EXPERIMENTAL INVESTIGATION OF COMPOSITE MATERIAL TO INCREASE THE MECHANICAL CHARACTERIZATION USING ALUMINIUM WITH SILICON CARBIDE COMPOSITES

[1]G.Paulraj,[2]R.Harimaheswaran,[3]P.Viswabharathy, [4]N. Surendiran
[1,]Professor,[2,3]Assistant Professor,[4],PG Scholar
[1,2,3,4]Department of Mechanical Engineering,
[1,2,3,4] Shivani College of Engineering and Technology,[1,2,3,4] Trichy,Tamilnadu, India

Abstract-Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. In recent years, Aluminium Metal Matrix Composites (AMMCs) have emerged as a promising high class of materials. The surface roughness and wear properties are the basic material parameters required in the design and optimization of composite structures and behaviors. Metal matrix composites are emerging as very promising materials especially in the fields of aerospace, electrical, electronics and automotive for their various applications and technical demanding properties. Silicon carbide is reinforced in the aluminium 2024 matrix composites to increase the more conductivity and characterized for their mechanical properties such as hardness and tensile strength and wear properties. Aluminium 2024 metal matrix composites reinforced with Silicon carbide particles up to (5%, 10% and 10 %) was produced by stir casting. Taguchi method and analysis of variance (ANOVA) has to be employed by using MINITAB-17 software to identify the level of importance of the machining parameters on metal composite % and wear load sliding velocity. The mechanical properties such as hardness, tensile test, wear test, microstructure have been investigated.

Keywords: Aluminium 2024,Silicon Carbide, Metal Matrix Composites, ANOVA, Mechanical Properties.

I. INTRODUCTION

1.1 METAL MATRIX COMPOSITES

In engineering designs, great interest is to search for new materials exhibiting good mechanical properties. For the development of such materials metal matrix composites (MMCs) have been proved to be one of the best selections for such materials. Metal matrix composites (MMCs), like all composites consist of at least two chemically and physically distinct phases, suitably distributed to provide properties not obtainable with either of the individual phases **[1]**.The constituents are combined at a microscopic level and are not soluble in each other. The reinforcing material may in the form of the fibres, particles or flakes. The matrix phase's materials are generally continuous. The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material **[2].**

1.2 CLASSIFICATION OF COMPOSITES

1. Particle Rein Forced
2. Fiber Rein Forced
3. Structural

1.2.1 COMMON TYPES OF PARTICLE REINFORCED MMC

- Aluminium Matrix Composites (AMC)
- Magnesium Matrix Composite
- Titanium Matrix Composite
- Copper Matrix Composites

1.3 Matrix

The selection of suitable matrix alloys is mainly determined by the intended application of the composite materials. With the development of light metal composite materials that are mostly easy to process, conventional light metal alloys are applied as matrix materials[3].The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. In structural applications, the matrix is usually a lighter metal such as Aluminium, magnesium, or titanium, and provides a compliant support for the reinforcement. In high temperature applications, cobalt and cobalt-nickel alloy matrices are common **[4]**.

1.3.1ALUMINIUM MATRIX COMPOSITES

Pure Aluminium obtained from the electrolytic reduction of alumina (Al_2O_3) is a relatively weak material. Therefore for applications requiring greater mechanical strength, it is alloyed with metals such as copper, zinc, magnesium and manganese, usually in combinations of two

or more of these elements together with iron and silicon. Wrought Aluminium alloys are divided into seven major classes according to their major alloying elements. In the internally agreed four-digit system, the first of the four digits in the designation indicates the principal alloying element of the alloys within the group Aluminium alloys can be divided into two categories: heat treatable and non-heat treatable alloys [5].

1.3.2 Aluminium Alloy 2024

Aluminium Alloy 2024 is a heat treatable Al-Cu-Mg-Fe- Ni forging alloy developed for high temperature applications **[6]**, especially in the manufacturing of aircraft engine components **[30].**This alloy has good elevated temperature strength up to 204 ^{0}C **[7]**. The addition of small amounts of Fe and Ni produces micro structural stability under thermal exposure **[7]**. This alloy derives its strength from a combination of precipitation and dispersion hardening. The main precipitates are coherent Guinier-Preston-Bagaryatskii (GPB) (Cu, Mg) zones **[11]** which form rapidly on aging at temperature up to at least 200 ^{0}C **[8]**, and a semi-coherent S' (Al2CuMg) phase. The S' phase forms as rods or laths on the {210} matrix planes and nucleates preferentially on dislocation lines. The precipitation of S' in the matrix is known to be facilitated by silicon due to this effect on increasing the available concerning of vacancies and/or the stability of the pre-existing GPB (Cu, Mg) zones **[9]**. The presence of stable inter metallic particles (such as aluminide particles of the phase Al9FeNi helps to control grain size and impede dislocation movement **[12]**. Here, balanced amounts of iron and nickel are needed; otherwise, these elements combine with some of the copper to form stable compounds which reduce the response of the alloy to age hardening **[10]**. Recent studies have shown that AA2618 prepared from ingots has relatively low quench sensitivity while that prepared from rapidly solidified powders is more quench sensitive **[12]**.

1.3.3 Particle reinforcement

In the past two decades, a strong interest has been shown in the application of metal matrix composites (MMCs) in the design of many engineering and non-engineering components **[13].** Potential uses of these materials are numerous in industries and they include such areas of application as aerospace (satellite struts), defense (electronic instrument racks), automotive (drive shafts and brakes discs), sports goods (golf clubs and mountain bicycle frames), and marine (yacht fittings). When compared with the unreinforced matrix alloy, MMCs in general have superior mechanical properties, for example, high strength, high stiffness, high wear resistance, and very good elevated temperature properties. These properties can be tailored to meet specific requirements. The early work on MMCs focused mainly on continuous fiber reinforcement. However, high cost of fibers, complex fabrication techniques, and limited fabricablity restricted their use to those application where the end could justify the means. This opened the way for the development of low cost discontinuously reinforced MMCs, such as particle-reinforced MMCs**[14].**Alumina particles have become one of the popular reinforcing phases or many aluminium alloy-based metal matrix composites. They are hard but brittle ceramic particles with high strength, high modulus of elasticity, and high thermal and electrical resistance. The size of the particles depends on both the manufacturer and type o alloy. However, the mean particle dimension normally lies in the range 2-20µm **[9].**Partical-reinforced MMCs are produced via various routes. They have additional advantages over the continuous fiber-reinforced MMCs are now being produced commercially. There is evidence in the open literature that the presence of a ceramic reinforcement affects the characteristics of age-hardenable aluminium alloys. Change in quench sensitivity, high dislocation density, and accelerated aging response have been reported in MMCs **[10-11].**

