crack propagation during testing, which occur at the SiC matrix interface, are likely to be the cause of the observed decrease in UTS.

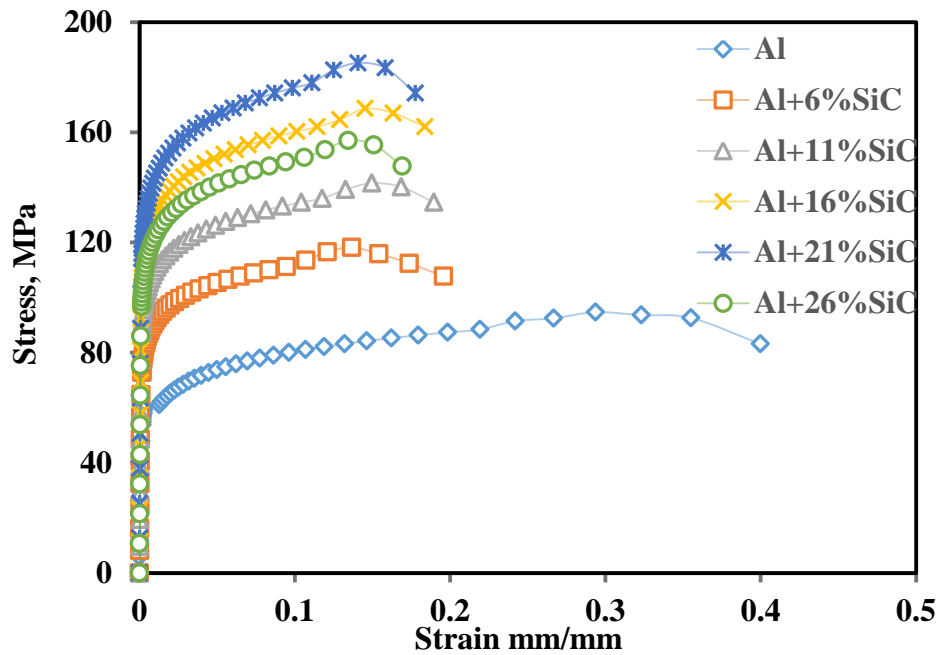


Figure 4.1: Stress-strain curve of Al and Al based composite with various wt. % of SiC

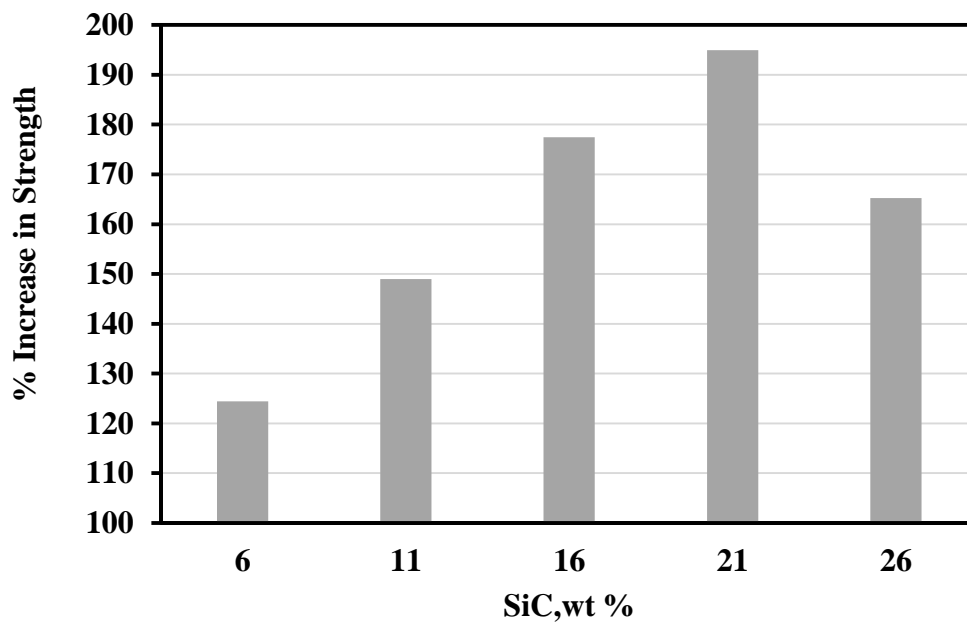


Figure 4.2: % increase in ultimate strength of various composites from base Al metal

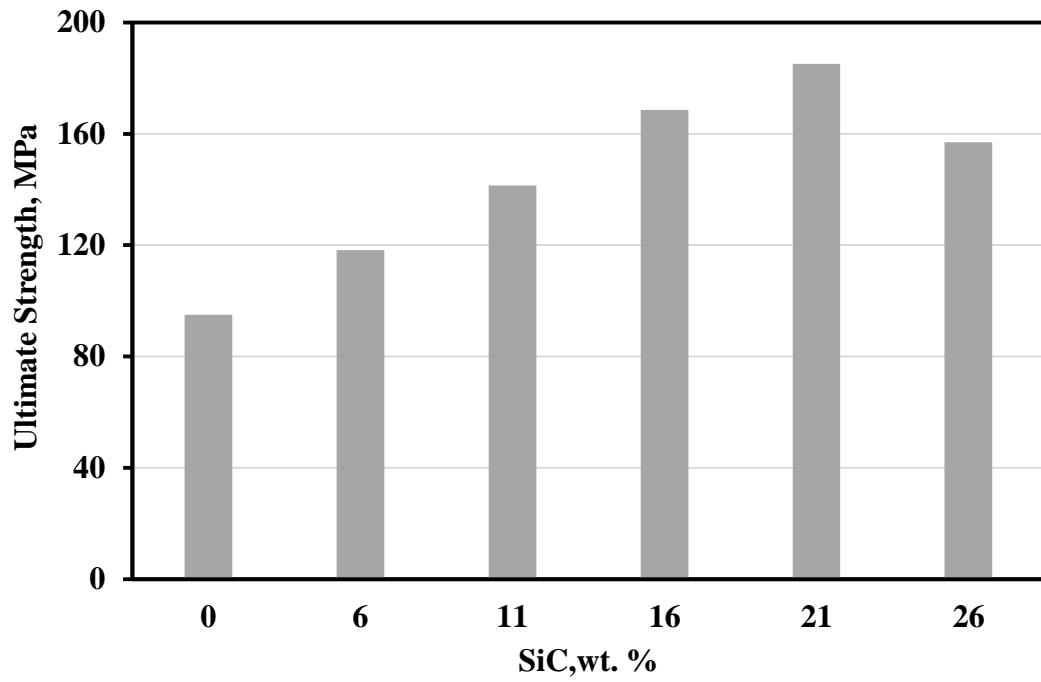


Figure 4.3: Ultimate strength of Al and Al based composite with various wt % of SiC

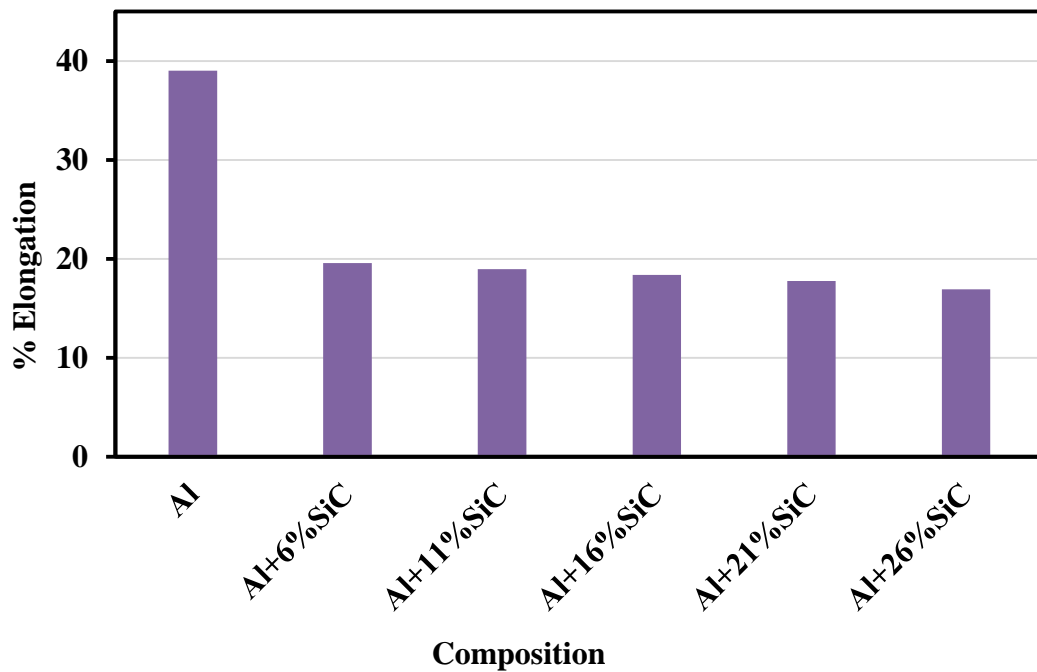


Figure 4.4: % elongation of various compositions of SiC and Al matrix

The composite's percentage elongation was found to be lower than that of an unreinforced alloy, indicating that the inclusion of SiC lowers the composite's ductility. Composites become more brittle as the amount of SiC increases. Debonding between the SiC and the Al matrix occurs at greater stresses, resulting in particle pullout and a decrease in elongation. This could be due to the fact that failure appears to be caused by the accumulation of internal damage to particles, which can be caused by particle fracture or interfacial failure. Such damage causes voids to form, which grow and reduce the ductility of these composites.

$$\% \text{ Elongation} = \frac{l_o - l_f}{l_o} \times 100$$

Where  $l_o$  is original length and  $l_f$  final length.

The ductility of various composites is shown in Figure 4.4. The term "ductile material" refers to materials that have more than 5% elongation. The above diagram shows that all composites are ductile, however composites containing 26 wt. % SiC are brittle. Ductility is a major concern because it has a direct impact on the material's toughness.

**Table 4.1: Tensile properties of Al with different wt. % of SiC**

S. No.	Specimen	YS (MPa)	UTS (MPa)	E (GPa)	% Elongation
1	Al	60	95	68	39
2	Al + 6% SiC	80.95	118.19	69.77	19.569
3	Al + 10% SiC	96.92	141.51	86.41	18.964
4	Al + 16% SiC	115.48	168.6	97.52	18.373
5	Al + 21% SiC	126.84	185.18	111.39	17.766
6	Al + 26% SiC	107.52	156.99	125.27	16.925

#### 4.2 Density

Density is the measure of heaviness of matter. SiC has a density 3.21 gm/cm<sup>3</sup>, higher than that of aluminum (2.70 gm/cm<sup>3</sup>) and hence an increase in SiC content will increase the density of the composite.

**Table 4.2: Density and porosity of aluminum matrix with different wt. % of SiC**

Composition	$\rho_{th}$	$\rho_{ex}$	Porosity( $\phi$ )
Al-6 SiC	2.71	2.69	0.59
Al-11 SiC	2.72	2.70	0.70
Al-16 SiC	2.74	2.71	0.77
Al-21 SiC	2.75	2.72	0.95
Al-26 SiC	2.77	2.74	0.98

The volume fraction of microstructural porosities was increased by increasing the SiC weight %. The influence of SiC concentration on the density of Al-based SiC composites is shown in Table 4.2. Because SiC has a higher density than aluminium, the theoretical density of the composites is found to increase as the wt % of SiC is increased. Similarly, the actual density of the composite as determined by experimental measurements increased with the addition of SiC. The reason for this is that SiC has a higher density than aluminium, and the smaller particle size of SiC allowed it to fill the pores.

