# Fabrication of Aluminium based Metal Matrix Composite using Silicon Carbide Reinforcement and Evaluation of Mechanical Properties

Dissertation-II

Submitted in partial fulfilment of the requirement for the award of degree

Of

**Master of Technology**

**IN**

**MECHANICAL ENGINEERING**

By

Shrawan Kumar

(11300625)

Under the guidance of

Mr. Baljeet Singh

(16938)


**DEPARTMENT OF MECHANICAL ENGINEERING**
**LOVELY PROFESSIONAL UNIVERSITY**
**PUNJAB**

**TOPIC APPROVAL PERFORMA**

School of Mechanical Engineering

**Program :** 1208D::B.Tech -M.Tech (Dual Degree) - ME

**COURSE CODE :** MEC604 **REGULAR/BACKLOG :** Regular **GROUP NUMBER :** MERGD0030

**Supervisor Name** : Baljeet Singh **UID :** 16938 **Designation :** Assistant Professor

**Qualification :** _____ **Research Experience :** _____

| SR.NO. | NAME OF STUDENT | REGISTRATION NO | BATCH | SECTION | CONTACT NUMBER |
|---|---|---|---|---|---|
| 1 | Shrawan Kumar | 11300625 | 2013 | M1326 | 08195879095 |

**SPECIALIZATION AREA** : Manufacturing Engineering **Supervisor Signature:** _____

**PROPOSED TOPIC** : Fabrication of aluminium based metal matrix composites and evaluation of mechanical properties

| Qualitative Assessment of Proposed Topic by PAC | | |
|---|---|---|
| **Sr.No.** | **Parameter** | **Rating (out of 10)** |
| 1 | Project Novelty: Potential of the project to create new knowledge | 5.00 |
| 2 | Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students. | 4.00 |
| 3 | Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program. | 5.00 |
| 4 | Project Supervision: Project supervisor's is technically competent to guide students, resolve any issues, and impart necessary skills. | 7.00 |
| 5 | Social Applicability: Project work intends to solve a practical problem. | 6.00 |
| 6 | Future Scope: Project has potential to become basis of future research work, publication or patent. | 4.00 |

| PAC Committee Members | | |
|---|---|---|
| PAC Member 1 Name: Ankur Bahl | UID: 11108 | Recommended (Y/N): NA |
| PAC Member 2 Name: Jasvinder Singh | UID: 15854 | Recommended (Y/N): NA |
| PAC Member 3 Name: Dr. Uday Krishna Ravella | UID: 18604 | Recommended (Y/N): NA |
| PAC Member 4 Name: Anil Kumar | UID: 20296 | Recommended (Y/N): NA |
| DAA Nominee Name: Kamal Hassan | UID: 17469 | Recommended (Y/N): Yes |

**Final Topic Approved by PAC:** **Fabrication of aluminium based metal matrix composite using silicon carbide reinforcement and evaluation of mechanical properties**

**Overall Remarks:** Approved (with minor changes)

**PAC CHAIRPERSON Name:** 12174::Gurpreet Singh Phull **Approval Date:** 14 Nov 2017

# ABSTRACT

In Recent years, a great research has been carried out on the aluminium metal matrix composites, but since these materials have vast scope in different applications because of lightweight, good mechanical and wear properties. In this research, a research of aluminium metal matrix composite is being carried out, mainly focused on the aluminium alloy Al6061. The stir casting method is selected for producing aluminium metal matrix composite because stir casting is observed as low cost and it provides a homogeneous mixture of constituents of the composite. The matrix material is Al6061 and as the reinforcement material aluminium oxide, silicon carbide and copper is selected. Aluminium MMC extensively used in the automotive engine components, body parts, brake pads etc.



Keywords: Aluminium metal matrix composite, reinforcement; stir casting; alumina; silicon carbide

# CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "**Fabrication of Aluminium based Metal Matrix Composite using Silicon Carbide Reinforcement and Evaluation of Mechanical Properties**" in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of **Mr. Baljeet Singh (Asst. Professor)** Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

Date: Shrawan Kumar

11300625

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date: Mr. Baljeet Singh

16938

COD (ME)

---

The external viva-voce examination of the student was held on successfully _____

Signature of Examiner

# ACKNOWLEDGEMENT

I express my deep sense of gratitude to my research supervisor, Mr Baljeet Singh, Assistant Professor, Department of Mechanical Engineering, for providing precious guidance, inspiring discussion and constant supervision throughout the course of this work. His timely help, constructive criticism, conscientious efforts made it possible to present the work contained in this report. I would also like to show my sincere gratitude to the University for providing me all the necessary facilities.

.

Shrawan Kumar

Reg. No. 11300625

# Table of Contents

# CHAPTER I

# INTRODUCTION

## 1.1 COMPOSITES:

A composite material is developed by the combination of two or more materials. Usually the materials does not possess similar properties but have different properties in higher amount. The two or more materials possessing different properties provide the composite unique and impressive properties. However, within the composite, it can be easy to tell the different materials apart as they do not dissolve or blend into each other. In composites, two phases of materials are there, one of the two phases is called reinforcing phase, which is in fibre form and other phases is called matrix phase, which is embedded over reinforcing phase. After combining, the reinforcing phase material and matrix phase material can be metal, ceramic or polymer. Typically, reinforcing materials are considered as strong as well as having low densities while the matrix usually considered as a ductile or a tough material.

### 1.1.1 METAL MATRIX COMPOSITES:

Composite materials have been one of the major areas of scientific and applied research for many decades; however, only in the past decade they have been viewed and applied as engineering materials. Today we have a very significant and impressive progress and advances in our understanding of these materials and their metallurgical behaviour. The greatest advantage that we consider is in the fact that we can inherit or derive properties of both material present in the composite, the metal matrix and the reinforcements, providing a material with having unique, different and impressive properties which can be applied in specific and challenging requirements in many applications. There is a wide spectrum of the types of metal matrix composite (MMC), each with a specific property profile. Metal matrix composites have been attractive and focused research subjects in the field of materials science during the past two decades. Most of the work is being done for light weight metrices like aluminium, magnesium etc. for the applications requiring lightweight combined with a high strength and/or stiffness. Although manufacturing of continuous fibre reinforced Aluminium matrix composites is considered to be complicated as well as expensive as they are being utilized in a daily use applications, especially in the automotive and aerospace industry.