1.3.4 SILICON CARBIDE AS REINFORCEMENT

Silicon carbide as a group of materials with attractive combinations of properties have generated substantial attention of ceramic research groups worldwide for more than three decades. They have high strength over a wide temperature range, good thermal shock resistance, and strong wear and corrosion resistance, which make them suitable for use in automotive, petrochemical, metallurgical and chemical industries. As a result of its covalent bonding and low diffusivity, Si_3 cannot be densified by solid state sintering. Sintering additives, which create a liquid-phase at high temperatures, allow mass transport through a solution re-precipitation-process which leads finally to full densification. They react with the SiO_2 adhered on the particle surface to form a silicate phase, which is liquid at the sintering temperature.**[12]** Liquid phase sintering can be subdivided into three stage: (*i*) particle rearrangement by the development of capillary forces among the particles due to the formation of an eutectic melt consisting of the used additives and SiO_2 on the Si_3 surface, (*ii*) Solution of α- Si_3, the diffusion of Si and N through the liquid phase and re-precipitation of β- Si_3 nuclei,**[13]** followed by β- Si_3 coarsening,**[14]** and (*iii*) the coalescence of the β - Si_3 crystals which is of limited importance due to the low volume diffusion in Si_3. Although it is well known that densification is assisted by a liquid-phase, its role varies depending on the composition, type and concentration of additives while the properties of the sintered material strongly depend on the morphology of the silicon nitride grains and the character of the inter granular phase.**[15]**Today, most silicon nitride ceramics are prepared using α-rich Si_3N_4 powders. In silicon nitride ceramics, the microstructure is similar to whisker-reinforced ceramic composites, with large rod like β-Si_3 grains as the reinforcing agents.

By incorporating a controlled amount of elongated β-Si_3 single-crystal particles into the ceramics, the toughening mechanisms, such as crack deflection and/or bridging *via* interfacial debonding at elongated seeds, are activated. Therefore, the seeding method provides an effective way to improve the fracture resistance while retaining high strength if the size, content and distribution of the elongated β-Si_3 single-crystal particles are carefully regulated **[16–17]**. Ceramics based on Si_3N_4 obtained by gas pressure sintering or by hot pressing have rather high fabrication costs. For wide use, fabrication of these materials, by a low cost procedure, such as pressureless sintering, is mandatory. This work describes a preliminary attempt to produce silicon nitride in the beta form as seed particles, as well as to synthesize self-reinforced Si_3 composites using the pressureless sintering procedure. The obtained results show that with carefully controlled preparation of the starting powder mixtures, very good results can be obtained as far as the mechanical properties are concerned.

1.4 Properties of Silicon carbide

- High strength over a wide temperature range
- High fracture toughness
- High hardness
- Outstanding wear resistance, both impingement and frictional modes

- Good thermal shock resistance
- Good chemical resistance

1.4.1 Typical Uses of Silicon carbide

- Rotating bearing balls and rollers
- Cutting tools
- Engine moving parts - valves, turbocharger rotors
- Engine wear parts - cam followers, tappet shims
- Turbine blades, vanes, buckets
- Metal tube forming rolls and dies
- Precision shafts and axles in high wear environments
- Weld positioners

1.5 PROCESSING OF MMCs

Accordingly to the temperature of the metallic matrix during processing the fabrication of MMCs can be classified into three categories:

- Liquid phase processes
- Solid state processes
- Two phase (solid-liquid) processes.

1.5.1 Liquid Metal Techniques

Liquid state fabrication of Metal Matrix Composites involves incorporation of dispersed phase into a molten matrix metal, followed by its Solidification. In order to provide high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and the liquid matrix should be obtained. Wetting improvement may be achieved by coating the dispersed phase particles (fibers). Proper coating not only reduces interfacial energy, but also prevents chemical interaction between the dispersed phase and the matrix. The simplest and the most cost effective method of liquid state fabrication is Stir Casting[18].

1.5.2 STIR CASTING METHOD OF FABRICATION OF MMCS

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring as shown in figure 1.2. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies [19].

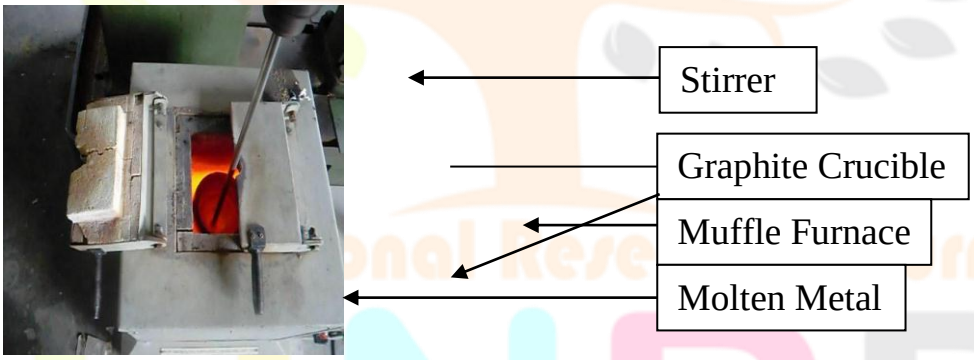

Fig.1.1 Stir casting set up

1.6 Stir Casting is characterized by the following features

Content of dispersed phase is limited (usually not more than 30 vol. %).

- Distribution of dispersed phase throughout the matrix is not perfectly homogeneous:
  1. There are local clouds (clusters) of the dispersed particles (fibers).
  2. There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase.
- The technology is relatively simple and low cost.

II.LITERATURE REVIEW

Aluminium alloys with silicon as the main alloying element are the most important of the aluminium casting alloys mainly because of the high fluidity imparted by the presence of relatively large volume of the Al-Si eutectic. These age hardenable alloys have attracted increased attention in recent years particularly due to the demand for lighter vehicles as part of the overall goal to improve fuel efficiencies and reduced vehicle emissions .It is estimated that substituting aluminium for steel in an automobile body structure will directly reduce the weight by 5 percent without compromising its performance. A weight reduction of 10 percent can increase the fuel economy of the vehicle by 6 to 8 percent[20].

F J Tavitas-Medrano et al have carried out extensive investigation to examine the effect of strontium modification and addition of Mg on the tensile strength and impact properties of 319 Type alloys over a range of ageing temperatures and time. Chemical and thermal treatments are applied to 319 type alloys in order to obtain improved mechanical properties. The most common chemical treatment consists of modifying the morphology of eutectic silicon phase from an ascicular to fibrous one , thus improving the mechanical properties , particularly the elongation.

Heat treatment is carried out to obtain the desired combination of mechanical properties such as strength and ductility. The T6 treatment provides the best combination of mechanical properties.When Mg is added to the alloy, a more marked response to artificial ageing is evidenced in the yield strength and micro hardness values obtained in the T6 treatment. This can be explained by the co operative precipitation of Al_2 Cu and Mg_2Si. The addition of Mg proves to be an excellent way of achieving a high level of tensile strength and micro harness at the expense of elongation and impact toughness.