Porosity, according to **(Ghosh and Ray, 1998)**, is a casting defect that is undesirable in aluminium matrix composites. Porosity is caused by three factors: (a) gas entrapment during mixing, (b) hydrogen evolution, and (c) solidification shrinkage. Casting parameters are the primary source of porosity formation. Casting parameters include the casting route used, impeller speed and position, volume fraction of reinforcement material, and process characteristics such as holding time. Porosity in cast composites can be categorized into two categories, according to **(Ray, 1993)**. (a) In the absence of the matrix alloy's ceramic particles; (b) At the interface between the matrix phase and the reinforcement.

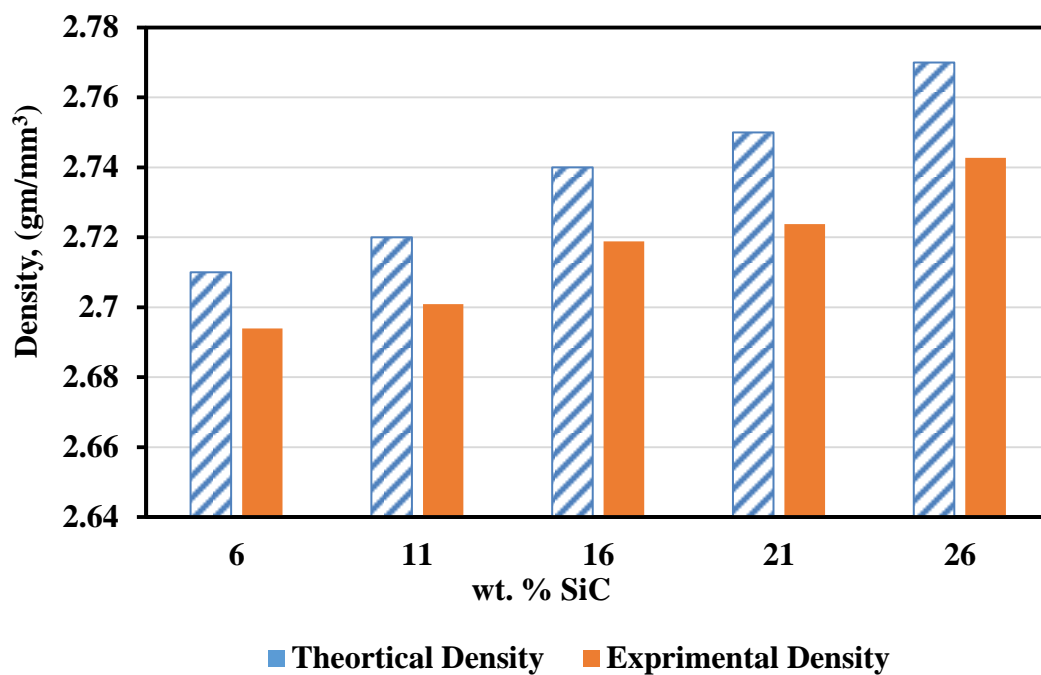


Figure 4.5: Comparison of theoretical and experimental density with varying wt. % of SiC

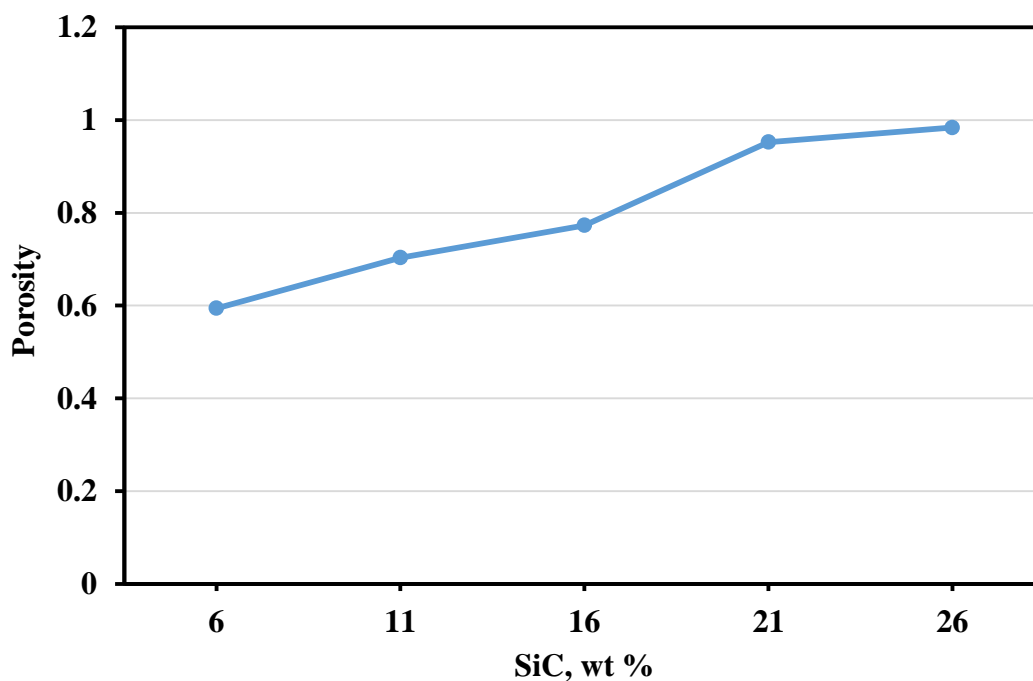
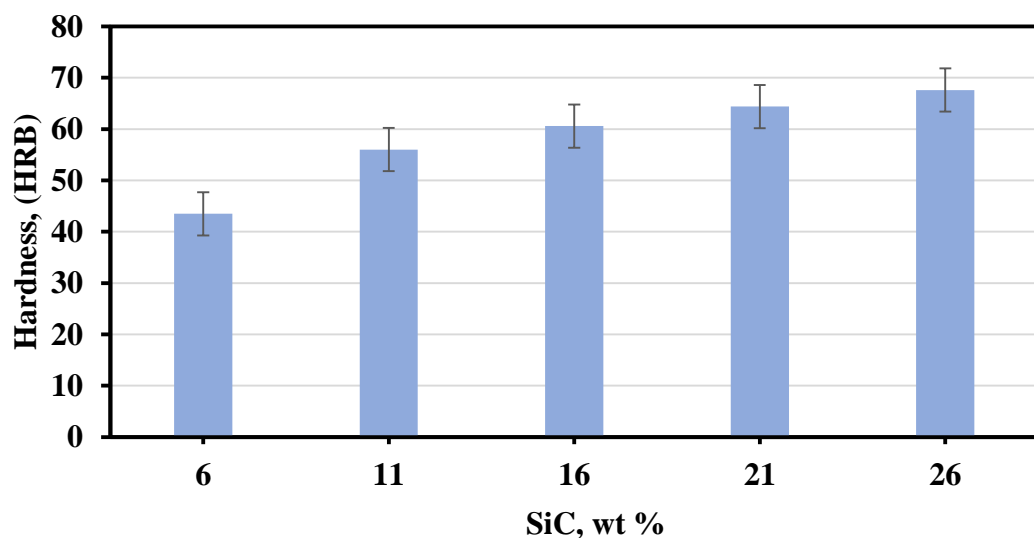


Figure 4.6: Comparison of porosity with varying wt. % of SiC

### 4.3 Hardness

The permanent depth of the indentation is used to determine hardness, which is defined as the resistance to indentation. The hardness value of a composite material is significantly affected by the reinforcing weight fraction. Hardness of composite depends on the hardness of the reinforcement and the matrix. The hardness of the composite was found to be higher than that of the unreinforced alloy in the current investigation.

The composite's hardness is determined by the hardness of the reinforcement and matrix. Because the coefficient of thermal expansion (CTE) of particulates (SiC: 4.03 m/m°C) is lower than that of aluminium alloy (22.3 m/m°C), a considerable number of dislocations are formed at the particle-matrix interface during solidification, increasing the matrix's hardness. The larger the particle-matrix contact, the greater the degree of dislocation hardening. Hence, as the volume fraction of the reinforcement increased, the composites' hardness increased. Figure 4.7 illustrates that when the proportion of reinforcement increased, the hardness increased as well. The microstructure refinement and rapid solidification effect increased composite hardness. (Singh, M *et al.*, 2002) observed that the higher dislocation density in the matrix caused by the difference in coefficients of thermal expansion of the aluminium matrix alloy and reinforcement increased the hardness of the composites.



**Figure 4.7: Variation in Hardness of the composites with wt % of SiC**

**Table 4.3: Hardness values of aluminum matrix composite with different wt. % of SiC**

Specimen	Point 1	Point 2	Point 3	Point 4	Point 5	Mean Hardness
Al-6 SiC	42.8	42.3	43.1	42.3	43.9	42.7 ± 0.4
Al-11 SiC	55.3	53.9	54.5	54.3	55.2	54.6 ± 0.7
Al-16 SiC	59.5	59.6	59.2	59.9	58.8	59.4 ± 0.6
Al-21 SiC	63.6	62.5	62	62.8	63.1	62.8 ± 0.8
Al-26 SiC	66.4	66.1	66.9	67.1	66.8	66.6 ± 0.5

#### 4.4 Sliding wear test

A pin on disc apparatus was used to investigate the dry wear behaviour of composites. The wear behaviour of Al/SiC composites was studied with different sliding distances while maintaining the sliding velocity, applied load, and reinforcing effect. Wear rate reduced as the wt % of SiC increased up to 21, after which an increase in wt.% will increase wear rate due to a decrease in tensile strength. The brittleness of the material is increased by the decrease in tensile strength and increase in hardness. Table 4.4 shows that as the wt.% of SiC and sliding distance increase, the wear rate decreases. This is because as the wt % of SiC increases, so does its hardness, and Archard's wear law states that the amount of wear is inversely proportional to the material's hardness, so the wear rate decreases.

**Table 4.4: Wear rate with varying sliding distance**

Composition	Sliding distance(m)					
	250	500	750	1000	1250	1500
Al-6 SiC	0.07	0.06	0.05	0.045	0.043	0.04
Al-11 SiC	0.06	0.05	0.047	0.04	0.038	0.036
Al-16 SiC	0.05	0.047	0.042	0.036	0.033	0.032
Al-21 SiC	0.047	0.042	0.037	0.032	0.03	0.028
Al-26 SiC	0.05	0.046	0.041	0.035	0.033	0.031

The main effect plot of mean wear rate (Figure 4.8) shows that for a constant speed of 2.5 m/s and a load of 20 N, the wear rate decreases with increasing distance. SEM micrograph of Al/SiC wear surface at 20N load and 2.5 m/s sliding speed reveals significant ploughing and delamination. Under a load of 20N and a sliding speed of 2.5 m/s, SEM micrographs of the wear surface of composition show a lower degree of delamination. At low speeds, wear is mostly caused by ploughing of the counter face on the pin, followed by delamination.

Table 4.4 shows the wear rate variation for sliding distance, and as the sliding distance increases, the wear rate in composite decreases. This is due to SiC's excellent wear resistance, as well as the fact that at the initial sliding distance, the initial protrusion of the reinforcements in contact with the opposing surface becomes blunt and smoothed. This smoothing of the reinforcing particles leads to the formation of a self-lubricating layer, which aids in the reduction of wear rate as the sliding distance increases.

Wear resistance is inversely proportional to the applied load because an increase in the load increases the pressure on the pin, the interfacial temperature rises, causing the material to soften and the plastic flow to increase. SEM micrograph of Al/SiC wear surface at 20N load and 2.5 m/s sliding speed exhibits minimal ploughing, scratch marks, and delamination. Because the applied load is less (20 N), the contact stresses caused by the applied pressure are less as well, resulting in a lower wear rate.

As shown in the table (4.4), the wear rate of composites decreased as the SiC content increased. The decrease could be attributed to SiC composites increased hardness when compared to the unreinforced alloy. Delamination and severe abrasion became the wear mechanisms as the % SiC increased.