However, these days most of the stress is put on refining the cost efficiency of mass production methods for particulate reinforced Al matrix composites which possesses reasonable properties but they are found to be much more expensive than continuous fibre reinforced materials. A metal matrix composite (MMC) is a composite material which contains two or more constituent parts, one of these are metal and the other material can be ceramic or any other organic compound, when at least three materials are combined together then it is also called as hybrid composite.

Metal matrix composites have various benefits over monolithic metals including a higher specific modulus, higher specific strength, improved properties at preeminent temperatures, inferior coefficients of thermal expansion and improved wear resistance. Because of these qualities, metal matrix composites (MMCs) are under attention for a extensive range of applications. However, on the other side, their toughness is lower than the monolithic metals and they are quite affluent at present-day. By comparing with most polymer matrix composites, MMCs possesses various superior mechanical properties, including advanced transverse strength and stiffness, superior shear and compressive strengths and improved high-temperature capabilities. There also have benefits in certain physical characteristics of MMCs such as no significant moisture absorption possessions, flammability, good electrical and thermal conductivities, and resistance to most of the radiations.

Metal matrix composites is being widely studied and analyzed for many years, the main provision has originate from the aerospace industry for airframe and spacecraft components. Lately, automotive, electronics and recreation industries have been occupied diffusively with composites. MMC reinforcements can be normally separated into five key categories: continuous fibres, discontinuous fibres, whiskers, wires and particulate (including platelets). With concession of wires, which are metals, reinforcements are usually ceramics. Naturally these ceramics are oxides, carbides, and nitrides which are being used for the reason that their outstanding amalgamations of specific strength and stiffness equally at ambient temperature and higher the temperature.

The two furthermost frequently used metal matrices are grounded on aluminium and titanium. Both of these metals have reasonably low specific gravities and are existing in a diversity of alloy arrangements. Although magnesium is even lighter, its excessive attraction for oxygen indorses atmospheric corrosion and makes it not suitable for numerous applications. Beryllium is the lightest of all structural metals and possesses tensile modulus advanced than that of steel. Yet, it

suffers from very extreme brittleness, which is the cause for its elimination as a probable matrix material. Nickel and cobalt-based superalloys have also been cast-off as matrices, but the alloying elements in these materials incline to emphasize the oxidation of fibres at raised temperatures.

## A. METHODS FOR PRODUCING PARTICULATE REINFORCED METAL MATRIX COMPOSITES:

These methods are mainly of two types: solid and liquid.

**a. Solid state method**:

Powder metallurgy: Metal in the form of powder and reinforcements also in powder form are mixed together and then attached via a compaction, degassing and extrusion (thermos-mechanical treatment).

Foil diffusion bonding: In this technique metal foil in layers are crammed with fibres and passed through to produce a matrix.

**b. Liquid State methods**: liquid state methods are more efficient and economical as compared to solid state production methods.

Stir Casting: Reinforcements are enthused into the molten metal, which is permitted to freeze well along.

Squeeze casting: In this technique the molten metal is inserted into a die or a form with fibres preplaced in it.

Spray deposition: In this process the molten metal is sprayed over a continuous fibre substrate.

Amongst numerous kinds of the casting method, we use stir casting process because in this method by preheating and after that stir casting is done by stirring the molten material with the reinforcements and the material is uniformly distributed in the crucible and is finely distributed so that the stir casting is used for the casting of material.

**c. Stir Casting**:

Stir Casting is a considered as liquid phase technique, used to produce composite materials, in which a isolated phase (ceramic particles, short fibres) is assorted with a molten matrix metal by

use of mechanical stirring. Stir Casting is the easiest among other method and also the furthermost cost-effective technique of liquid phase production. The liquid composite material is then cast by conventional casting procedures and may also be handled by conventional Metal forming machineries.

Stir Casting is characterized by the following features:

In this method the amount of content of reinforcements (dispersed phase) is limited, (usually, it is about 30% by volume ).

Distribution of reinforcements all over the matrix is sometimes not flawlessly homogeneous because of gravity segregation of reinforcements caused by density differences of reinforcement and matrix materials but comparatively provides good characterization.

The process is comparatively easy and low cost.

Distribution of dispersed state may be enhanced by using the matrix is in semi-solid state.

The high viscosity of the semi-solid matrix material permits healthier mixing of the dispersed phase.

# CHAPTER II

# REVIEW OF LITERATURE

There has been a wide research is in this field and still, there are many researchers still working in this field to extemporize the properties of composites materials because of its extensive choice of application in diverse fields, so there are many kinds of literature available for aluminium metal matrix composite and some of the relevant are as follows:

**Z.Z. Chen et al**. **2004** [1] studied the consequence of element (particle) size on fatigue crack initiation and crack growth in aluminium matrix composites. They used Aluminium alloy 2024 to carry out the study in their stated field. Silicon carbide (SiC) was used in different sizes (5 µm, 10 µm, 60µm) for reinforcement. The material was produced by using powder metallurgy process. Fully reversed axial fatigue tests were completed using electro servohydraulic fatigue testing machine. Scanning electron microscope and optical microscope were used to analyze the crack growth path and fracture surface of the specimen.the good fracture resistance and resistance to crack growth was found in silicon carbide particles of size 5µm and 20µm.

**G. B. Veeresh Kumar et al. 2010** [2] carried out the study on Aluminium alloy (Al6061) - Silicon Carbide (SiC) and Aluminium alloy (Al7075)- Alumina ($Al_2O_3$) metal matrix composite for analyzing the mechanical charcateristics and tribological properties and compared them. The liquid metallurgy method (stir casting) was used to manufacture the metal matrix composite. The dissimilar weight percentage of reinforced material were used while fabricating the specimens for testing. The microstructure results exposed the unchanging distribution of the reinforced particles in the matrix. The tensile strength of the composites was improved reasonably as compare to base material and also Al6061-SiC showed higher tensile strength properties than that of Al7075-$Al_2O_3$. Hardness results showed hardness value to be increasing with the increase in weight percentage of the reinforced particles. The wear resistance cahracteristics of composites were improved and also wear resistance of Al6061-SiC was improved than the alloy.