J.Y. Hwang et al. studied the effect of Mg on the structure and properties of Type 319 Aluminium casting alloys. The precipitation hardening behavior of a Type 319 Aluminium alloy (Al–6.7 wt.% Si–3.75 wt.% Cu) with and without 0.45 wt.% Mg has been investigated. A considerably greater enhancement in UTS was observed after heat treating the alloys to their T6 condition. Specifically, there is an approximately 67% increase in the UTS of the Mg-containing alloy from 196 to 328 MPa upon ageing, while in the case of the Mg-free alloy, only a 30% increase in UTS was observed after the same heat treatment. Unfortunately, the Mg-containing material displays a significant decrease in ductility after ageing.

P. Apichai et al. studied the effect of Precipitation Hardening Temperatures and Times on Microstructure, Hardness and Tensile Properties of Cast Aluminium Alloy A319.At lower aging temperatures or shorter times, the hardness and tensile strength were decreased due to incomplete precipitation. However, at higher aging temperature or longer time, the hardness and tensile strength were decreased most probably due to precipitate coarsening and associated loss in coherency effects. A319 alloy is a hypoeutectic Al-Si alloy with two main solidification stages: the formation of primary aluminium rich (Al) dendrites followed by Al-Si eutectic. However, the presence of additional alloying elements such as Cu and Mg leads to a more complex solidification sequence and giving rise to other intermetallic eutectic phases such as Al_2Cu, Mg_2Si.

N. Crowell et al. studied Solution Treatment Effects in cast Al-Si-Cu alloys.Sr modification also reduces the number of Fe needles in alloys with high Fe content. The tensile properties of thee castings improve slowly with solution treatment time. Sr modification has a beneficial effect in improving the strength and elongation, further more modification also lowers the solution time necessary to attain the desired property level. At a Sr concentration of .005%, even after a solution time of 128hr the casting contain several highly angular Si particles. By comparison, at a Sr concentration of .014% nearly all the Si particles are highly spheroidized even for times less then 8-16hr.

J.Gauthier et al., studied the heat treatment of 319.2 aluminium automotive alloy part 1, solution treatment. Heat treatment is one of the important controlling factors used to enhance the mechanical properties of an alloy casting. This involves optimizing both the solution heat treatment and the ageing treatment given to the alloy. An alternative solution treatment is suggested consisting of solutionizing for a short period at 540^0C to allow for spheroidization of the Si particles and dissolution of a significant part of the Cu, followed by slow cooling to 515^0C, followed by quenching into water. This process is found to produce better ductility than the 8hr at 515^0C treatment, maintaining the same time high levels of yield and ultimate tensile strengths.

J.Gauthier et al., studied the heat treatment of 319.2 aluminium automotive alloy part 2, Ageing behavior. In this paper the hardening behavior upon artificial ageing in the range $155\text{-}220^0$C for periods of up to 24hr has been investigated. Inclusion and oxides have a marginal effect on the yield strength; they deteriorate both UTS and %elongation to levels below those obtained in the as cast condition. The results show that peak ageing is achieved after 24hr at 150^0C or 5hr at 180^0C.

Emma Sjolander etal., studied the heat treatment of Al-Si-Cu-Mg casting alloys.The mechanical properties of aluminium- silicon casting alloys containing Cu and Mg are known to be improved by heat treatment. A lower temperature will not give an optimal solution treatment because there will be a lower concentration of alloying elements and vacancies in solid solution and there will be less spheroidization of Si particles. An addition of Mg to an Al-Si-Cu alloy did not provide an increase in strength at a solution treatment temperature of 480^0C, but when the temperature was increased to 500^0C an increase in strength was achieved. If too high a temperature is used localized melting occurs and the mechanical properties decrease drastically.

III.EXPERIMENTAL SET UP

3.1 WORK MATERIAL DETAILS

3.1.1 Details of Raw Materials

A brief description of the raw materials used in the synthesis of composite is presented as follows:

3.1.2 Al2024 Matrix Materials

Aluminium is used as matrix in the synthesis of composite. Aluminium was cut from its ingot size into smaller pieces by an electric power saw in order to feed the crucible properly. Composition of matrix alloy was analyzed and the chemical composition of the matrix alloy is given in table 31.Aluminium alloy 2024 is an aluminum alloy, with copper as the primary alloying element. It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance. It is weld able only through friction welding, and has average machinability. Due to poor corrosion resistance, it is often clad with Aluminium or Al-1Zn for protection, although this may reduce the fatigue strength. In older systems of terminology.

3.1.3 CHEMICAL PROPERTIES

Table 3.1 chemical composition of the Al2024 matrix alloy

Cu	Mg	Ti	Sn	Fe	Mn	Sb	v
4.089	0.425	0.039	0.013	0.123	0.425	0.015	0.010

3.1.4 PHYSICAL PROPERTIES

Physical properties of 2024 Al are given below:

Table 3.2 Physical properties

Physical properties	**Metric**	**Imperial**
Density	2.78 g/cm	0.284 lb/in3

Melting point	500 °C	932 °F

3.1.5 THERMAL PROPERTIES

The following table shows the thermal properties of 2024 Al.

Table 3.3 Physical properties

Properties	**Conditions T (°C)**	**Max Treatment**
Thermal expansion 12 x 10-6/ºC	**20-100ºC**	-

3.1.6 MECHANICAL PROPERTIES

The mechanical properties of 2024 Al steels are tabulated below:

Table 3.4 Physical properties

Property	**Quality**
Max Hardness	46.8 - 47
Heat Resistance	Low
Wear Resistance	Medium
Machinability	Good
Deformation During Hardening	Medium
Hardening Temperature	**493°C**
Resistance To Decarburization	Good
Micro Hardness	137 Vhn

3.1.7 APPLICATION

- AL2024 Material is used in aerospace applications requiring a high degree of accuracy in hardening, such as draw dies, forming rolls, powder metal tooling and blanking and forming dies and bushes

3.2 Reinforcement Material Silicon Carbide

Silicon carbide is composed of tetrahedra of carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material. Silicon carbide is not attacked by any acids or alkalis or molten salts up to 800°C. In air, SiC forms a protective silicon oxide coating at 1200°C and is able to be used up to 1600°C. The high thermal conductivity coupled with low thermal expansion and high strength give this material exceptional thermal shock resistant qualities. Silicon carbide ceramics with little or no grain boundary impurities maintain their strength to very high temperatures, approaching 1600°C with no strength loss. Chemical purity, resistance to chemical attack at temperature, and strength retention at high temperatures has made this material very popular as wafer tray supports and paddles in semiconductor furnaces. The received reinforcement particles were sieved and required particle size were selected as given in the table 3.5.

Table 3.5 Particle size range of Silicon Carbide

REINFORCEMENT	**NOTATIONS**	**PARTICLE SIZE RANGE (µM)**
Silicon Carbide	sic	50

3.2.1 CHEMICAL PROPERTIES

Table 3.6 chemical composition of the Silicon Carbide

Cu	**Mg**	**Ti**	**Si**	**fe**	**ga**	**sb**	**v**
2.089	2.40	0.039	1.12	0.123	1.43	0.75	0.83

3.2.2 PHYSICAL PROPERTIES

Physical properties of Silicon Carbide are given below:

Table 3.7 Physical properties

Physical properties	**Metric**	**Imperial**
Density	3.1g/cm	193.5 lb/in3
Melting point	2,730 °C	4,946 °F

3.2.3 THERMAL PROPERTIES

The following table shows the thermal properties of Silicon Carbide.