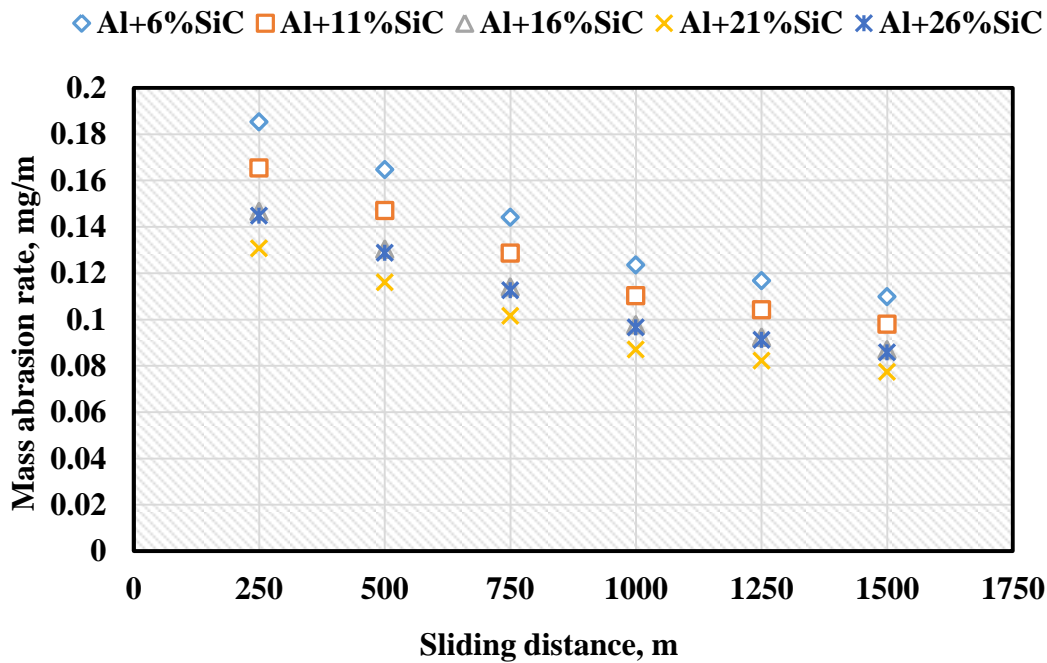


Figure 4.8: Mass wear rate of different compositions with varying sliding distance

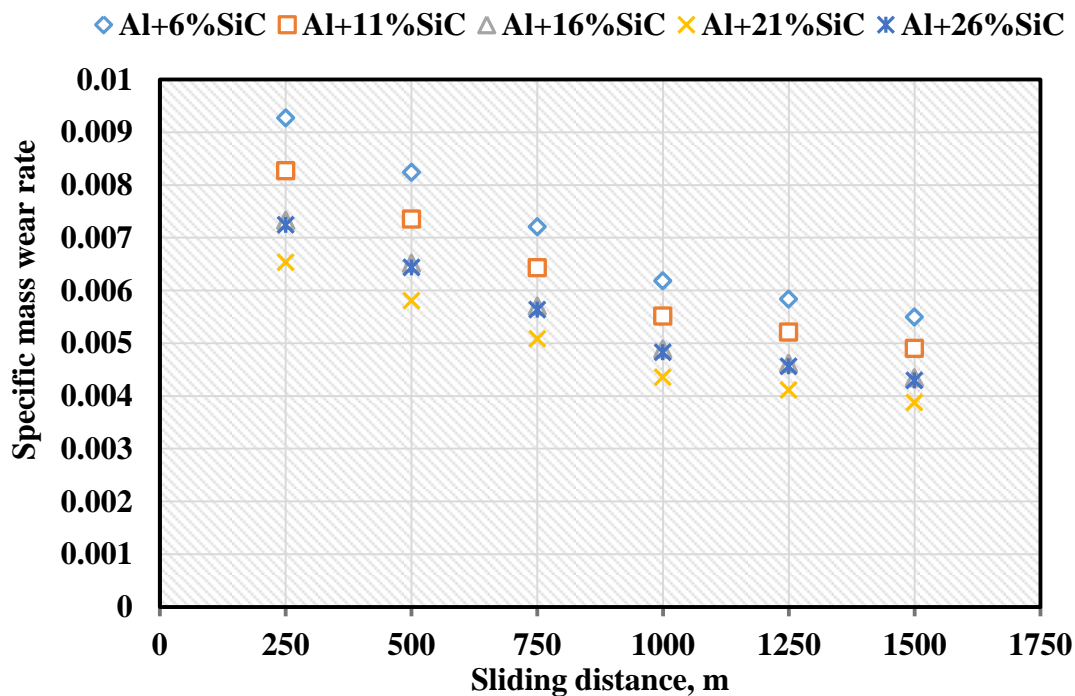


Figure 4.9: Specific Mass wear rate of different compositions with varying sliding distance

Table 4.5: Coefficient of Friction with varying sliding distance

Composition	Sliding distance(m)					
	250	500	750	1000	1250	1500
Al-6 SiC	0.62	0.65	0.67	0.74	0.84	0.85
Al-11 SiC	0.59	0.63	0.64	0.72	0.81	0.82
Al-16 SiC	0.57	0.61	0.62	0.68	0.78	0.77
Al-21 SiC	0.54	0.58	0.59	0.65	0.75	0.76
Al-26 SiC	0.52	0.55	0.57	0.63	0.72	0.73

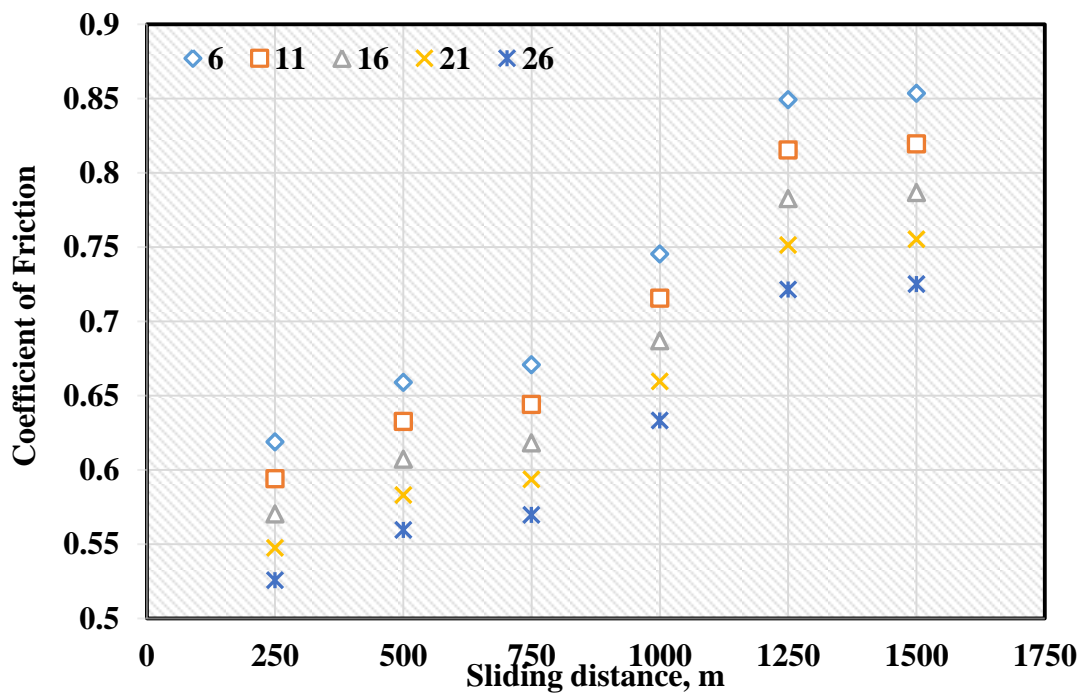


Figure 4.10: Coefficient of Friction of different compositions with varying sliding distance

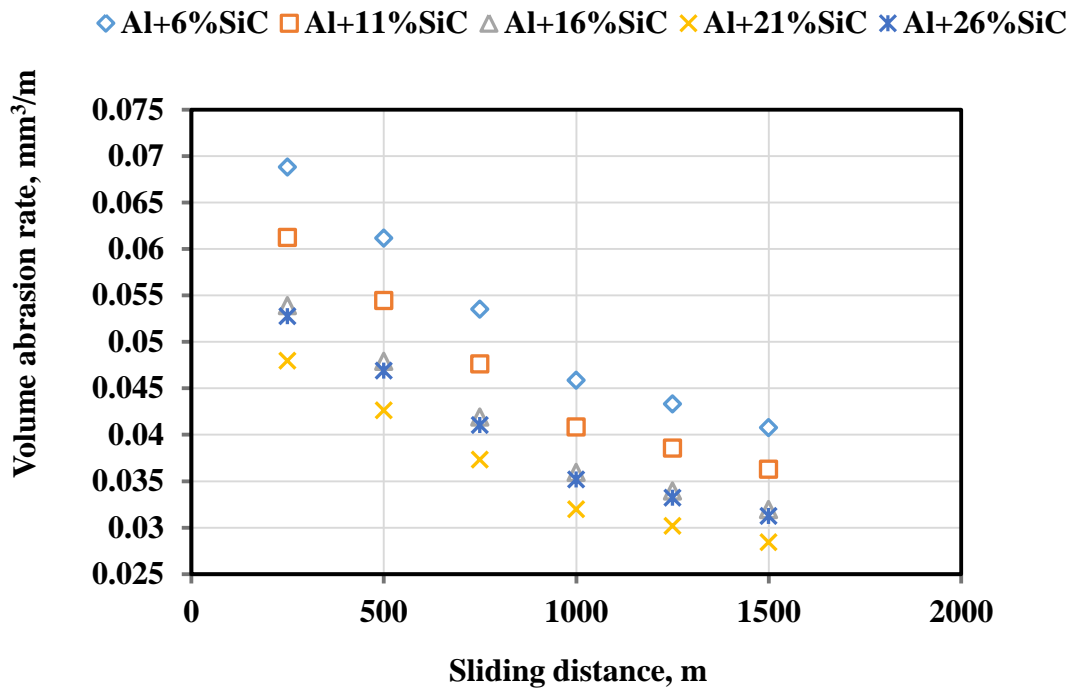


Figure 4.11: Volume wear rate of different compositions with varying sliding distance