**N. Radhika et al. 2011** [3] studied and evaluated the tribological characteristics of metal matrix composite composed of aluminium alloy (Al-Si10Mg) reinforced with alumina and graphite and also the consequence of wear constraints like sliding distance, sliding speed and applied load on the dry sliding behaviour of Al/$Al_2O_3$/Gr observed. Taguchi technique was used for generating the

design of experiments and for analysis of parameters ANOVA technique was used. The liquid metallurgy process was used for production of metal matrix composite. The material and reinforcement were taken in dissimilar weight percentage. For testing the wear behaviour, pin on disc test apparatus was used. The test result presented that the sliding distance has the more effect on wear rate and applied load has also a very substantial impact on wear rate and sliding speed has a minor effect on wear rate.

**A.R.I. Khedar et al. 2004** [4] fabricated aluminium metal matrix composite by taking pure aluminium as a base matrix material and, alumina ($Al_2O_3$), silicon carbide (SiC) and magnesium oxide (MgO) as reinforcements. The reinforced elements were added individually one at a time in dissimilar volume fractions. The stir casting process was used to manufacture the composites. During melting and mixing silicon particles were added before reinforcement in order to advance wettability and achieve homogeneous distribution. After testing it was found that enhancement in mechanical properties depends upon the accumulation of particulates and homogeneous distribution be contingent on the wetting ability of the material. The addition of reinforcements led to amplified mechanical characteristics of material such as hardness, tensile strength and yield strength but ductility diminished to some extent and the reason was the accumulation of SiC. The application of these produced composites in the manufacturing of automotive engine parts.

**Chang-Yeol Jeong 2012** [5] detected the consequence of alloying elements on the mechanical properties of Aluminium – Silicon alloys which are used to fabricate the piston. Casting alloys were fabricated by permanent mould casting. Alloying elements such as Fe, Cu, Ni and mg were studied on fatigue and creep behaviour. Chemical compositions of these elements were varied. The results concluded from this paper showed finer microstructure and uniform precipitation with an increase in the content of Ni and Cu. The mechanical properties were upgraded with an upsurge in Cu and Ni content and Also creep properties were increased suggestively with increasing of Ni and Cu content.

**G. G. Sozhamannan et al. 2012** [6] studied and analyzed the impact of process parameters of stir casting procedure on aluminium metal matrix composites. They observed the influence of process parameters such as holding time and processing temperature on unvarying distribution of reinforced particles and also on mechanical properties such as ductility, hardness, tensile and impact behaviour. Al-11Si-Mg alloy included as the matrix material. Silicon carbide (SiC) was

used as reinforcement. While experimentation and fabrication process the applied different temperatures, different holding time and stirring speed was kept constant. The finest temperature for uniform distribution was found 750 $^0$C and 800 $^0$C. The value of tensile strength and the value hardness were found to be enhanced with the processing temperature up to 800℃ and with the increase in holding time ultimate tensile strength results were found to be diminishing.

**S. Rama Rao and G. Padmanabhan 2012** [7] fabricated aluminium- boron carbide composite and analyzed the mechanical properties of the same. The liquid metallurgy practice was used to manufacture the composites. The reinforce material boron carbide was included in different weight percentage. The microstructure of the composite was analyzed by scanning electron microscopy and distribution observed was uniform. Hardness value and ultimate compression strength were found to be growing with the rise in the quantity of boron carbide particles. Density was diminished with upsurge in the quantity of reinforcement particles.

**T. Rajmohan et al. 2012** [8] studied and analyzed the wear behaviour and mechanical characteristics of hybrid metal matrix composites. In the research as a matrix material, Al356 alloy was used. Silicon carbide and mica were considered as reinforcing materials. The stir casting process was used to produce the composites. The particulates were preheated before introducing to molten metal in the crucible. The microstructure studied by SEM micrograph was noticeably uniform. The chemical configuration was examined by energy dispersive X-ray (EDX). The optimum result was found at 10% silicon carbide and 3% mica. With increased reinforcement wear characteristics were improved.

**Dinesh M. Pargunde et al. 2013** [9] experimentally observed the properties and behaviour of aluminium – silicon carbide metal matrix composites. The stir casting process was used for production purpose of composites. Silicon carbide was used in dissimilar weight percentage with aluminium alloy. Tests for Hardness, impact strength, microstructure, and corrosion were carried out and it was detected that hardness, density, and impact strength was amplified with the rise in weight percentage of silicon carbide, and corrosion rate was found to be satisfactory.

**Faiz Ahmad et al. 2013** [10] attempted to detect the wear resistance characteristics of the aluminium metal matrix composite and also investigated about brake disc material. Aluminium alloy 242 was considered as the matrix material with aluminium oxide particles as reinforcing material. Composite was produced by the squeeze casting process. SEM analysis was carried out

to understand the surface properties of test samples. Wear testing of composites and brake disc was done and the results were compared. The test results showed a different type of wear such as adhesive, fatigue and abrasive type were experienced by test samples. With the increased sliding speed, the coefficient of friction diminished and wear resistance amplified and for composites, the results were better than brake disc material.

**Sudindra S et al. 2013** [11] experimentally carried out the study on aluminium metal matrix composites. Aluminium alloy 6061 was used as base matrix material and $Al_2O_3$ and graphite particulates were used as reinforcing materials. Stir casting was selected to fabricate and prepare the composites. A dissimilar weight percentage of reinforcing materials were used. It was detected that with the adding of $Al_2O_3$ alone results in amplified hardness and tensile strength and lessened wear rate, while the accumulation of graphite particulates alone results in decreased hardness and increased ductility but the cumulative effect resulted in decreased wear rate and improved tensile strength.

**Mahendra Boopathi M et al. 2013** [12] estimated the mechanical characteristics of the hybrid metal matrix composites. In the research aluminium alloy 2024 was considered as the base matrix material and silicon carbide and fly ash were included as reinforcing particles. Stir casting process was used to fabricate and prepare the samples of composites material. Al-SiC, Al-fly ash, and Al-SiC-fly ash composites of various concentration fabricated. Magnesium was added to upsurge the wettability. After preparation of composites, microstructure was observed using optical microscopy and X-Ray Diffraction analysis was completed to observe the existence of different elements and compounds in the composites. It was originated that with an rise in the content of reinforcement density was diminished but tensile strength, yield strength, and hardness were increased.