Table 3.8 Physical properties

Properties	**Conditions T (°C)**	**Max Treatment**
Thermal expansion 12 x 10-6/ºC	120 **ºC**	830 **ºC**

3.2.4 MECHANICAL PROPERTIES

The mechanical properties of Silicon Carbide are tabulated below:

Table 3.9 Physical properties

Property	**Quality**
Max Hardness	2800
Heat Resistance	Low
Wear Resistance	Medium
Machinability	Good
Deformation During Hardening	Medium
Hardening Temperature	1650 **°C**
Resistance To Decarburization	Good
Micro Hardness	2900 Vhn

3.2.5 SILICON CARBIDE OF APPLICATION

- Fixed and moving turbine components, and Suction box covers
- Seals, bearings, Ball valve parts, Hot gas flow liners, Heat exchangers, and Semiconductor process equipment

3.3 COMPOSITION OF SAMPLES

Aluminium 2024 was reinforce in silicon carbide 5% 10% and 15% table: 3.10 show in mixed ratio in %

SAMPLE NO	ALUMINIUM 2024 (GM)	REINFORCEMENT SILICON CARBIDE IN (%) AND (GM)
1	100	Silicon Carbide = 5%,5 gm
2	100	Silicon Carbide = 10%,10 gm
3	100	Silicon Carbide =15%,15 gm

Table 3.10 Composition of Samples

IV.EXPERIMENTAL SETUP FOR STIR CASTING

4.1 STEPS INVOLVED IN STIR CASTING

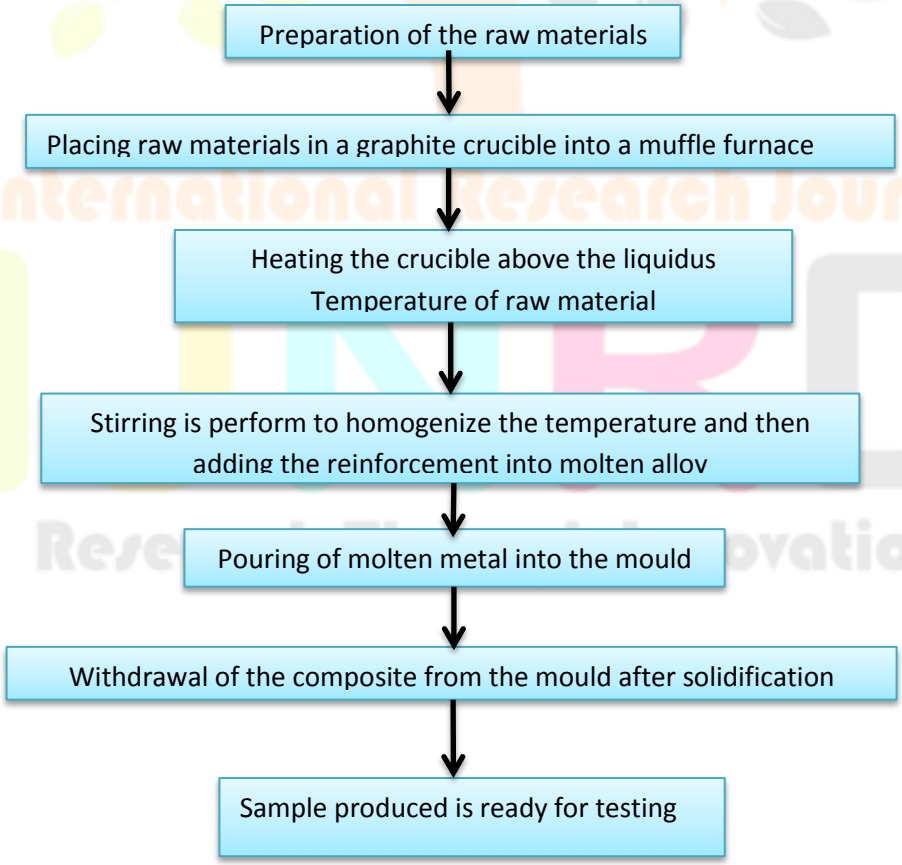

Figure: 4.1 Flow Chart Steps Involved In Stir Casting

Performing the stir casting operation and testing of composites the following Machines/equipment was used:

- Sieve Analysis Tester
- Reinforcement (Silicon carbide)
- Matrix (Al)
- Muffle Furnace
- Radial Drilling Machine
- Silicon carbide and magnesium Crucible/ mould

4.2 COMPOSITES PREPARATION BY STIR CASTING METHOD

A stir casting setup (Figure. 4.2), which consisted of a resistance furnace and a stirrer assembly, was used to synthesize the composite. The stirrer assembly consisted of a graphite turbine stirrer, which was connected to a variable speed vertical drilling machine (speed 0 to 890 rpm) by means of a steel shaft. The stirrer was made by cutting and shaping a graphite block to desired shape and size manually. The stirrer consisted of three blades at angles of 120° apart. Figure 4.2 show the photograph of the stirrer from two different angles. Clay graphite crucible of 1.5 Kg capacity was placed inside the furnace. The stirrer assembly consisted of a graphite turbine stirrer fixed to a steel rod. Approximately 1Kg of alloy was then melted at 820°C in the resistance furnace of stir casting setup. Preheating of Silicon Nitride, Aluminium Nitride, and Zirconium Boride mixture at 800°C was done For one hour to remove moisture and gases from the surface of the particulates. The stirrer was then lowered vertically up to 3 cm from the bottom of the crucible (total height of the melt was 9 cm). The speed of the stirrer was gradually raised to 800 rpm and the preheated Silicon and Iron particle was added with a spoon at the rate of 10- 20g/min into the melt. The speed controller maintained a constant speed, as the stirrer speed got reduced by 50-60 rpm due to the increase in viscosity of the melt when particulates were added into the melt. After the addition of Aluminium alloy 2618 , Silicon and Iron particle, stirring was continued for 10 minutes for better distribution. The melt was kept in the crucible for one minute in static condition and it was then poured in the metal mould.

4.2.1 IMPORTANT PARAMETERS

Synthesis of composite is done by stir casting route. The parameters which are important in this work are stirrer design, preheating temperature for particulate and stirring speed. These parameters are discussed below.

4.2.2 Stirrer Design

It is very important parameter for stir casting process. It is essentially requires for vortex formation for the uniformly dispersion of particles. There is different type of stirrer some 90º form the shaft and some are bent at 45º. There is a no uniform dispersion of particles in case of no vortex formation.

4.2.3 Particle Preheating Temperature

Preheating of particulate is necessary to avoid moisture from the particulate otherwise there is chance of agglomeration of particulate due moisture and gases. Along this Silicon, and Iron particles are heated at 800ºC to form a oxide layer on the Silicon, and Iron particles which make it chemically more stable and by the oxide layer formation wettability will increase so particles will effectively embedded in aluminium matrix and less number of porosities in casting.