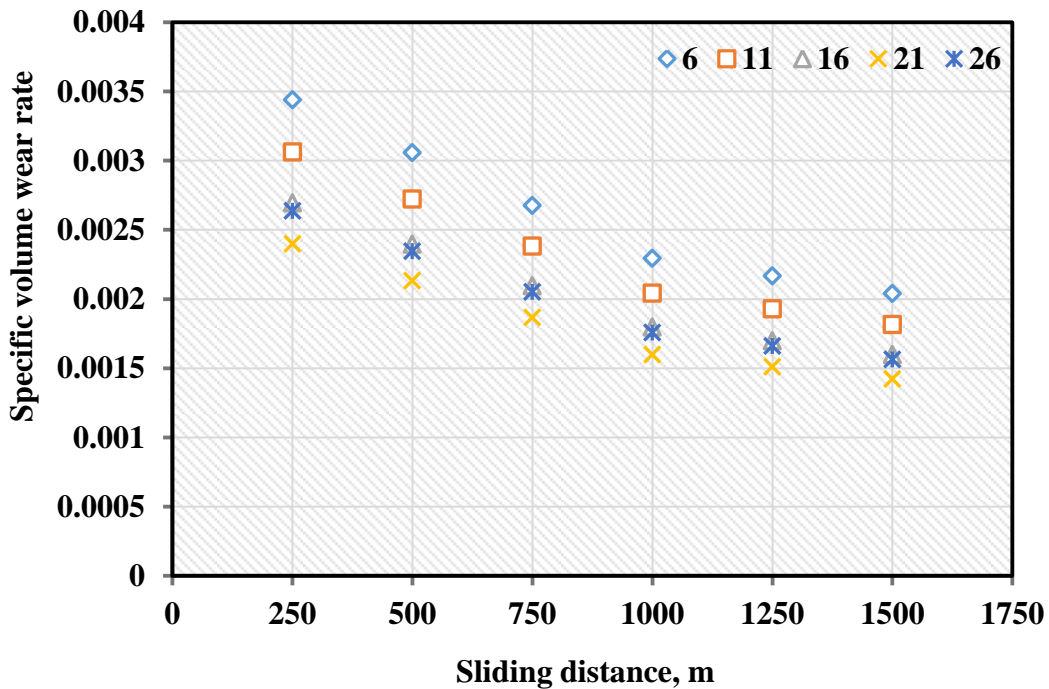
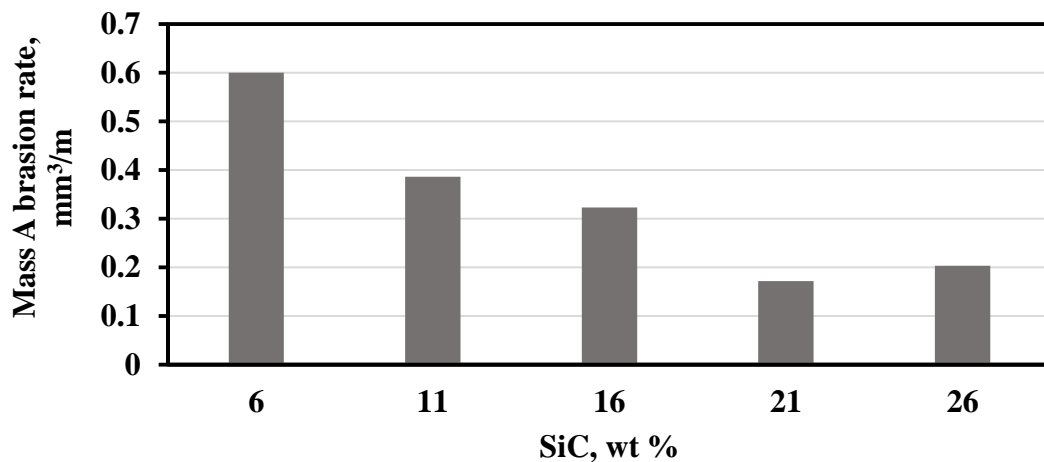


Figure 4.12: Specific Volume wear rate of different compositions with varying sliding distance

#### 4.5 Abrasive wear test

The sand particles come into contact with both the specimen and the rubber wheel during the experiment. The rubber wheel forces the falling sand particles against the specimen, and the rubber wheel and sand particles glide across the specimen's surface in an instant. The abrasive particles abrade the specimen as a result of this action, and the degree of abrasion is controlled by the applied load. The low surface load (20 N) decreases the pressure at the interface, allowing sand particles to roll easily between the specimen and the rubber wheel. The specimen is subjected to significantly less material loss due to the nature of falling. Table 4.5 indicates that for low wt. % SiC, the mass abrasion rate is much higher than at higher wt. % SiC. The material's hardness isn't quite as great at low wt. % of composition, hence its surface is softer. During pitting, grinding, and ploughing operations, the matrix surface is unable to reject sand particles, resulting in significant material loss. As a result, reinforcing particles and their hardness play a major role in enhancing composite abrasion wear resistance. The hardness of the composite material is essential in resisting the abrading action of the fine sand abrasive medium. The surface of the composite has an impact on the wear rate's magnitude. The protrusion of reinforcing particles on the surface could be the reason. Because of centrifugal force or the density mismatch between the reinforcements and the matrix, the reinforcements segregate, resulting in a large number of reinforcing zones on the outside surface, which prevent sand particles from reaching the surface and reduce wear.



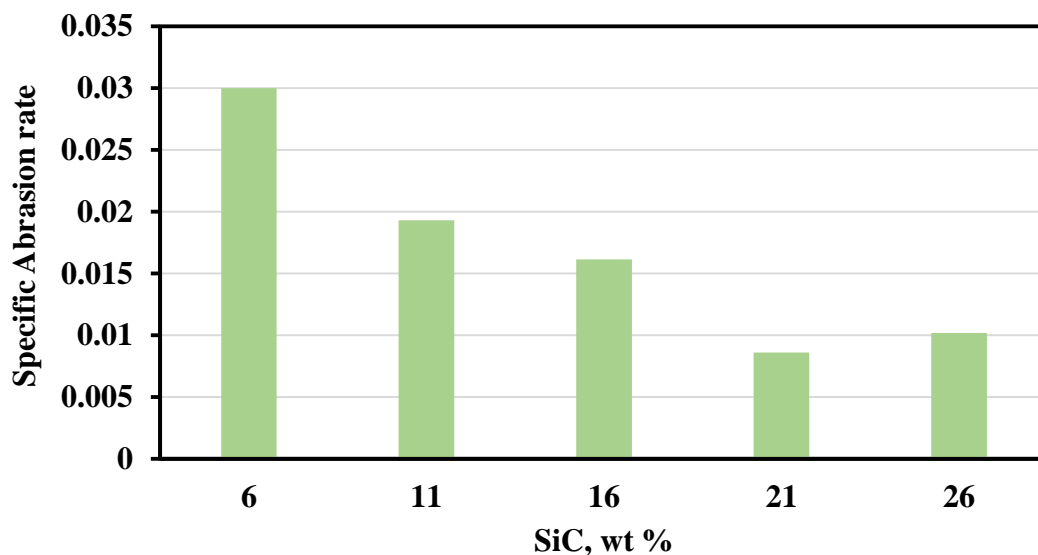
**Figure 4.13:** Mass abrasion rate of different compositions with varying wt % of reinforcement

**Table 4.6: Mass abrasion rate of composites**

Composition	Initial weight(gm)	Final weight(gm)	Weight reduction(gm)	Mass abrasion rate
Al-6 SiC	70.25	67.82	2.43	0.60
Al-11 SiC	70.96	69.39	1.57	0.38
Al-16 SiC	70.2	68.88	1.32	0.32
Al-21 SiC	69.16	68.46	0.7	0.17
Al-26 SiC	68.11	67.27	0.84	0.20

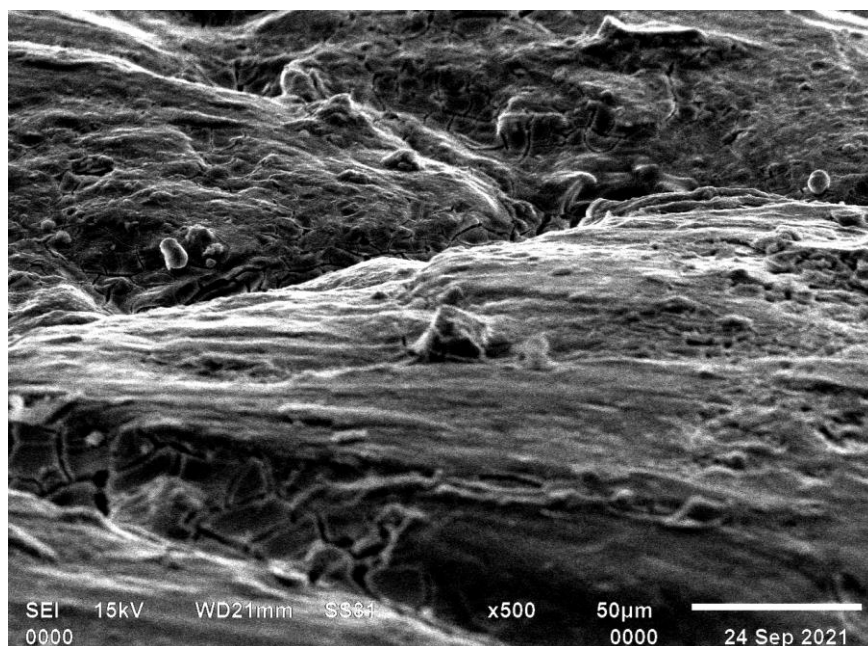
**Table 4.7: Specific Mass abrasion rate of composites**

Composition	Initial weight(gm)	Final weight(gm)	Weight reduction(gm)	Specific abrasion rate
Al-6 SiC	70.25	67.82	2.43	0.03
Al-11 SiC	70.96	69.39	1.57	0.019
Al-16 SiC	70.2	68.88	1.32	0.016
Al-21 SiC	69.16	68.46	0.7	0.008
Al-26 SiC	68.11	67.27	0.84	0.01

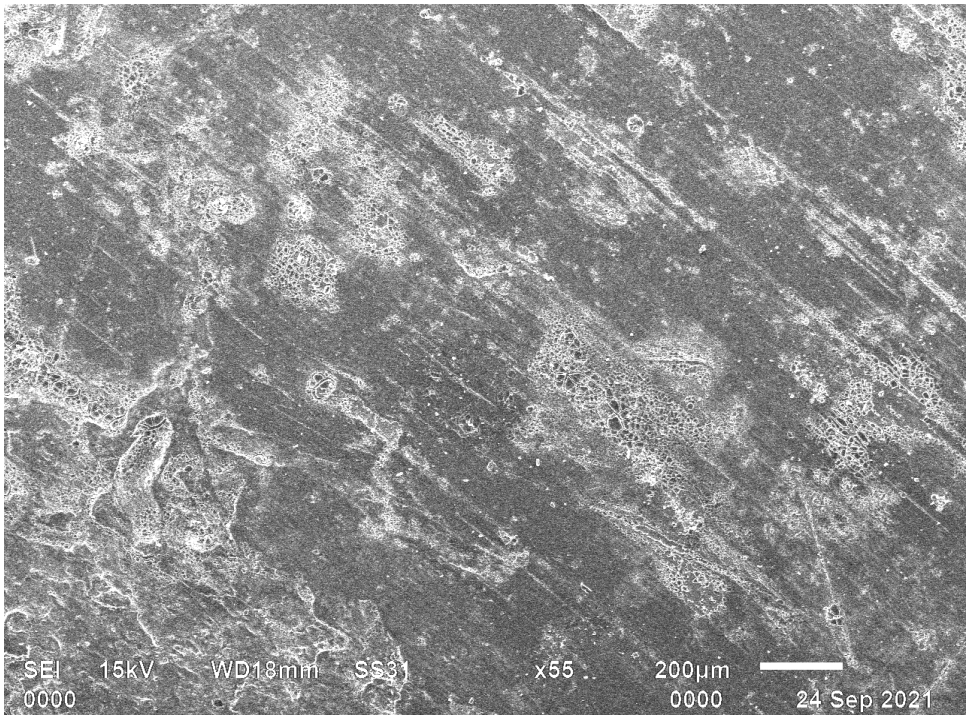
**Figure 4.14: Specific Mass abrasion rate of different compositions with varying wt % of reinforcement**