**S. Suresh et al. 2013** [13] produced aluminium metal matrix composites by taking aluminium alloy Al6061 as main matrix material and $TiB_2$ particles as a reinforcing material. For the development of the composite and sample of composite material, stir casting process was used. The key purpose of this research was to explore the consequence of $TiB_2$ in aluminium alloy Al6061. In the experiment, they used dissimilar compositions of $TiB_2$. In testing of mechanical properties such as hardness, strength and also wear characteristics were investigated. Scanning electron microscope was selected to examine the spreading of the $TiB_2$ in composites. For hardness testing, Vickers

hardness tester was used. To the wear characteristics of the prepared composites, pin on disc tribometer was used. after studying the result it was observed that with the rise in the quantity of $TiB_2$ hardness and strength of the material was increased and also with the upsurge of the quantity of $TiB_2$ wear resistance of material was improved.

**K. Umanath et al. 2013** [14] experimented to inspect the characteristics of the hybrid metal matrix composites. For fabrication purpose aluminium alloy Al6061-T6 was selected as a prime matrix material, silicon carbide (SiC) and aluminium oxide ($Al_2O_3$) were taken as reinforcement materials. The composite was fabricated and preparation of samples done by stir casting process. silicon carbide and aluminium oxide were taken in equivalent volume fraction. Scanning electron micrograph and x-ray diffractogram were used inspect the spreading of constituents and the spreading was found to be uniform. For accompanying the experiment ANOVA technique was used for the design of experiments. The stimulus of wear testing parameters was investigated and it was detected that all the aspects have a substantial influence on wear characteristic of these hybrid composites. The rise in the volume fraction of reinforcement led to improving the wear resistance.

**Chinta Neelima Devi et al. 2014** [15] fabricated and evaluated mechanical properties of aluminium-silicon carbide-zinc-copper metal matrix composite. Al6061 alloy was selected as matrix material. Reinforcement materials silicon carbide, zinc and copper were added in dissimilar weight proportion. The test for tensile strength, yield stress and % elongation was done on UTM, whereas impact test was completed by using Charpy test and Izod test. It was observed by test results that optimum values zinc and copper are 6 % and 8% for better mechanical properties.

**V Mani Kumar et al. 2014** [16] carried out the study to evaluate mechanical properties of aluminium-copper metal matrix composite. Aluminium alloy al6061 was considered for base material and copper was designated as a reinforcing material. The method of fabrication was die casting process. Copper was included in varying mass fraction. The microstructure study showed the unvarying dispersal of copper particulates in an aluminium matrix. The observed mechanical properties which are hardness, tensile strength, and impact strength were enhanced with the increased weight % of copper up to 8%.

**P.B.Pawar et al. 2014** [17] prepared aluminium metal matrix composites for the application of spur gear. Aluminium alloy was used as base material and silicon carbide (SiC) was selected as a

reinforcing material. For fabrication purpose, stir casting procedure was used. While preparing composites, silicon carbide was included on the basis of mass ratio. The borax powder was used to enhance the wetting ability of silicon carbide. The microstructure of the composite was examined by optical microscope. Brinell hardness testing machine was used to check the hardness of composites, the outcomes exhibited that with growing content of silicon carbide, hardness tends to increase. Theoretical design of spur gear was completed by using Lewis formula and Hertz equation. Modelling was done by using CATIA software and finite element analysis was also done to investigate the stress distribution, by using ANSYS14.0. Stress distribution In FEA analysis disclosed that highest value of stress occurred at the tip of the tooth. The application of this composite is to make power transmission element like gears.

**Bharath V et al. 2014** [18] in this study, the purpose was to prepare aluminium metal matrix composite and investigate the mechanical and wear properties. For the study, aluminium alloy 6061 was considered. For reinforcement, aluminium oxide ($Al_2O_3$) was considered. The stir casting process was selected for fabrication and sample preparation purpose. The particulate was preheated and mixed with molten metal in 3 steps to attain the unvarying distribution and improve wettability. The microstructure study was carried out by using scanning electron micrograph and also x-ray diffraction analysis was done. The distribution was found to be fairly uniform. The test results exhibited that the hardness and strength (both tensile and yield) amplified with increased weight % of $Al_2O_3$ particulates however ductility was found to be decreased. The wear resistance was also improved with an increase in weight% of reinforcement.

**Md. Habibur Rahman et al. 2014** [19] carried out their study to examine the microstructure, mechanical properties and wear resistance properties of the aluminium metal matrix composites. Aluminium was selected as the basic matrix material and silicon carbide was chosen as a reinforcing material. Using stir casting process they fabricated composite, silicon carbide was added in dissimilar weight proportions. The microstructure was examined by using an optical microscope, which showed the uniform and unvarying spreading of the SiC particles. Hardness and tensile strength of the material were amplified with increased in qualtity of SiC particles. The maximum hardness and tensile strength were found with 20% SiC contents in the composite. Similarly, wear resistance was also enhanced with the accumulation of the SiC content.

**Dora Siva Prasad et al. 2014** [20] In this research, author carried out an examination on the mechanical behaviour of aluminium hybrid composites. In their study, they took the aluminium alloy A356.2 as basic matrix material. Rice husk ash (RHA) as well as silicon carbide (SiC) were considered as reinforcement materials. Magnesium was also included as a wetting agent to improve wetting ability of reinforcing materials in the matrix material. Double stir casting procedure was used to produce the composites. The microstructure of composites was studied and it was found to be in uniform distribution. The density and coefficient of thermal expansion (CTE) of composites decreased when weight percentage of reinforcing material increased whereas hardness was increased with this change. The ultimate tensile strength and yield strength amplified with the increased reinforcement.

**M.Vamsi Krishna et al. 2014** [21] prepared aluminium metal matrix composites and examined the mechanical characteristics of the composites. They used Al6061 as basic matrix material. Silicon carbide and graphite particles were included as reinforcements. Stir casting practice was used for fabricating and sample preparation purpose. During fabrication, magnesium was included to advance the wetting ability of the reinforcements in the matrix material. After fabrication testing was carried out. SEM analysis was done to explore the microstructure of the composites and uniform distribution was found in results. The testing results presented that the weight fractions of reinforcements have a great influence on mechanical properties of the composites. The tensile strength was increased with amplified weight % of the reinforcements. The density increased with SiC alone but the inclusion of Graphite led to decreased density.

**K.R.Padmavathi et al. 2014** [22] fabricated aluminium metal matrix composites. They used aluminium alloy Al6061 as basic matrix material. For reinforcement, multiwall carbon nanotubes (MWCNT) was used and also silicon carbide (SiC) were included. The composite was produced by using ball milling and hot pressing processes. The main purpose of the addition of SiC was to enhance dispersity of reinforcement material in the matrix material. The SEM analysis showed the better dispersion of MWCNTs in composites. The addition of SiC led to a better dispersion of MWCNTs in an aluminium matrix. The hardness of composites observed to be improved than the pure aluminium. The author implied the necessity for a further detailed study to examine the impact of SiC and MWNCTs on mechanical properties of metal matrix composites.