4.2.4 Stirring Speed

In stir casting process stirring speed is very important parameter for consideration. In this process stirring speed was 800 rpm which was effectively producing vortex without any spattering. Stirring speed is decided by fluidity of metal if metal having more fluidity then stirring speed will be low. It is also found that at less speed, dispersion of Particulates is not proper because of ineffective vortex.

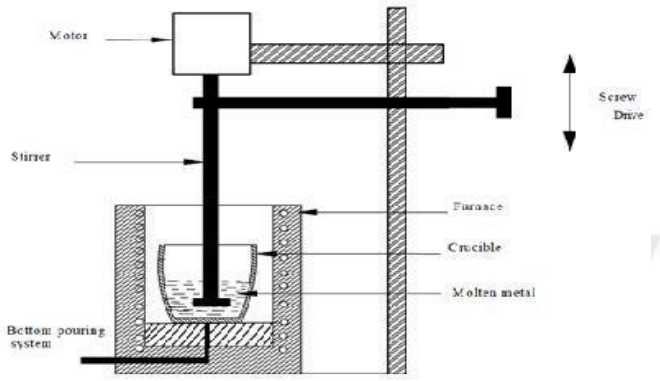

Fig.4.2 MMC Preparations by Stir Casting Route

The temperature of the furnace was gradually lowered until the melt reached a temperature in the liquid solid range while stirring was continued. Then the stirrer was positioned just below the surface of the slurry and the oxidized particles were added uniformly at a rate of 20 g/min over a time period of approximately 3–5 min. At the end of charging the slurry was allowed to mix in the semisolid state isothermally for another 15 min while the stirrer was positioned near the bottom of the crucible.

Figure: 4.3 Crucible

Fig.4.4 mould

Fig.4.9 Preparation of Samples

Fig.4.10. sample Preparation after casting

Fig.4.11 After casting sample Machining

Figure 4.12 After casting 5%, 10%, 15% sample

Figure 4.13 After casting 5%, 10%, 15% sample ready to tensile testing

4.3 MECHANICAL TESTING

4.3.1 Wear Testing

Pin on disk test method was used to measure the wear and wear loss of the material. Work piece keep at fixed position on a rotating disk under a loaded condition. Initially weight of the specimen was measured and after the test also weight of the specimen measured. The loss of weight was calculated and coefficient of friction was measured from the system.

Fig 4.14 Wear test set up.

4.3.2 Hardness Testing

Hardness samples were prepared from the casting (15mm diameter and 10mm height) and subjected to T6 heat treatment. The hardness of the sample was measured by compressing a ball indenter on its surface. The indentation made with a ball indenter of diameter 2.5mm using a Hecket Brinell hardness tester shown in Fig 4.13

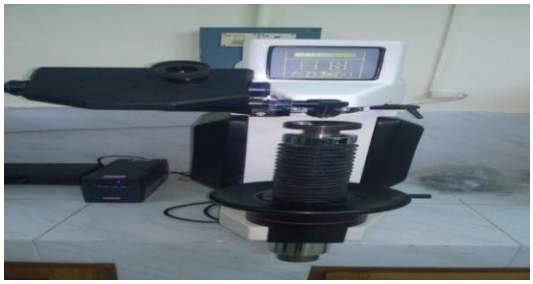

Fig 4.15 Hardness testing Machine

V.EXPERIMRNTAL DESIGN

5.1 TAGUCHI INTRODUCTION

Basically, experimental design methods were developed original fisher. However experimental design methods are too complex and not easy to use. Furthermore, a large number of experiments have to be carried out when the number of the process parameters increases, to solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. The experimental results are then transformed into a signal– to – noise (S/N) ratio to measure the quality characteristics deviating from the desired values Usually, there are three categories of quality characteristics in the analysis of the S/N ratio, i.e., the–lower–better, the–higher–better, and the–nominal–better. The S/N ratio for each level of process parameter is compared based on the S/N analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio Furthermore, a statistically significant with the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design.

There are 3Signal-to-Noise ratios of common interest for optimization of Static Problems. The formulae for signal to noise ratio are designed so that an experimenter can always select the largest factor level setting to optimize the quality characteristic of an experiment. Therefore a method of calculating the Signal-To-Noise ratio we had gone for quality characteristic. They are

1. Smaller-The-Better,
2. Larger-The-Better,
3. Nominal is Best.

5.1.1 SMALLER IS BETTER

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the smaller-is-better S/N ratio using base 10 log is:

$S/N = -10*\log(S (Y^2)/n)$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

5.1.2 LARGER IS BETTER

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the larger-is-better S/N ratio using base 10 log is:

$S/N = -10*\log(S(1/Y^2)/n)$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

5.1.3 NOMINAL IS BEST

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the nominal-is-best I S/N ratio using base 10 log is:

$S/N = -10*\log (s^2)$

Where s = standard deviation of the responses for all noise factors for the given factor level combination

5.2 DESIGN OF EXPERIMENT

Process parameters and their levels

Table 5.1 Process parameters and their levels

Levels	Process parameters		
	COMPOSITE (%)	SPEED (RPM)	LOAD (N)
1	5%	600	30
2	10%	900	45
3	15%	1200	60

5.2.1 MINITAB-17 SOFTWARE

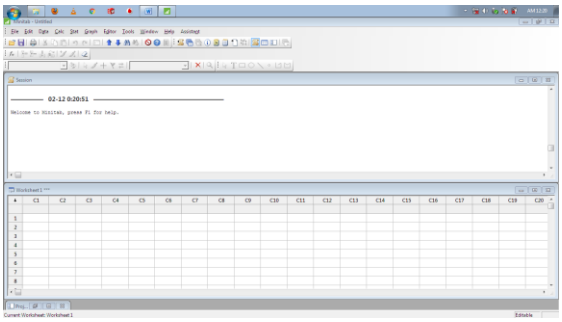

Figure 5.1 Minitab software

5.3 DESIGN OF ORTHOGONAL ARRAY

First Taguchi Orthogonal array is designed in minitab-16 to calculate S/N ratio and means which steps is given below.Create Taguchi Design is selected as shown in figure. Then a window of Taguchi design is opened.To start Minitab, click shortcut of Minitab on Desktop of computer. A window is opened in computer as shown in Figure,