#### 4.6 Micro structural Analysis

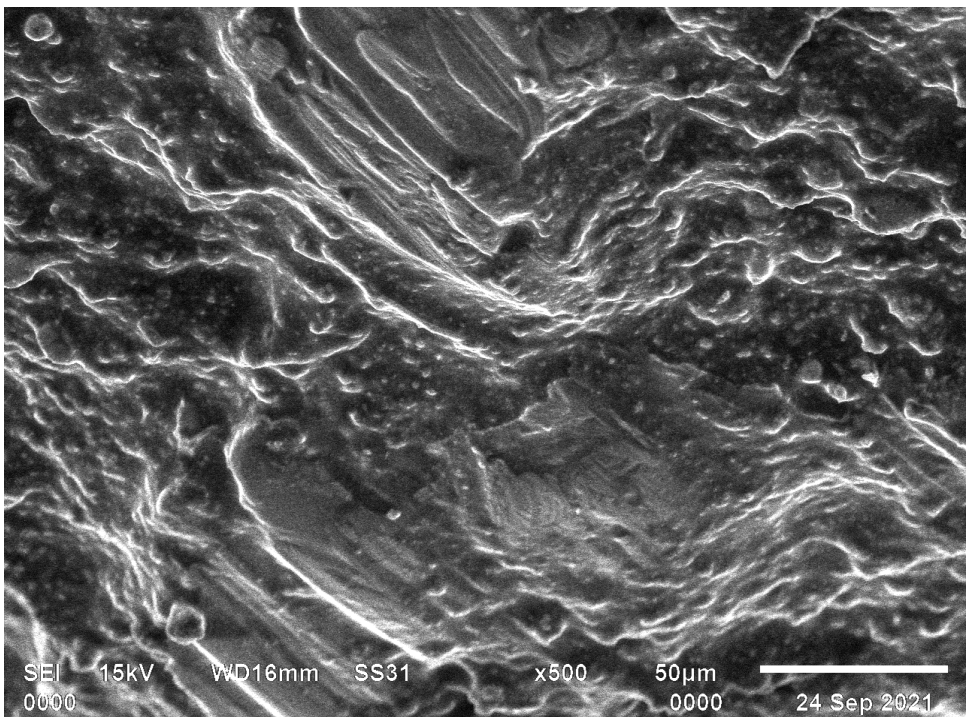
To obtain microscopic properties and micrograph scanning electron microscopy were performed. The magnification range is X50-X3000. The voltage used 10-15 kV. Analysis is done to obtained wear and abrasion pattern on the surface and interfacial bonding between reinforcement and matrix materials. Scanning electron microscopy (SEM) is used in the detailed analysis of material failure, microanalysis, mechanism of fracture, particle dispersion, and voids, among other things. It may be utilized at high magnification, generate extremely high-resolution images, and measure objects very precisely. The SEM generates a variety of signals at the surface of solid specimens using a focused beam of high-energy electrons. The signals produced by electron sample interactions reveal information on the sample's exterior morphology, chemical composition, crystalline structure, and orientation of the materials that make it up. The state of dispersion of reinforcing particles into the metal matrix plays a significant role on the mechanical properties of the composite. SEM was carried out for composite containing different weight percentage of silicon carbide to evaluate the particle matrix interface and dispersion of the silicon carbide particle in the aluminium matrix. The presence of silicon carbide in matrix produces small grain size.



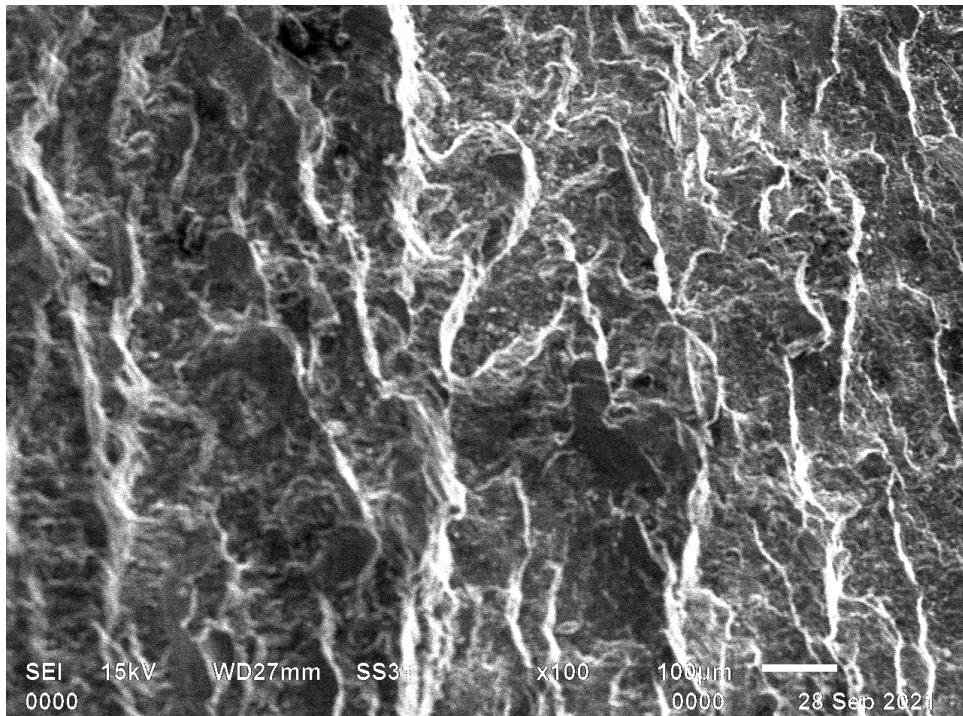
**Figure 4.15: Scanning micrograph of 21 wt % of SiC**



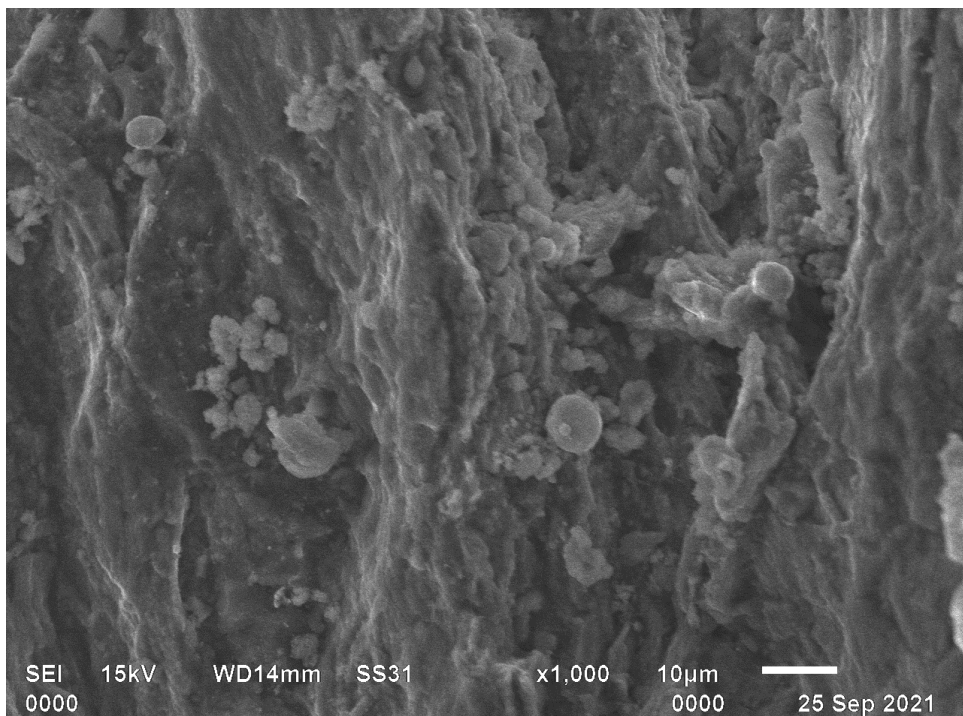
**Figure 4.16: Scanning micrograph of 21 wt % of SiC**



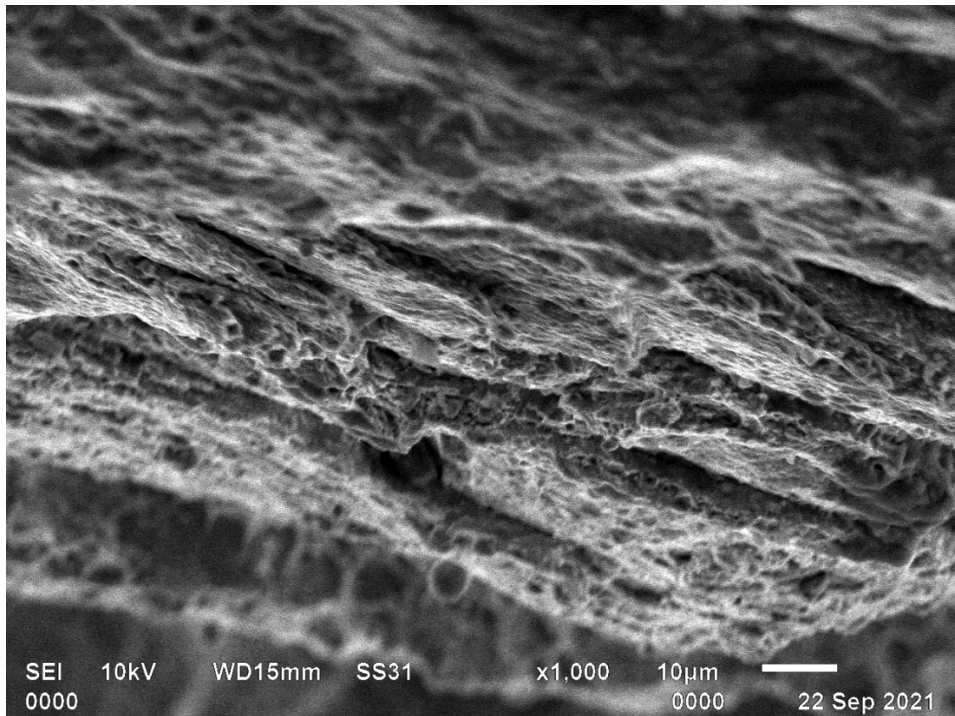
**Figure 4.17: Scanning micrograph of 26 wt % of SiC**



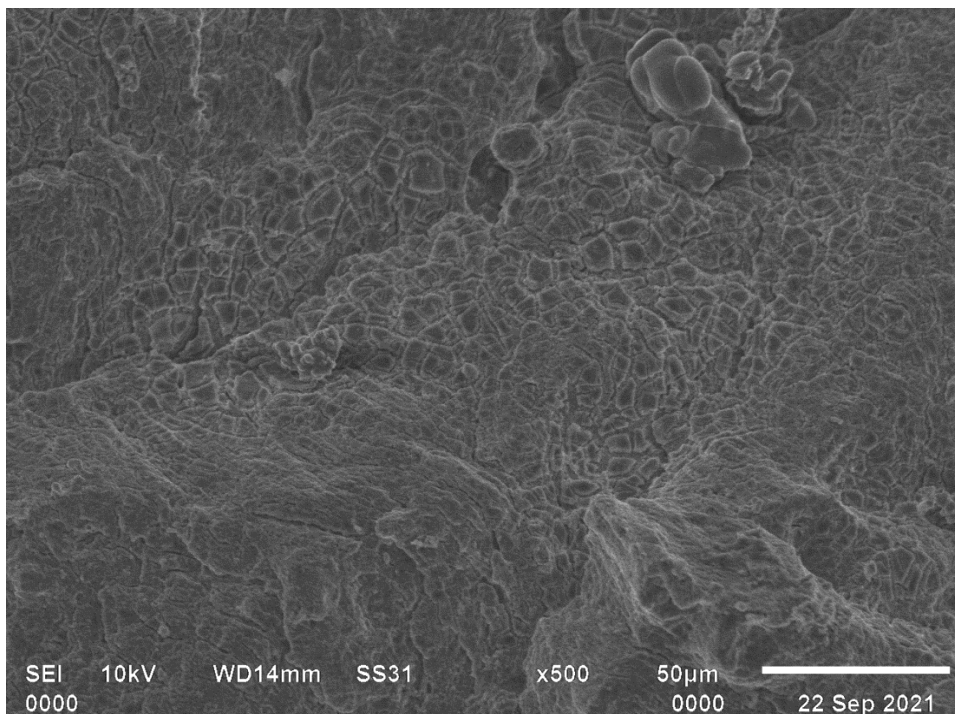
**Figure 4.18: Scanning micrograph of 21 wt % of SiC**