**Siddhartha Prabhakar. N et al. 2014** [23] carried out an inspection to study the preparation of aluminium metal matrix composites and investigated its tribological behaviour. LM14 aluminium alloy was selected as the basic matrix material and boron carbide ($B_4C$) particles were chosen as a reinforcement material. Taguchi's technique was used design the parameter for the experiment. Stir casting route was selected to prepare the composites. The microstructure of composites was studied using an inverted metallurgical microscope and uniform distribution was found. SEM analysis was also carried out to investigate worn out surfaces of composites. Different wear parameters were analyzed to check their influence on wear behaviour of composites. The results showed that with increased sliding velocity and sliding distance, wear behaviour of composites was enhanced, And composites were having good wear resistance at low load. The author suggested the replacement of automotive engine components such as a piston, cylinder liners etc. with these MMCs.

**Kenneth kanayo Alanene et al. 2015** [24] investigated the microstructure characteristics, mechanical properties and wear behaviour of aluminium matrix hybrid composites. Aluminium alloy 6063 was tselected as basic matrix material for composite preparation. Alumina of various particle sizes, rice husk ash (RHA) and graphite was used as reinforcing materials. The two-step stir casting process was used to produce composites. The microstructure study done by SEM analysis showed the fairly well spreading of reinforcement materials. The test result exhibited that the hardness diminished with increasing content of RHA. The tensile strength of composite was enhanced when graphite was added with RHA, but wear resistance decreased because of graphite addition[24].

**Shobhit Jain et al. 2016** [25] fabricated and studied the microstructure and behaviour mechanical properties of aluminium metal matrix composite. Pure aluminium was chosen as the basic matrix material and copper (4%) boron carbide ($B_4C$) particles were taken as reinforcements. The composites were produced by powder metallurgy process. The SEM analysis showed the similar distribution of particulates. The tensile and compressive strength amplified with increase in $B_4C$ content up to 10% whereas the hardness result was oberved and found to be directly proportional to the increasing $B_4C$ content.

**K. Kanthavel et al. 2016** [26] studied and evaluated the tribological properties of the hybrid composite. They took alumina ($Al_2O_3$) as well as molybdenum disulphide ($MoS_2$) as a reinforcing

material and pure aluminium as matrix material. The $MoS_2$ was considered for the reason that of its self-lubricating property. The powder metallurgy procedure was selected to prepare the composites. SEM analysis was done to check the spreading of constituents. And the results disclosed the unchanging distribution of the elements. Wear characteristics of composites were analyzed. The result presented that up to 5 weight % of the $MoS_2$ is optimum for improving wear resistance. The author suggested that the design of experiments can be changed or extended to analyze and improve tribological properties of the composites.

**G. Pitchayyapillai et al. 2016** [27] fabricated hybrid metal matrix composite to investigate wear characteristic of the composite. The material selected as a basic matrix material was aluminium alloy Al6061. For reinforcements, selected materials were hard ceramic alumina ($Al_2O_3$) and solid lubricant molybdenum disulphide ($MoS_2$). The stir casting practice was used to preppare and produce the composites. The inclusion of reinforcement was done in dissimilar weight %. The wear behaviour was done by varying different wear parameters such sliding velocity and applied load. Wear rate enlarged with the increased load but it was found that wear characteristics of the composite were better than the alloy. The inclusion of reinforcement led to enhancement in wear resistance as well as friction resistance. The mechanical behaviour was also studied found to be amplified with increased amount of reinforcement. The result showed that the optimum composition was of $MoS_2$ as 4 weight % and alumina as 12 weight %.

**S.C. Prasanna et al. 2014** [28] in this paper author prepared aluminium metal matrix composite by selecting aluminium alloy Al6061 as base matrix material. For reinforcement material, they selected silicon carbide (SiC) along with neem leaf ash and fly ash. The stir casting procedure was taken into consideration to produce the material. The dispersion of particulates in the composite matrix was observed by optical and scanning electron micrograph and in results it was observed to be homogeneous distribution. The tensile test performed on universal testing machine and after observing the result it was presented that strength has been amplified with the inclusion of neem leaf ash. The hardness value of the composite, tested by using Rockwell hardness tester, amplified with the increased weight % of reinforcements. Wear test was carried out on pin-on-disc tribometer. The wear characteristics of composite enhanced with the increased weight % of the reinforcement constituents.

**A. Manikandan et al. 2016** [29] fabricated and studied the hardness as well as tensile properties of the aluminium based metal matrix composites used for the application of piston. They selected the Al6061 alloy as base matrix material. Silicon carbide, aluminium oxide along with zirconium oxide were included as reinforcing material to boost the strength of piston material. The material was fabricated by using stir casting technique. The reinforcing materials were included in steps in dissimilar compositions of weight. The hardness of the material was tested by Vickers hardness testing machine. The result concluded that mixing of reinforcement led to amplified mechanical properties of the composites as compared to the base material.

**A.A. Agbeleye et al. 2017** [30] in this paper author carried out a study to explore mechanical properties as well as wear behaviour of aluminium based metal matrix composites for brake pad application. Aluminium alloy 6063 was chosen as a base matrix material and aluminosilicate clay particles were included as a reinforcing material. The stir casting practice was used to fabricate the composites. The author calculated the outcome of various weight fraction of clay on properties of the material and compared the result with the existing brake pad material semimetallic brake pad. The hardness (measured by using Vickers hardness tester) and tensile strength of material amplified with increased weight % of clay up to 15%, after that it started to decrease. The similar effects experienced in wear behaviour where wear resistance also amplified up to 15 weight % of the clay. The distribution of particles was found to be uniform in the matrix.

# CHAPTER III

## 3.1 SCOPE OF THE STUDY:

It is been observed that the practice of using composites has been increased extensively since past two decades. Composites provide greater materials properties as compare to other conventional and pure materials. Nowadays the usage of metal matrix composites, especially aluminium, in the automotive and space application has been increased, the reason being its higher strength and less weight, less cost, easy accessibility. A lot of research has been carried out to advance the properties of the Al MMCs. But in the automotive applications, particularly in the engine components, transmission, braking system, the material is subjected to wear and higher temperatures, so the research required in this field to improve wear and friction characteristics, keeping in the mind of less weight, also to amplify the fuel efficiency of the engine.