5.4 AN ORTHOGONAL ARRAY L9 FORMATION (INTERACTION)

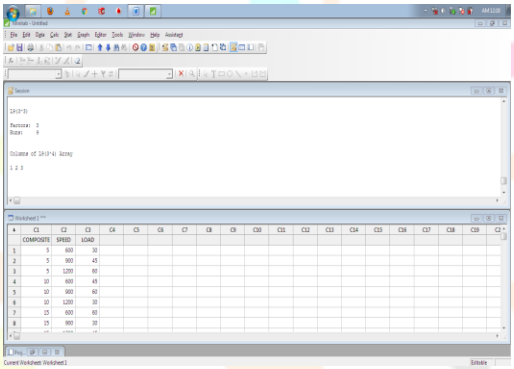

Figure 5.2 Create Taguchi Design

Table 5.2 L9 Array formation

COMPOSITE	SPEED RPM)	LOAD N)
5	600	30
5	900	45
5	1200	60
10	600	45
10	900	60
10	1200	30
15	600	60
15	900	30
15	1200	45

VI.RESULTS AND DISCUSSIONS

6.1. WEAR RESULT FOR ANNOVA AND TAGUCHI METHODS

In a dynamic response design, the quality characteristic operates along a range of values and the goal is to improve the relationship between a signal factor and an output response. For example, the amount of deceleration is a measure of brake performance. The signal factor is the degree of depression on the brake pedal. As the driver pushes down on the brake pedal, deceleration increases. The degree of pedal depression has a significant effect on deceleration. Because no optimal setting for pedal depression exists, it is not logical to test it as a control factor. Instead, engineers want to design a brake system that produces the most efficient and least variable amount of deceleration through the range of brake pedal depression. Return to top Conduct a Taguchi designed experiment conducting a Taguchi designed experiment can have the following steps:

- Before you start using Minitab, you need to choose control factors for the inner array and noise factors for the outer array. Control factors are factors you can control to optimize the process. Noise factors are factors that can affect the performance of a system but are

not in control during the intended use of the product. Engineering knowledge should guide the selection of control factors and responses. You should also scale control factors and responses so that interactions are unlikely. When interactions between control factors are likely or not well understood, you should choose a design that is capable of estimating those interactions. Minitab can help you design a Taguchi experiment that does not confound interactions of interest with each other or with main effects. Noise factors for the outer array should also be carefully selected and might require preliminary experimentation.

- The noise levels selected should represent the range of conditions under which the response variable should remain robust.
  Note: While you cannot control noise factors during the process or product use, you need to be able to control noise factors for experimentation purposes.
- Go to **Stat > DOE > Taguchi > Create Taguchi Design** to generate a Taguchi design (orthogonal array). Each column in the orthogonal array represents a specific factor with two or more levels. Each row represents a run; the cell values identify the factor settings for the run. By default, Minitab's orthogonal array designs use the integers 1, 2, 3, to represent factor levels. If you enter factor levels, the integers 1, 2, 3, will be the coded levels for the design.
- You can also use **Stat > DOE > Taguchi > Define Custom Taguchi Design** to create a design from data that you already have in the worksheet. Define Custom Taguchi Design lets you specify which columns are your factors and signal factors. You can then easily analyze the design and generate plots.
- After you create the design, you can use **Stat > DOE > Modify Design** to rename the factors, change the factor levels, add a signal factor to a static design, ignore an existing signal factor (treat the design as static), and add new levels to an existing signal factor.
- After you create the design, you can use **Stat > DOE > Display Design** to change the units (coded or un-coded) in which Minitab expresses the factors in the worksheet.
- Use **Stat > DOE > Taguchi > Analyze Taguchi Design** to analyze the experimental data. You should analyze each response variable separately with Taguchi designs. Although Taguchi analysis accepts multiple response columns, these responses should be the same variable measured under different noise factor conditions.
- Use **Stat > DOE > Taguchi > Predict Taguchi Results** to predict signal to noise ratios and response characteristics for selected new factor settings. Finally gets the graph is wear rate Vs speeds, loads and composite percentages

The result is given below in the orders of

1. Response Tables for Means
2. Main Effects Plot for Means
3. Interaction Plot - Data Means for Wear Rate
4. Main Effects Plot for S/R Ratio
5. Comparison of Wear rate for L9 series with SNRA1 AND MEAN1

6.2. HARDNESS TEST

The hardness of the 2024 Aluminium Alloy Reinforced with Silicon Carbide in 5%, 10%, and 15%specimen were carried out. In this test the 2024 Aluminium Alloy samples of the size 40 mm length and 18 mm diameter were applied a load of 1000kg for 5 to 10 sec. The values are calculated as shown in figure 2024 Aluminium Alloy specimen with different treated conditions used for measuring hardness.

TABLE: 6.1. HARDNESS TEST RESULT

EQUIPMENT USED : METALLURGICAL MICROSCOPE- METSCOPE-1A	
COMPOSITE(2024 ALUMINIUM REINFORCED SILICON CARBIDE)	**HVI KG**
SAMPLE 5%	120
SAMPLE 10%	138
SAMPLE 15%	12

6.3. ULTIMATE TENSILE STRENGTH

The Ultimate Tensile Strength of the 2024 Aluminium Alloy Reinforced with Silicon Carbide in 5%, 10%, and 15%specimen were carried out. In this test the 2024 Aluminium Alloy samples of the size 40 mm length and 18 mm diameter were applied a load of 1000kg for 5 to 10 sec. The values are calculated as shown in figure 2024 Aluminium Alloy specimen with different treated conditions used for measuring ultimate tensile strength.

TABLE: 6.2. ULTIMATE TENSILE STRENGTH

EQUIPMENT USED :UTM.MAKE : FIE. MODEL UTN 40. SR NO: 11/98 – 2450.			
COMPOSITE (2024 ALUMINIUM REINFORCED SILICON CARBIDE)			
	5%	**10%**	**15%**
Tensile Strength In Mpa	221.45	229.7	246.57
Yield Stress In Mpa	426	447	477
Elongation	10.26 %	14.56 %	15.86%

6.4. ULTIMATE COMPRESSIVE STRENGT

The Ultimate Compressive Strength of the the 2024 Aluminium Alloy Reinforced with Silicon Carbide in 5%, 10%, and 15%specimen were carried out. In this test the 2024 Aluminium Alloy samples of the size 40 mm length and 18 mm diameter were applied a load of 1000kg for

5 to 10 sec. The values are calculated as shown in figure 2024 Aluminium Alloy specimen with different treated conditions used for measuring Compressive Strength.

TABLE: 6.3 COMPRESSIVE STRENGTH

EQUIPMENT USED : MODEL: UTE 60 M/C, SL.NO:6/20073672	
COMPOSITE(2024 ALUMINIUM REINFORCED (SILICON CARBIDE)	**Mpa**
SAMPLE 5%	370
SAMPLE 10%	383
SAMPLE 15%	398

6.5 PLAN OF EXPERIMENTS

Wear tests of the base alloy and the composite specimen where conducted under dry sliding condition for three parameters composite, sliding speed(rpm), and applied load(N).With the variation of five levels and the process parameter are shown in table 2 Experiments have planed based on of L_9 orthogonal array (OA)

Table 6.4 Experimental Design Using L9 OA

SL.NO	**Composite %**	**Speed Rpm**	**Load N**	**Wear rate**	**SNRA1**	**MEAN1**
1	5	600	30	0.0001303	77.7011	0.0001303
2	5	900	45	0.0001387	77.1585	0.0001387
3	5	1200	60	0.0001392	77.1272	0.0001392
4	10	600	45	0.0000955	80.3999	0.0000955
5	10	900	60	0.0000993	80.0610	0.0000993
6	10	1200	30	0.0001086	79.2834	0.0001086
7	**15**	**600**	**60**	**0.0000706**	**83.0239**	**0.0000706**
8	15	900	30	0.0000769	82.2815	0.0000769
9	15	1200	45	0.0000898	80.9345	0.0000898