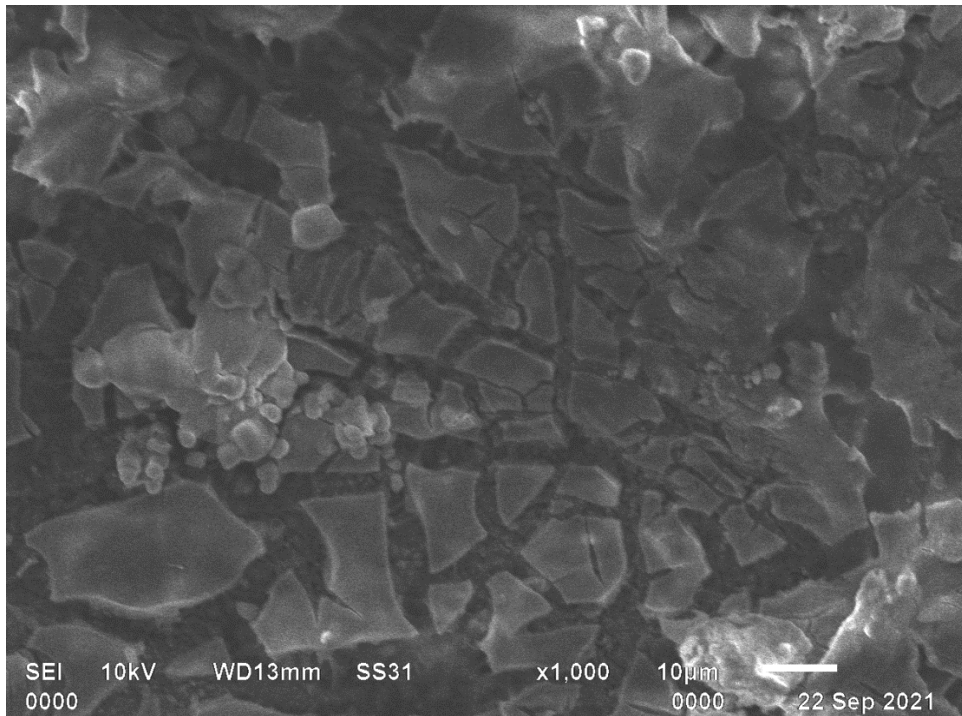
**Figure 4.19: Scanning micrograph of Clustering of SiC particles in 26 wt % of SiC**



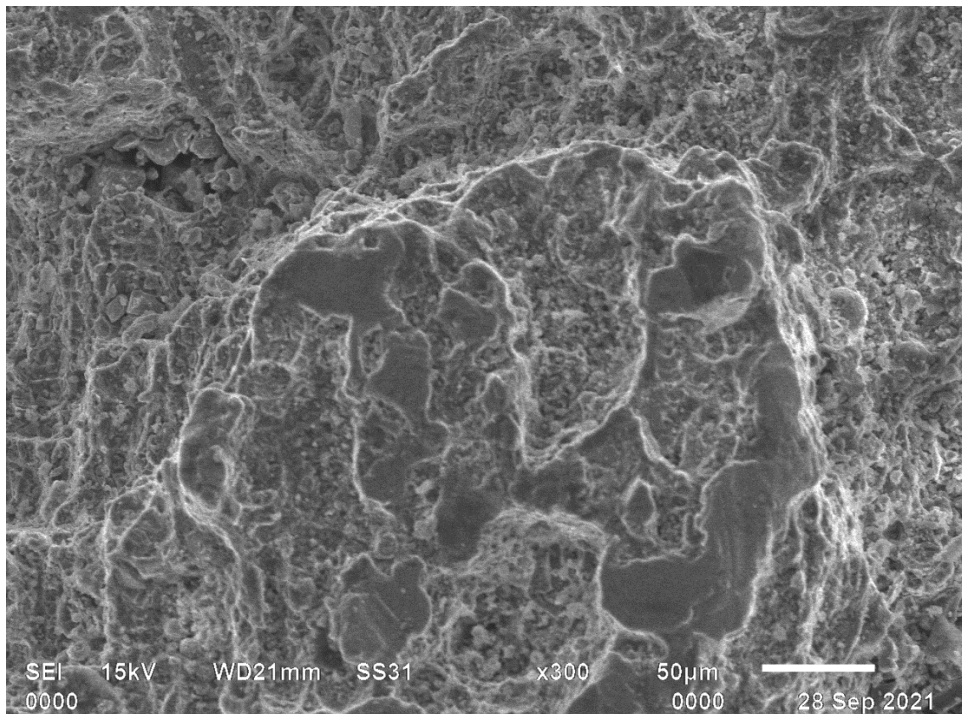
**Figure 4.20: Scanning micrograph of Abrased surface in 16 wt % of SiC**



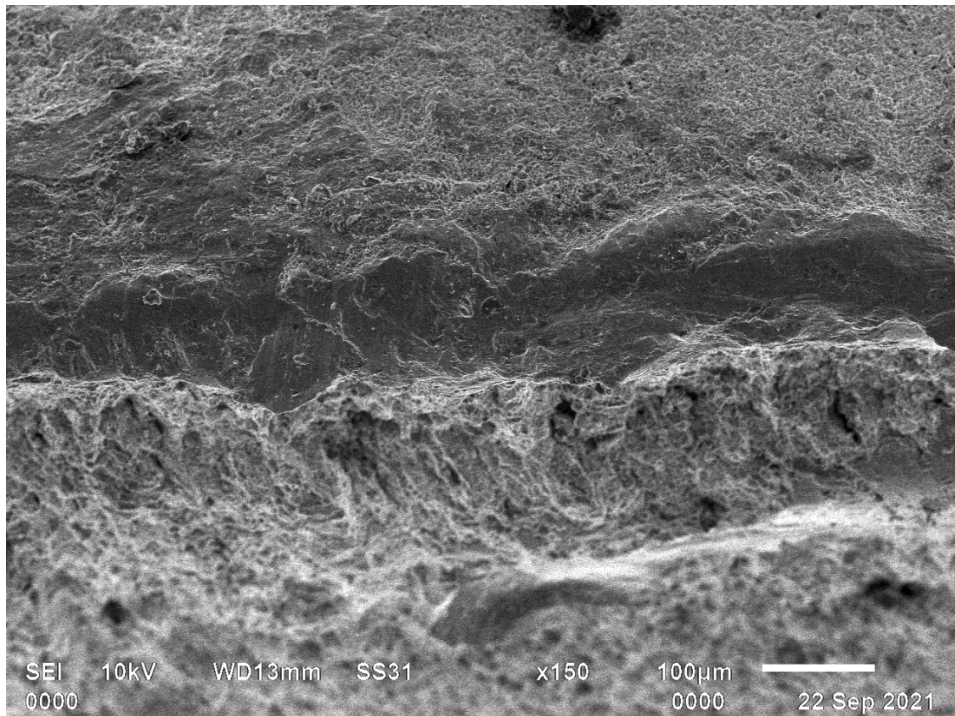
**Figure 4.21: Scanning micrograph of grain distribution in 16 wt. % of SiC**



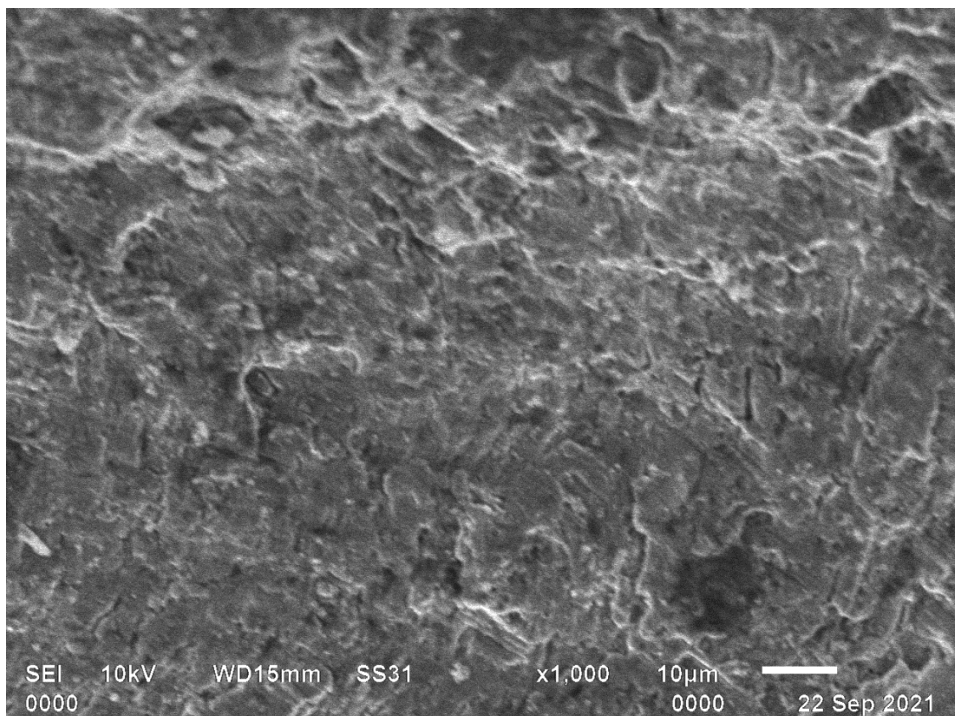
**Figure 4.22: Scanning micrograph of grain distribution in 21 wt. % of SiC**



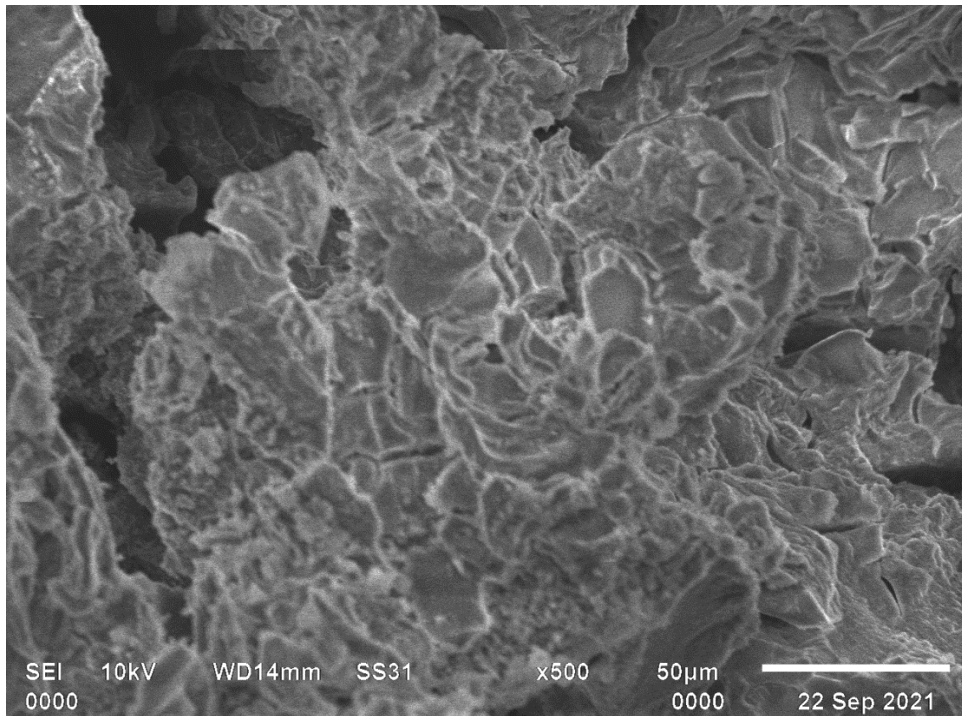
**Figure 4.23: Scanning micrograph of several delamination in 21 wt. % of SiC**



**Figure 4.24: Scanning micrograph of abrasion of surface in 6 wt. % of SiC**



**Figure 4.25: Scanning micrograph of porosities in 21 wt. % of SiC**



**Figure 4.26: Scanning micrograph of porosities in 26 wt. % of SiC**

Figures 4.15 to 4.26 shows the SEM micrographs of different composite material investigated in the present work. In all the cases, good dispersion of silicon carbide particle in the aluminium matrix has been observed. As per the micrographs, the presence of  $Al_4C_3$  clusters are verified with help of micrograph. These clusters are the main reason for reduction in properties as the wt. % of SiC reinforcement is greater than 21 wt. %. These clusters of  $Al_4C_3$  affect the tribological and mechanical properties of SiC reinforced MMCs. As per the micrographs, the clustering of reinforcement material is verified in the higher wt. % of MMCs. These clustering and agglomeration result in partial ductile and partial brittle fracture. Since, somewhere presence of SiC is extreme and somewhere no SiC can be found therefore dislocation lines move freely in the matrix. Hence, strength of material decreases to great extent. These clusters also influence in increment of porosity in the composites.