## 3.2 OBJECTIVE OF THE STUDY:

1. To fabricate the aluminium metal matrix composites with reinforcements (Aluminium oxide, Silicon Carbide and Copper) with the stir casting process.
2. To enhance the mechanical properties such as hardness, strength, impact strength, and wear characteristics of materials.
3. To compare the material properties of automobile engine push rod material.

# CHAPTER IV

# MATERIAL SELECTION AND EXPERIMENTAL SETUP

## 4.1 MATERIAL SELECTION:

### 4.1.1 Metal matrix

After carrying out the literature review it was detected that consideration of different aspects in the selection of matrix material is very crucial. The chemical compatibility of the matrix material with the reinforcing meterial, its wettability with reinforcement, and also it's own properties and processing behaviour is highly considered while choosing the matrix material. Load transfer capability of the matrix to the constituents and reinforcement depends on the how strong the interface is. For strong interface, the material should possess good wettability. Sometimes it can be attained by varying the chemical composition of materials but it's not suggestable since it is difficult to achieve because of involvement many subtleties.

After various consideration and literature survey, Aluminium alloy 6061 of aluminium alloy 6xxx series selected as matrix material reason being its good machinability, relatively low cost and also strength is also good.

**Physical and Thermal Properties of aluminium alloy 6061**:

| Property | Value |
|---|---|
| Melting point | Approx. 580℃ |
| Modulus of Elasticity | 70-80 GPa |
| Poisson's Ratio | 0.33 |
| Density | 2.7 g/cm$^3$ |
| Co-Efficient of Thermal Expansion (20-100℃) | 24.3 µm/m℃ |
| Thermal Conductivity | 173 W/mK |

**Table 4.1** – Properties of aluminium alloy 6061

**Chemical Composition of Al6061**:

| Elements | Si | Fe | Cu | Mg | Mn | Zn | Ti | Cr | others | Al |
|---|---|---|---|---|---|---|---|---|---|---|
| Amount (Wt %) | 0.4-0.8 | 0.7 | 0.15-0.40 | 0.8-1.2 | 0.15 | 0.25 | 0.15 | 0.04-0.35 | 0.15-0.20 | Balance |

**Table 4.2** – composition of aluminium alloy 6061

### 4.1.2 Reinforcements:

The prime objective of reinforcing material in the composite to advance the properties like strength, stiffness and temperature resistance and also it helps to decrease the density of MMC. To accomplish the stated properties, the choice of reinforcements should be by considering the type of reinforcement, size & shape of the reinforcement and method of process and also its chemical compatibility with the matrix.

After carrying out the literature review and according to the scope of the study selected reinforcement are:

- Silicon Carbide (SiC)
- Aluminium Oxide ($Al_2O_3$)
- Copper (Cu)

#### 4.1.2.1 Silicon Carbide (SiC):

Silicon carbide is a compound which is composed of carbon and silicon atoms with a strong bond in the crystal lattice. This leads to the production of the strong and hard material. SiC has high thermal conductivity, low thermal expansion, and impressive strength and it gives the material a very good thermal shock resistance property. SiC is considered as a very good abrasive and used to produce grinding wheels and some other abrasive products.

SiC is used to produce many parts like turbine components, seals and bearings, ball halve parts, heat exchangers, semiconductor process equipment, floor tiles etc.

**Properties of Silicon Carbide (SiC)**:

| Properties | Value |
|---|---|
| Melting Point | 2200-2700℃ |
| Density | 3.2 g/cm$^3$ |
| Hardness | 2800 kg/mm$^2$ |
| Co-Efficient of thermal expansion | 4 µm/m℃ |
| Elastic Modulus | 410 GPa |
| Poisson's Ratio | 0.14 |

**Table 4.3** – Properties of Silicon Carbide

**4.1.2.2 Aluminium Oxide (Al2O3)**:

Aluminium oxide is also acknowledged as alumina and in its crystalline form, it is known as corundum. It has very decent mechanical properties and available at very reasonable priced. Mostly used to make aluminium metal also sometimes used in abrasive reason being its hardness property. It has high melting point and because of this it is also used as a refractory material. Alumina possesses properties like high wear resistant, good hardness and good thermal conductivity and also has high strength and stiffness.

**Properties of Aluminium Oxide ($Al_2O_3$)**:

| Properties | Value |
|---|---|
| Melting Point | 2072℃ |
| Density | 3.69 g/cm$^3$ |
| Hardness | 1175 kg/mm$^2$ |
| Co-Efficient of thermal expansion | 8.1 µm/m℃ |
| Elastic Modulus | 300 GPa |
| Poisson's Ratio | 0.21 |

**Table 4.4** – Properties of aluminium oxide

#### 4.1.2.3 Copper (Cu):

Copper is considered as a very good alloying elements. It possesses certain properties in impressive amount like high thermal conductivity, high ductility & tensile strength and good toughness as well as high corrosion resistance also low thermal expansion. It is used in the production of industrial machinery, plumbing equipment, electrical wire and related devices.

**Properties of Copper (Cu)**:

| Properties | Value |
|---|---|
| Melting Point | 1084℃ |
| Density | 8.9 g/cm$^3$ |
| Co-Efficient of thermal expansion | 17 µm/m℃ |
| Elastic Modulus | 130 GPa |
| Poisson's Ratio | 0.36 |

**Table 4.5** – Properties of copper

## 4.2 EQUIPMENT AND EXPERIMENTAL SETUP:

To fabricate the composites the stir casting technique will be used. Stir casting setup consisting of ceramic crucible for melting the material, stirr, a motor for rotation purpose and for machining the composite lathe machining and grinding will be used.

Various tests will be carried out after the fabrication of composite. the test which will be done is hardness test, tensile strength on the universal testing machine, impact test using Charpy technique, wear test using a pin on disc tribometer, material distribution test using scanning electron microscopy.