6.6.WEAR RATE RESPONSE FOR EACH LEVEL OF THE PROCESS PARAMETER

Response Table for Signal to Noise Ratios

Table 6.5 Smaller is better

LEVEL	COMPOSITE	SPEED	LOAD
1	0.000136	0.000099	0.000105
2	0.000136	0.000136	0.000136
3	0.000079	0.000113	0.000103
Delta	0.000057	0.000014	0.000005
Rank	1	2	3

Table 6.6 Response Table for Standard Deviations

LEVEL	**COM**	**SPEED**	**LOAD**
1	77.33	80.37	79.76
2	79.91	79.83	79.83
3	82.08	79.12	80.07
Delta	4.75	1.26	0.57
Rank	1	2	3

Main Effects Plot for SN ratios

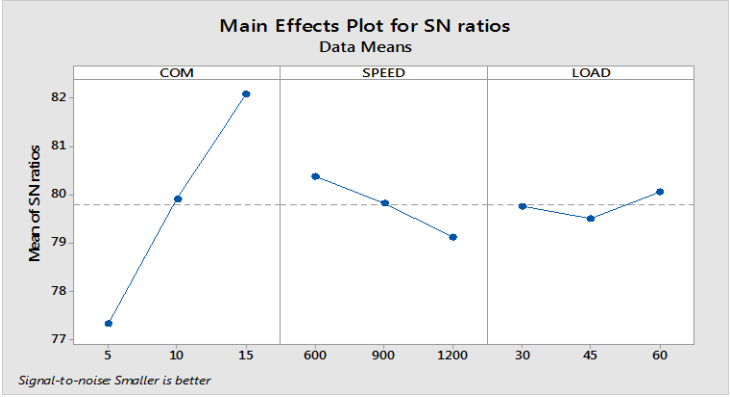

Figure 5.4 Main effects plot for SN ratios

Main Effects Plot for means

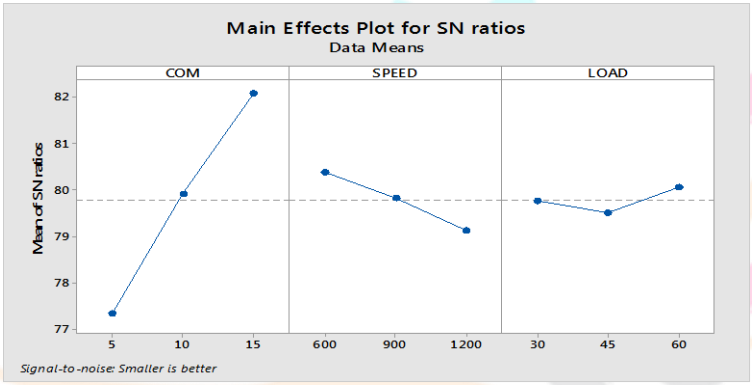

Figure 5.4 Main effects plot for means

6.7. SEM STRUCTURE FOR AFTER WEAR TEST

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample. 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. Areas ranging from approximately 1 cm to 5 microns in width can be imaged in a scanning mode using conventional SEM techniques (magnification ranging from 20X to approximately 30,000X, spatial resolution of 50 to 100 nm). The SEM is also capable of performing analyses of selected point locations on the sample; this approach is especially useful in qualitatively or semi-quantitatively determining chemical compositions (using EDS), crystalline structure, and crystal orientations (using EBSD).