*Summary  
and  
Conclusions*



The following conclusions can be drawn from the present study

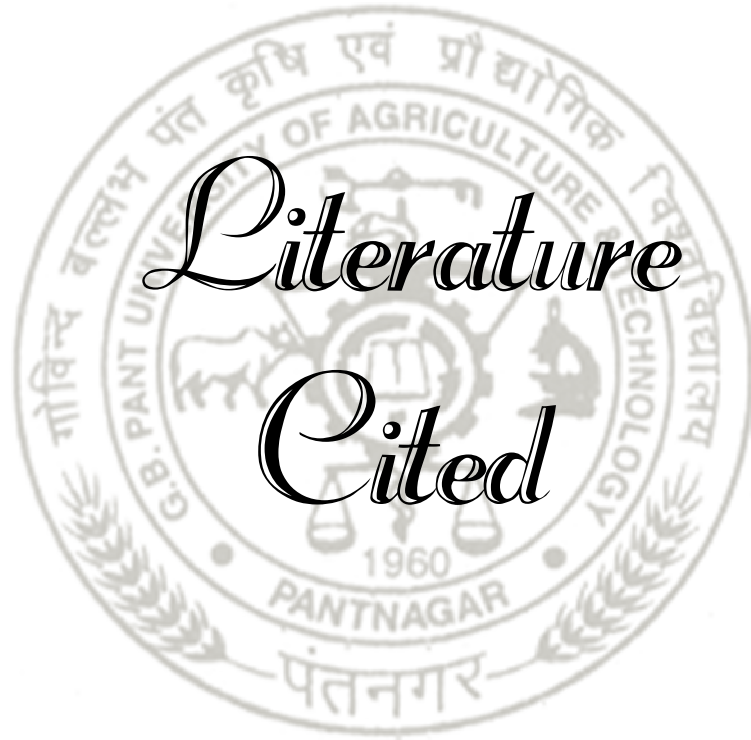
1. To enhance the properties of the base metal, the stir casting method is used in the fabrication of SiC reinforced aluminium metal matrix composite. Different weight percents of Silicon carbide (6, 11, 16, 21, and 26 wt. %) particle reinforced aluminium MMCs are fabricated, and physical and mechanical properties of the materials are characterised based on the experimental results.
2. Adding Magnesium (Mg) has improved wettability between Al and SiC particles by reducing the SiO<sub>2</sub> layer on the surface of the SiC.
3. Porosity and hardness is maximum at 26 wt. % of SiC and increase with wt. % of reinforcement. In the case of SiC reinforcement the presence of aluminium carbide is verified with the help of SEM micrographs. Aluminium carbide is a brittle material.
4. In the case of SiC, the yield strength and ultimate tensile strength increases as the increment in reinforcement wt. % up to 21 wt. %. As the wt. % of reinforcement is higher than 21% the concentration of aluminium carbide (Al<sub>4</sub>C<sub>3</sub>) increases rapidly which introduce brittleness in the MMCs of higher wt. % of SiC.
5. The mechanical and tribological properties is optimum at 21 wt. % of SiC.
6. Microscopy tests, SEM show the dispersion of reinforcing phase in the matrix phase. Fracture surface morphology gives the idea of nature of fracture.
7. The reduction in volume wear rate, mass rate and abrasion rate is recorded up to 21 wt. % of SiC further increment in wt. % increase the overall volume wear rate, mass wear rate and abrasion rate.
8. In the SiC reinforced MMCs, the increment in wear rate due to the high rate formation of aluminium carbide increases brittleness and reduce strength of the MMCs.

9. In SiC reinforced MMCs, an increase in wear rate due to high rate formation of Aluminum carbide causes the MMCs to become brittle and thus reduction in strength.

### **5.1 Recommendation for Future Work**

The presented efforts leaves a huge extant of research work for the future generation of researchers to come. Some suggestions for future research that can be incorporated are as follows:

1. Try other aluminum series like Al-2024, Al-6061, Al-7075.
2. The effect of heat treatment on properties of the composites may possibly be studied.
3. Composite friction and wear behaviour can also be studied at high ambient temperatures in order to check the potential of fabricated composites at high temperature applications.



*Literature  
Cited*



## LITERATURE CITED

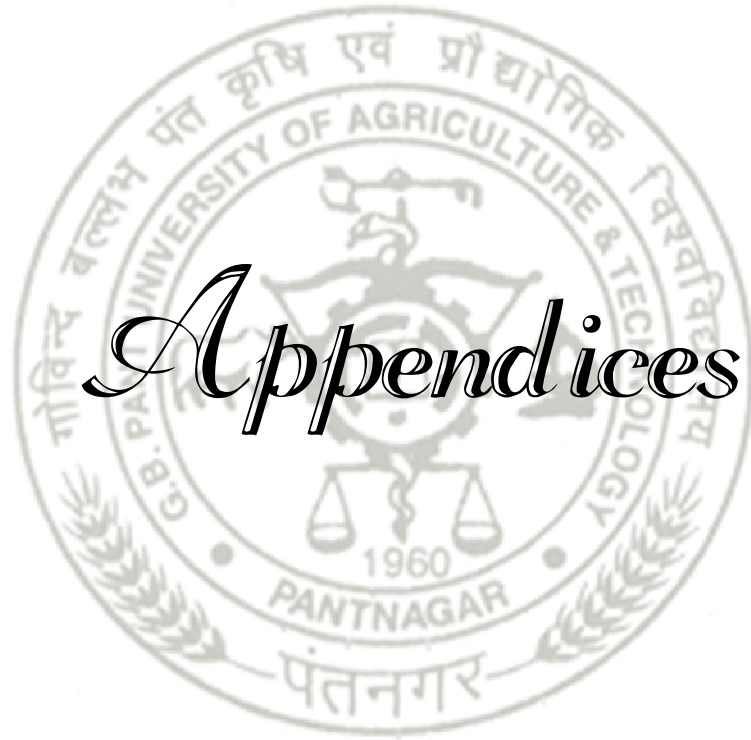
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# *Appendices*