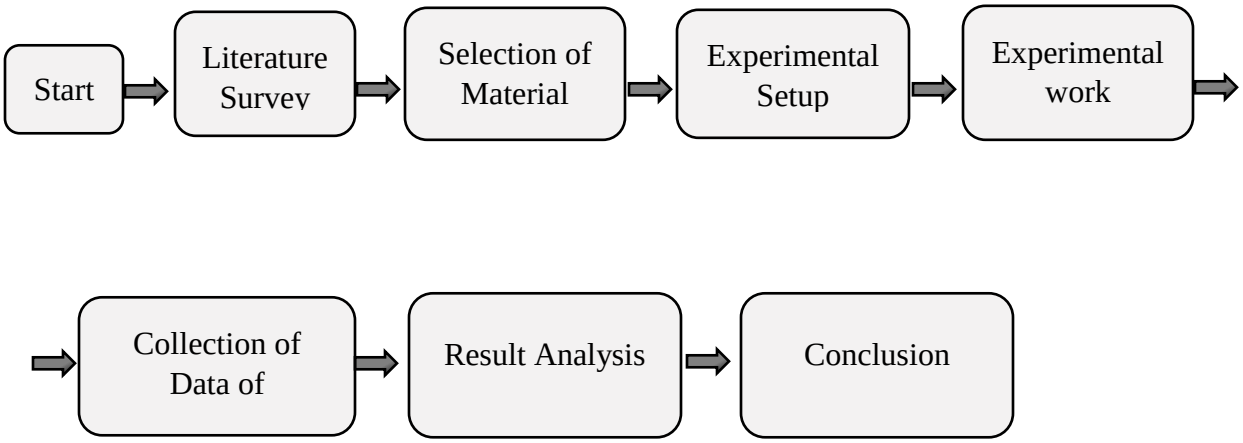
To fabricate the composite the configuration is decided by taking consideration the previous literature carried out by different researchers. The weight percentage of silicon carbide and aluminium oxide is decided to take as 10-10% by weight each in the composite because this is the optimum amount of these reinforcements to achieve impressive properties of composites, while the amount of copper is varied by weight %.

| Sample | Al (wt%) | $Al_2O_3$ (wt%) | SiC (wt%) | Cu (wt%) |
|---|---|---|---|---|
| Sample 1 | 78 | 10 | 10 | 2 |
| Sample 2 | 76 | 10 | 10 | 4 |
| Sample 3 | 74 | 10 | 10 | 6 |
| Sample 4 | 72 | 10 | 10 | 8 |

**Table-** Composition of material in samples

# CHAPTER V

# RESEARCH METHODOLOGY:




LITERATURE SURVEY: To carry out the research the field of research should be known, to recognize the research area, literature survey is carried out. It gives the direction and objectives of the research.

SELECTION OF MATERIAL: The literature survey provided the idea and knowledge about the material on which research is done and it gave me the idea to select material for my research work.

EXPERIMENTAL SETUP: To fabricate the composite material stir casting route will be used in my research work and different composition of reinforcements (alumina, silicon carbide and copper) will be used.

EXPERIMENTAL WORK: After deciding the various compositions of material, experimental work is done on stir casting machine and machining will be done on the lathe and after that various testing will be carried out

COLLECTION OF DATA: After sample preparation data collection will be done by carrying out the testing (mechanical and wear) on various machines.

RESULT ANALYSIS: After gathering data from testing result, the result will be analyzed and compared with the existing data.

CONCLUSION: The completion of experiment and result analysis will lead to provide the conclusion.

# CHAPTER VI

# PROPOSED WORK PLAN :

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Research Activities | | Aug | Sept | Oct | Nov | Dec | Jan | Feb | March | April |
| Literature Survey | Plan | | | | | | | | | |
| | Actual | | | | | | | | | |
| Problem Identification | Plan | | | | | | | | | |
| | Actual | | | | | | | | | |
| Material Selection | Plan | | | | | | | | | |
| | Actual | | | | | | | | | |
| Experimental work | Plan | | | | | | | | | |
| | Actual | | | | | | | | | |
| Analysis of Data | Plan | | | | | | | | | |
| | Actual | | | | | | | | | |
| Preparation of report | Plan | | | | | | | | | |
| | Actual | | | | | | | | | |
| Submission of report | Plan | | | | | | | | | |
| | Actual | | | | | | | | | |

We have started the research work in Aug 2017. The initial phase of literature survey took the maximum of the time since it was the crucial phase to recognize the research area and also to identify and formulate the research problem. The material selection was also the crucial phase because a very much work is done in this field. The production of the composite will be completed by the end of December and testing will be done in the January 2018 as per planning. The complete analysis and report and also the research paper will be completed by the end of March 2018.

# CHAPTER VII

## Expected Outcomes:

After successful completion of the research, the outcomes will be-

Successful fabrication of composites with homogeneous distribution.

Improved mechanical and wear properties of composites with an optimized value of reinforcements.

# CHAPTER VIII

## CONCLUSION

After conducting the review and evaluation of the literature , it was detected that every reinforcement that is being added to the matrix material, their particles size, the amount is being mixed have an effect on the different mechanical, tribological properties. Each material has compatibility with alloy, also depends on the processing method. In this report we have selected the aluminium alloy 6061 for matrix material and Aluminium oxide, silicon carbide and copper are selected as a reinforcing material. The stir casting procedure is chosen for the fabrication purpose since it is easy to handle and cost-effective as well as provides a homogeneous (uniform) distribution of the particulates. Mechanical properties such as hardness, tensile and impact strength and also wear properties will be analyzed.

# REFERENCES


[1]. Chen, Z. Z., & Tokaji, K. (2004). Effects of particle size on fatigue crack initiation and small crack growth in SiC particulate-reinforced aluminium alloy composites. *Materials Letters*, *58*(17), 2314-2321.

[2]. Kumar, G. V., Rao, C. S. P., Selvaraj, N., & Bhagyashekar, M. S. (2010). Studies on Al6061-SiC and Al7075-Al2O3 metal matrix composites. *Journal of Minerals and Materials Characterization and Engineering*, *9*(01), 43.

[3]. Radhika, N., Subramanian, R., & Prasat, S. V. (2011). Tribological behaviour of aluminium/alumina/graphite hybrid metal matrix composite using Taguchi's techniques. *Journal of Minerals and Materials Characterization and Engineering*, *10*(05), 427.

[4]. Kheder, A. R. I., Marahleh, G. S., & Al-Jamea, D. M. K. (2011). Strengthening of Aluminum by SiC, Al2O3 and MgO. *Jordan Journal of Mechanical & Industrial Engineering*, *5*(6).