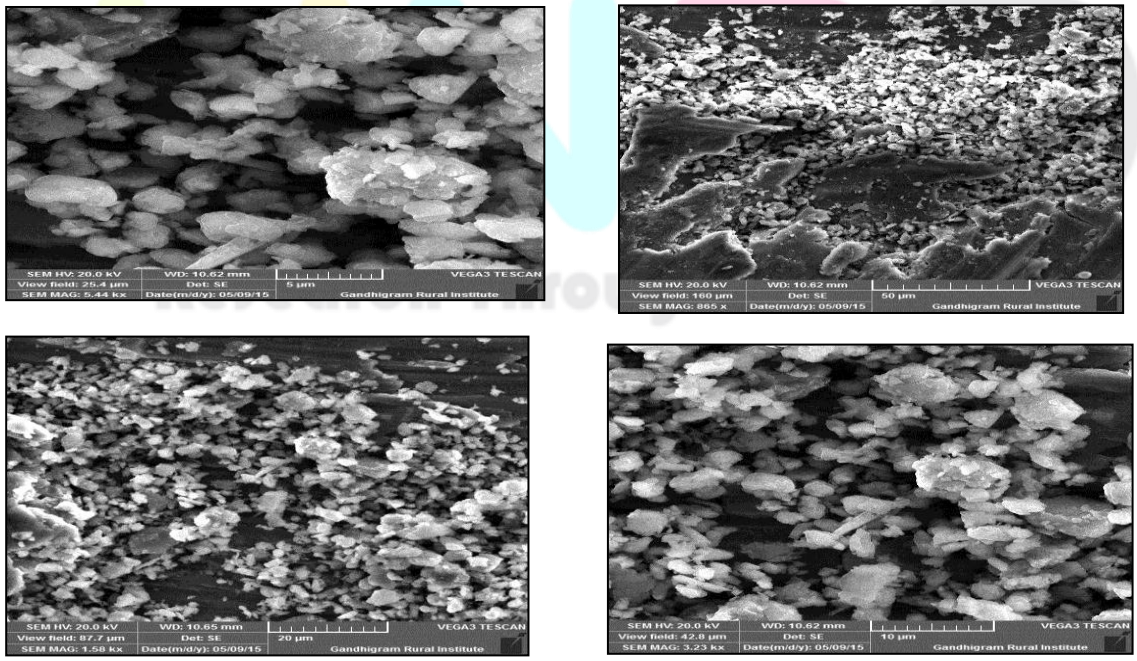

Fig6.5. SEM STRUCTURE 2024 ALUMINIUM ALLOY WITH SILICON CARBIDE 5% FOR AFTER WEAR TEST

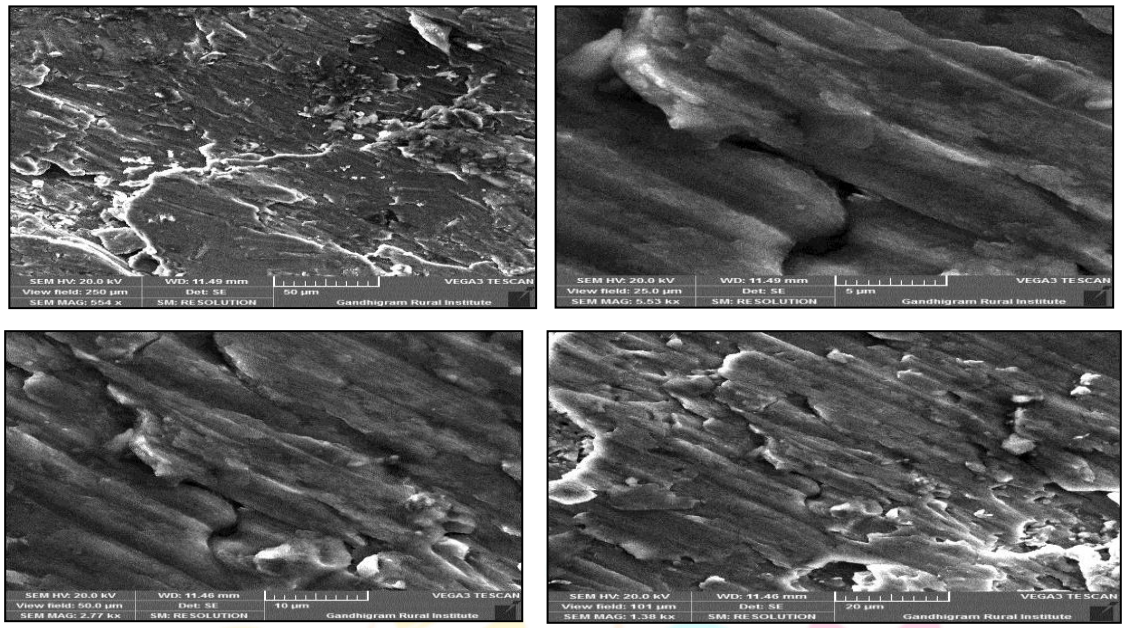

Fig6.6. SEM STRUCTURE 2024 ALUMINIUM ALLOY WITH SILICON CARBIDE IN 10 % FOR AFTER WEAR TEST

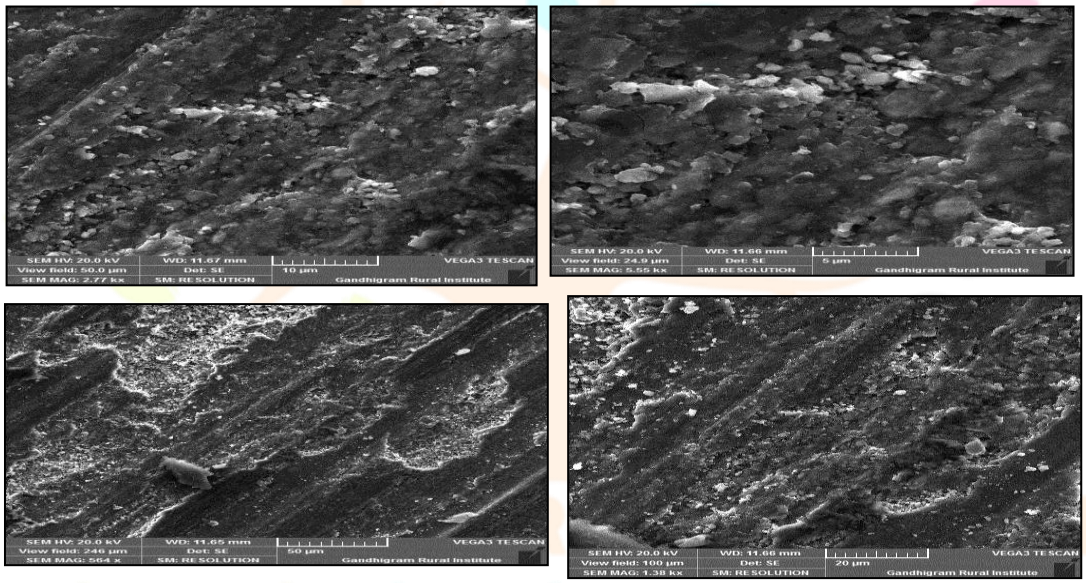

Fig6.7. SEM STRUCTURE 2024 ALUMINIUM ALLOY WITH SILICON CARBIDE IN 15% FOR AFTER WEAR TEST

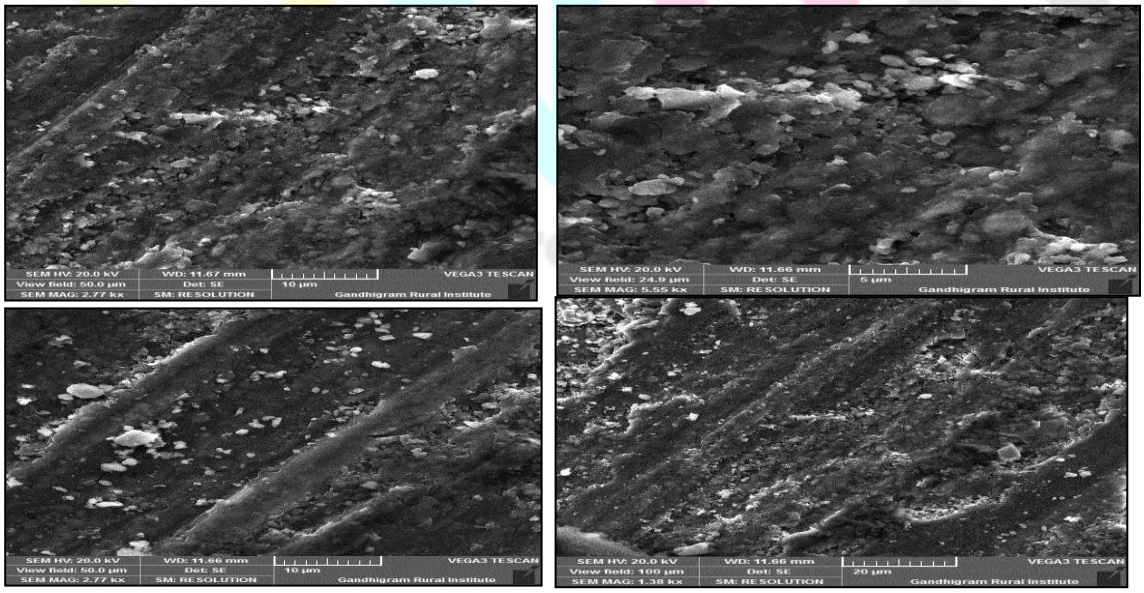

FIG6.8. SEM STRUCTURE ALUMINIUM LM24 REINFORCED WITH B4C, AND C IN 6% FOR AFTER WEAR TEST

VII.CONCLUSIONS

- ✓ Problem identified with the assistance of existing literatures
- ✓ Methodology selected
- ✓ Composite of different reinforcements with ratio were casted with the aid of stir casting
- ✓ The manufactured composites will be tested through Pin-on-desk test to find the effective tribological behaviour combination of composite based on different loads, speed and composite percentages.
- ✓ Gets the graph using ANOVA and Taguchi methods in MINITAB software. The graph is wear rate Vs load, speed and composite percentages.
- ✓ Checking wear rate in composites using SEM methods
- ✓ Finally, find is composite percentages is occurs minor wear rate.

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