Tensile test results

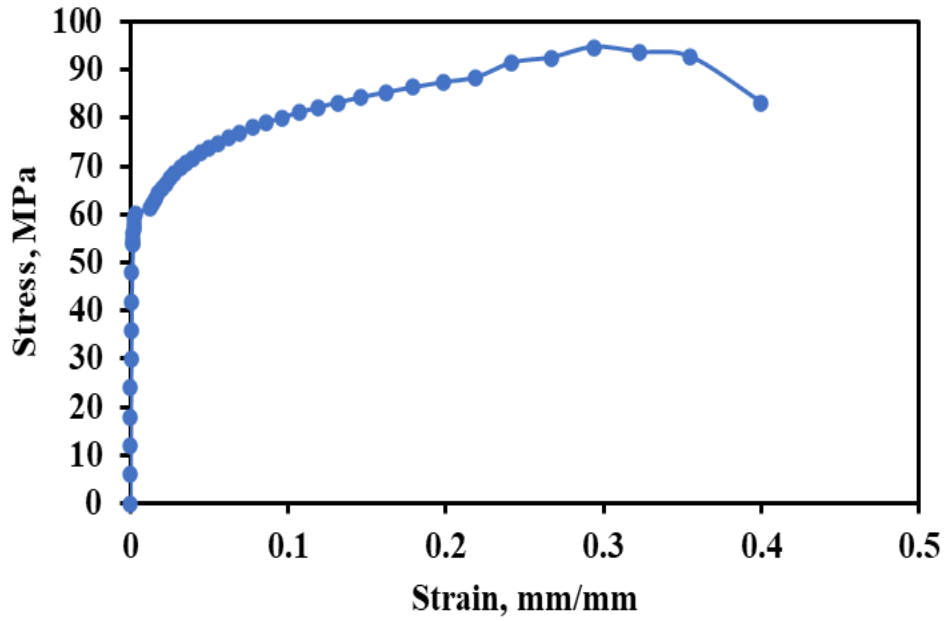


Figure 1: Stress-strain curve of Al

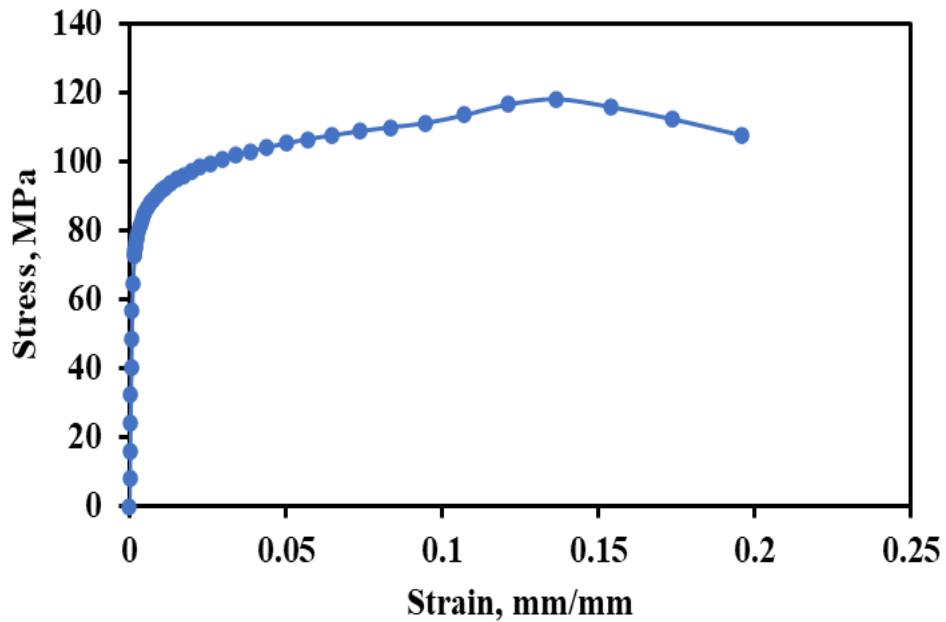


Figure 2: Stress-strain curve of Al composite with 6 wt. % of SiC

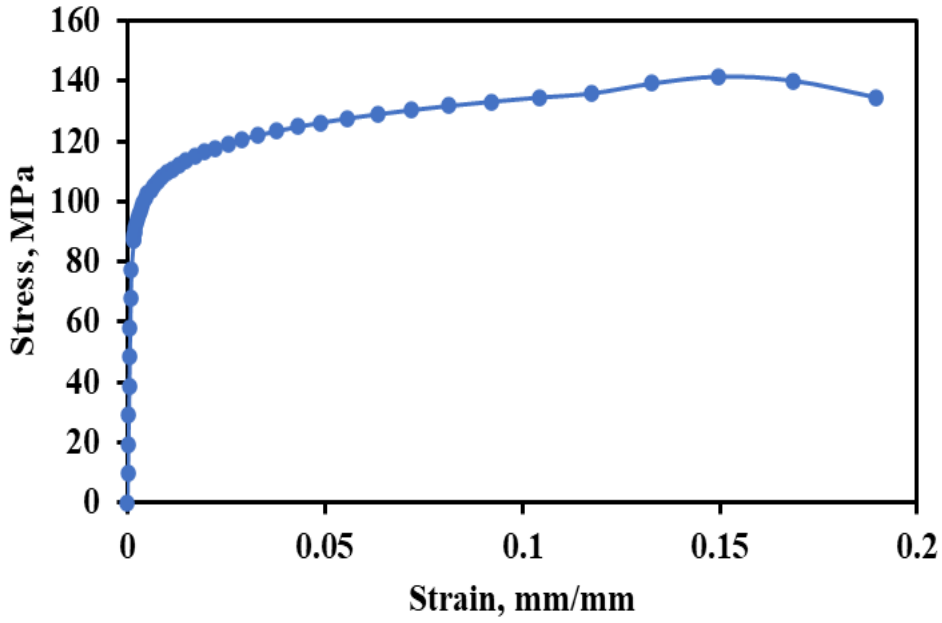


Figure 3: Stress-strain curve of Al composite with 11 wt. % of SiC

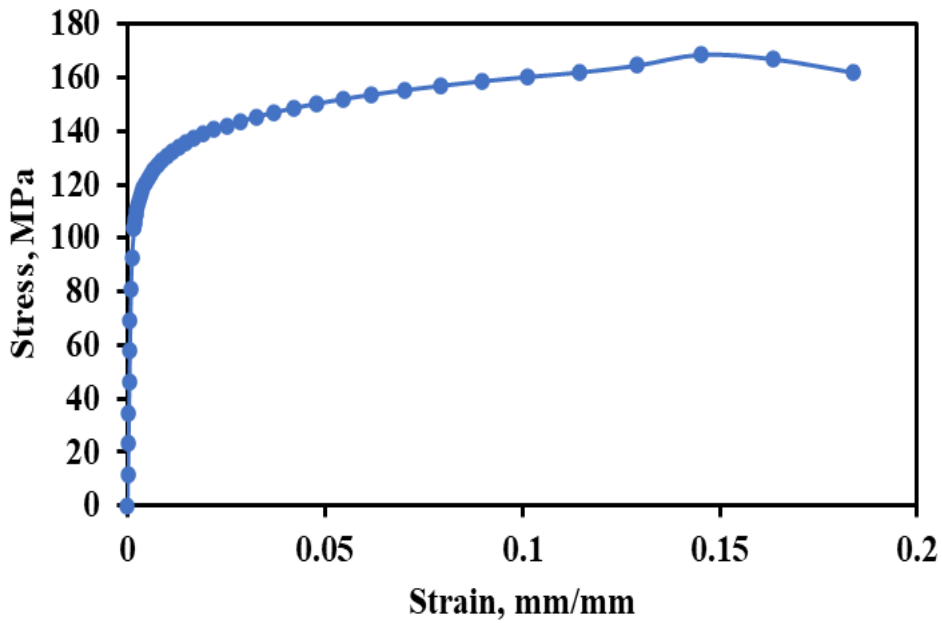


Figure 4: Stress-strain curve of Al composite with 16 wt. % of SiC

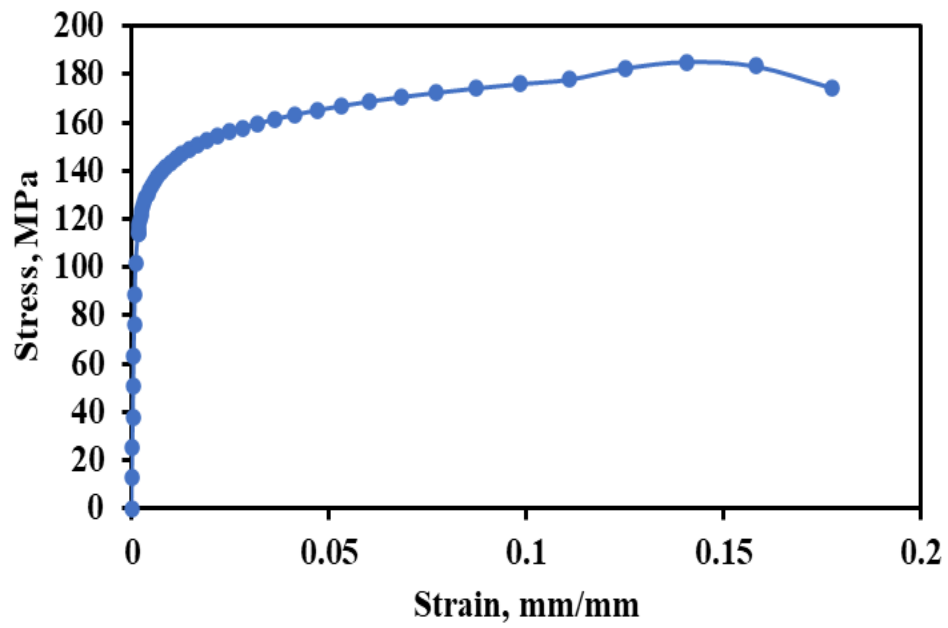


Figure 5: Stress-strain curve of Al composite with 21 wt. % of SiC

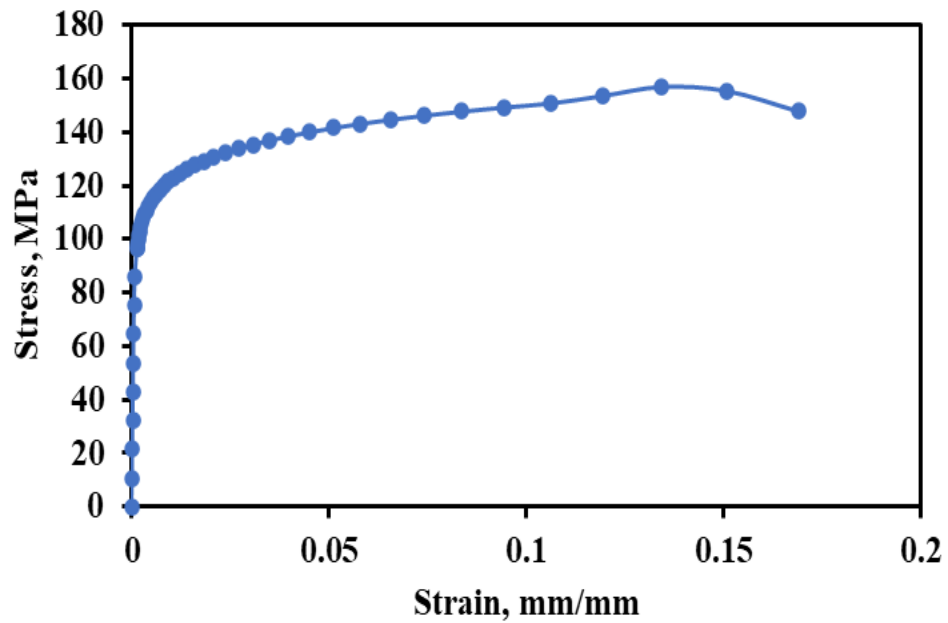


Figure 6: Stress-strain curve of Al composite with 26 wt. % of SiC

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2.	B. Tech (Mechanical Engineering)	HNB Garhwal University, Srinagar Garhwal	2015	75.12%
3.	Intermediate	RDSVMIC Timli, Pauri	2010	67.6%
4.	High school	RDSVMIC Timli, Pauri	2008	72.8%

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- **Software Skills:** AutoCAD, CAM, MS Office.
- **Professional Skills:** Problem Solving, Critical Thinking, Leadership, Ambitious and focused.

Place: Pantnagar, Uttarakhand

Date: November, 2021



(Rohit Rawat)

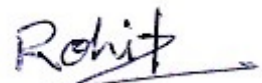
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**Major** : Design and Production                      **Department** : Mechanical Engineering Engineering  
**Thesis Title** : “**Experimental Investigation of Fabricated SiC Reinforced Aluminium Based Metal Matrix Composite**”  
**No. of Pages** : 59                      **Advisor** : Dr. V. K. Singh

### **ABSTRACT**

Aluminium has been widely used in engineering applications because it is light in weight. A vast number of experimental studies have been performed on addition of hard ceramic particles to aluminium matrix to enhance its strength, hardness and wear resistance. Every efforts aims to develop a material which can be appropriate for various industry and machinery purpose. In the present study, a modest attempt has been made to develop cast aluminium based silicon carbide particulate metal matrix composite. Here work objective is to develop a conventional low cost method of producing MMCs and to obtain homogeneous dispersion of ceramic particles. To achieve these objectives stir casting technique has been adopted. Adding Magnesium has improved wettability between aluminium and SiC particles by reducing the silicon di oxide layer on the surface of the SiC. In this work, we examine the influence of reinforcement on different mechanical and tribological properties. Density, porosity, microhardness, yield strength, ultimate tensile strength, percent elongation, and young modulus have been used to evaluate the mechanical properties. Pin on disc and dry sand abrasion tests were used to determine tribological characteristics. Microscopy tests, SEM show the dispersion of reinforcing phase in the matrix phase. In the case of SiC, mechanical and tribological properties are optimum at 21 wt. % of SiC.



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Advisor



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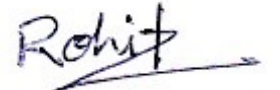
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मुख्य विषय	: परिकल्पना और उत्पादन अभियांत्रिकी	विभाग	: यांत्रिकी अभियांत्रिकी
शोध शीर्षक	: " फैब्रिकेटेड एसआईसी प्रबलित एल्युमिनियम आधारित धातु मैट्रिक्स समग्र की प्रायोगिक जांच "		
पृष्ठ संख्या	: 59	सलाहकार	: डॉ. वी. के. सिंह

### सारांश

अभियांत्रिकी अनुप्रयोगों में एल्युमिनियम का व्यापक रूप से उपयोग किया गया है क्योंकि यह वजन में हल्का है। एल्युमिनियम मैट्रिक्स की मजबूती, दृढ़ता और घिसाव प्रतिरोध को बढ़ाने के लिए कठोर सिरेमिक कणों को जोड़ने पर बड़ी संख्या में प्रयोगात्मक अध्ययन किए गए हैं। हर प्रयास का उद्देश्य ऐसी सामग्री विकसित करना है जो विभिन्न उद्योग और मशीनरी उद्देश्यों के लिए उपयुक्त हो। वर्तमान अध्ययन में कास्ट एल्युमिनियम आधारित सिलिकॉन कार्बाइड पार्टिकुलेट मेटल मैट्रिक्स कंपोजिट विकसित करने का एक मामूली प्रयास किया गया है। यहां काम का उद्देश्य एमएमसी के उत्पादन की पारंपरिक कम लागत वाली विधि विकसित करना और सिरेमिक कणों का सजातीय फैलाव प्राप्त करना है। इन उद्देश्यों को प्राप्त करने के लिए हलचल कास्टिंग तकनीक को अपनाया गया है। मैग्नीशियम जोड़ने से सिलिकॉन कार्बाइड की सतह पर सिलिकॉन डाइ ऑक्साइड परत को कम करके एल्युमिनियम और सिलिकॉन कार्बाइड कणों के बीच वैटाबिलिटी में सुधार हुआ है। इस काम में, हम विभिन्न यांत्रिक और जनजातीय गुणों पर सुदृढीकरण के प्रभाव की जांच करते हैं। यांत्रिक गुणों का मूल्यांकन करने के लिए घनत्व, सरंध्रता, सूक्ष्म कठोरता, यील्ड शक्ति, परम तन्य शक्ति, प्रतिशत बढ़ाव और यंग्स मॉड्युलस का उपयोग किया गया है। जनजातीय विशेषताओं को निर्धारित करने के लिए पिन ऑन डिस्क और सूखी रेत घर्षण परीक्षण का उपयोग किया गया था। माइक्रोस्कोपी परीक्षण मैट्रिक्स चरण में प्रबलक चरण के फैलाव को दर्शाता है। एसआईसी के मामले में, यांत्रिक और जनजातीय गुण 21वेट% पर इष्टतम हैं।



(वी. के. सिंह)  
सलाहकार



(रोहित रावत)  
लेखक