[5]. Jeong, C. Y. (2012). Effect of alloying elements on high-temperature mechanical properties for piston alloy. *Materials Transactions*, *53*(1), 234-239.

[6]. Sozhamannan, G. G., Prabu, S. B., & Venkatagalapathy, V. S. K. (2012). Effect of processing parameters on metal matrix composites: stir casting process. *Journal of Surface Engineered Materials and Advanced Technology*, *2*(01), 11.

[7]. Rao, S. R., & Padmanabhan, G. (2012). Fabrication and mechanical properties of aluminium-boron carbide composites. *International journal of materials and biomaterials applications*, *2*(3), 15-18.

[8]. Rajmohan, T., Palanikumar, K., & Ranganathan, S. (2013). Evaluation of mechanical and wear properties of hybrid aluminium matrix composites. *Transactions of nonferrous metals society of China*, *23*(9), 2509-2517.

[9]. Dinesh M. Pargunde, Prof. Gajanan N. Thokal, Prof. Dhanraj P. Tambuskar, & Mr Swapnil S. Kulkarni. (2013). DEVELOPMENT OF ALUMINIUM BASED METAL MATRIX COMPOSITE (AlSiC). *International Journal of Advanced Engineering Research and Studies*, 22-25.

[10]. Ahmad, F., Lo, S. J., Aslam, M., & Haziq, A. (2013). Tribology behaviour of alumina particles reinforced aluminium matrix composites and brake disc materials. *Procedia engineering*, *68*, 674-680.

[11]. Sudindra, S., & Kumar, A. (2013). Studies on Al6061/Al2O3 and graphite hybrid metal matrix composites. *International journal of metallurgical & materials science and engineering*, *3*, 35-42.

[12]. Boopathi, M. M., Arulshri, K. P., & Iyandurai, N. (2013). Evaluation of mechanical properties of aluminium alloy 2024 reinforced with silicon carbide and fly ash hybrid metal matrix composites. *American journal of applied sciences*, *10*(3), 219.

[13]. Suresh, S., & Moorthi, N. S. V. (2013). Process development in stir casting and investigation on microstructures and wear behaviour of TiB2 on Al6061 MMC. *Procedia Engineering*, *64*, 1183-1190.

[14]. Umanath, K., Palanikumar, K., & Selvamani, S. T. (2013). Analysis of dry sliding wear behaviour of Al6061/SiC/Al 2 O 3 hybrid metal matrix composites. *Composites Part B: Engineering*, *53*, 159-168.

[15]. Chinta Neelima Devi, V.Mahes, & N. Selvaraj. (2014). Tensile and impact behaviour of Al-SiC-Zn-Cu metal matrix composite. *Research Journal of Engineering and Sciences, 3(2),* 17-22.

[16]. Kumar, V. M., & Devi, C. N. (2014). Evaluation of mechanical characteristics for Aluminum-copper Metal matrix composite. *Research Journal of Engineering Sciences, ISSN, 2278*, 9472.

[17]. Pawar, P. B., & Utpat, A. A. (2014). Development of aluminium based silicon carbide particulate metal matrix composite for spur gear. *Procedia Materials Science*, *6*, 1150-1156.

[18]. Bharath, V., Nagaral, M., Auradi, V., & Kori, S. A. (2014). Preparation of 6061Al-Al2O3 MMC's by Stir Casting and Evaluation of Mechanical and Wear Properties. *Procedia Materials Science*, *6*, 1658-1667.

[19]. Rahman, M. H., & Al Rashed, H. M. (2014). Characterization of silicon carbide reinforced aluminium matrix composites. *Procedia Engineering*, *90*, 103-109.

[20]. Prasad, D. S., Shoba, C., & Ramanaiah, N. (2014). Investigations on mechanical properties of aluminium hybrid composites. *Journal of Materials Research and Technology*, *3*(1), 79-85.

[21]. Krishna, M. V., & Xavior, A. M. (2014). An investigation on the mechanical properties of hybrid metal matrix composites. *Procedia Engineering*, *97*, 918-924.

[22]. Padmavathi, K. R., & Ramakrishnan, R. (2014). INTERNATIONAL JOURNAL OF MECHANICAL ENGINEERING AND TECHNOLOGY (IJMET). *Journal Impact Factor*, *5*(5), 151-156.

[23]. Prabhakar, N. S., Radhika, N., & Raghu, R. (2014). Analysis of tribological behaviour of aluminium/B4C composite under dry sliding motion. *Procedia Engineering*, *97*, 994-1003.

[24]. Alaneme, K. K., & Sanusi, K. O. (2015). Microstructural characteristics, mechanical and wear behaviour of aluminium matrix hybrid composites reinforced with alumina, rice husk ash and graphite. *Engineering Science and Technology, an International Journal*, *18*(3), 416-422.

[25]. Jain, S., Rana, R. S., & Jain, P. (2016). STUDY OF MICROSTRUCTURE AND MECHANICAL PROPERTIES OF AL-Cu METAL MATRIX REINFORCED WITH B4C PARTICLES COMPOSITE.

[26]. Kanthavel, K., Sumesh, K. R., & Saravanakumar, P. (2016). Study of tribological properties on Al/Al 2 O 3/MoS 2 hybrid composite processed by powder metallurgy. *Alexandria Engineering Journal*, *55*(1), 13-17.

[27]. Pitchayyapillai, G., Seenikannan, P., Raja, K., & Chandrasekaran, K. (2016). Al6061 Hybrid Metal Matrix Composite Reinforced with Alumina and Molybdenum Disulphide. *Advances in Materials Science and Engineering*, *2016*.

[28]. Prasanna, S. C., Ramesh, C., Manivel, R., & Manikandan, A. (2016). Preparation of Al6061-SiC with Neem Leaf Ash in AMMC's by Using Stir Casting Method and Evaluation of Mechanical, Wear Properties and Investigation on Microstructures. *Applied Mechanics and Materials*, *854*, 115.

[29]. Manikandan, A., Gokulkumar, C., & Parthipan, N. Effect of Hardness and Tensile properties of Al6061 based composites for Piston alloy using Stir casting method. *Journal of Chemical and Pharmaceutical Sciences ISSN*, *974*, 2115.

[30]. Agbeleye, A. A., Esezobor, D. E., Balogun, S. A., Agunsoye, J. O., Solis, J., & Neville, A. (2017). Tribological properties of aluminium-clay composites for brake disc rotor applications. *Journal of King Saud University-Science*.