

**“Mechanical Properties Investigation of
Aluminum Silicon Carbide Hybrid Metal Matrix
Composites (MMCs)”.**

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DHAWAL ALEXANDER

(ENROLMENT NO.1800103534)

Under the Supervision of

**Dr. M.S Khan
(Associate. Professor)**



**DEPARTMENT OF MECHANICAL ENGINEERING
INTEGRAL UNIVERSITY, LUCKNOW**

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INTEGRAL UNIVERSITY



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CERTIFICATE

Certified that **DHAWAL ALEXANDER** (enrollment no:1800103534.) has carried out the research work presented in this thesis entitled “**Mechanical Properties Investigation of Aluminium Silicon Carbide Hybrid Metal Matrix Composites (MMCs)**” for the award of **Master of Technology** from Integral University, Lucknow under my supervision. The project / thesis embodies results of original work, and studies are carried out by the student himself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

Signature

A handwritten signature in blue ink, appearing to read 'Dr. M.S Khan', is written on a grey rectangular background.

(Dr. M.S Khan)

(Associate Professor)

(Integral University, Lucknow)

Date:14/09/20

ABSTRACT

Metal Matrix Composites (MMCs) have shown great interest in recent times due to its potential of applications in aerospace and automotive industries because of having superior strength to weight ratio.

The wide use of particular metal matrix composites for engineering application has been obstructed by the exact use of silicon carbide (SiC) by % , hence high cost of components. Although there are several techniques used for casting technology rather it can be used to overcome this problem. Materials are frequently chosen for structural applications because they have desirable combinations of mechanical characteristics. Development of hybrid metal matrix composites has become important area of research interest in Material Science . In view of this , the present study focuses on the behaviour of aluminium silicon carbide (AlSiC) hybrid metal matrix composites .The present study was aimed at evaluating the mechanical properties of Aluminium in the presence of silicon carbide with different weight percentage of silicon carbide (5%,10%,15% & 20%) combinations. Consequently Aluminium metal matrix composite combines and exhibits huge strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material . The compositions were added up to the ultimate level and stir casting method was used for the fabrication of aluminium metal matrix composites . To investigate the properties of AlSiC, Experiments have been conducted by varying weight fraction of SiC (5%,10%,15% & 20%) While keeping all other parameters constant .The results indicate the behavior and properties of material is quite successful to obtain exact use of aluminium silicon carbide metal matrix composites according to the requirement.

Keywords: Mechanical properties investigation of Aluminium silicon carbide metal matrix composites (MMC)

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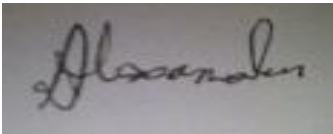
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Enrollment no: 1800103534



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LIST OF SYMBOLS

Symbols are used for two different parameter, however , the explanation in the text and the context in which the symbols are will make the meaning of all symbol explicit. Some other symbols are used in some cases. In some cases the symbols used in text and their meaning is clearly expalined within the text.

Symbol	Description
A	Cross Sectional Area
A_s	Surface area
I_p	Polar moment of inertia
H	Height of the beam
W	Width of the beam
G	Shear modulus
E	Young's modulus
N	Newton
L	Original Length
L'	Final Length
M	Meter

SYMBOL	Description
P	Load
ρ	Density
ν	Poisson's ratio
θ	Angle of twist
T	Torque applied
m	Mass
v	Volume
g	Gram
e	Engineering strain
C	Modulus of rigidity
q	Shear stress
r	radius

ABBREVIATIONS

Al	Aluminium
AlSiC	Aluminium Silicon Carbide
Al ₂ O ₃	Aluminium Oxide
BHN	Brennel hardness number
Cu	Copper
CuMo	Copper Molybdenum
CuW	Copper Tungsten
EDM	Electric Discharge Machine
EDX	Energy Dispersive X-ray
IGBT	Insulated Gate Bipolar Transistor
LED	Light Emitting Diode
MMC	Metal Removal Rate
PM	Powder Metallurgy
SiC	Silicon Carbide
SEM	Scanning Electron Microscope
TEM	Transmission Electron Microscopy

UTM	Universal testing machine
UTS	Ultimate tensile strength
WEDM	Wire Electric Discharge Machine
XRD	X-ray Diffraction

CHAPTER - 1

INTRODUCTION

CHAPTER – 1

INTRODUCTION

Aluminium silicon carbide metal matrix composites are combinations of two or more materials. They are made by combining two or more materials in such a way that the resulting materials have certain design properties or improved properties. Aluminium silicon carbide alloy composite materials are widely used in applications like engineering structures, industry and electronic applications, sporting goods etc. The properties of aluminium metal matrix composite mostly depend on the processing method which is capable of producing good properties to meet the industrial need. AlSiC composites can be easily produced by the stir casting technique due to its good cast ability and relatively inexpensive. The stir casting method is economical as well as easy to apply and convenient for mass production. However, the problem encountered for this technique is low wet ability and particle settling but for improving wet ability and particle homogeneity during casting, various methods have been used including coating and oxidizing the reinforcement particles, adding some surface active elements (magnesium, silicon carbide and lithium) into the matrix. Increasing the temperature and stirring of molten matrix composites for an adequate time period during incorporation. Study of wear properties of AlSiC composite is found that wear rate decreases linearly with increase of SiC content. Mechanical characterization of Al-SiC composite like hardness, impact strength and material toughness were evaluated. With the improved value of coefficient of thermal expansion of Aluminium composite is one of the reasons they are widely used by electronic industries and it has been found that the particles reinforcement of Aluminium matrix composites can improve considerably the strength and hardness of aluminium and its alloys. But, at the same time, the plasticity and ductility can substantially be reduced. This will severely affect the safety and reliability of components fabrication from Aluminium matrix composites (AMCs). Mechanical characterization of Aluminium silicon carbide mass fraction of SiC (5%, 10%, 15% and 20%) with Aluminium. Mechanical and Corrosion behaviour of Aluminium Silicon Carbide alloys suitable for spur gear. This paper analyses the tensile strength, impact strength, shear strength and bending strength of Al-SiC. The development of stress and strain fields in the MMC was analyzed and the mechanical properties like

ultimate torsion strength , hardness and ultimate tensile strength of matrix material were explored . It was found that tool particle interaction and stress , strain distribution in the particles of matrix are responsible for particle debonding , surface damage and tool wear during machining MMC.

1.1 ALUMINIUM

Aluminium is a metallic element which is represented by symbol Al , having atomic number 13 and melting point is 660.3°C. It is a silvery –white , soft , nonmagnetic, ductile metal . Aluminium is the third most abundant element after oxygen and silicon in the Earth's crust . It is about 8% by weight of the crust, though it is less common in the mantle below . Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments . Instead of this it is found to be combined with over 270 different minerals . The chief ore of aluminium is bauxite.

Aluminium is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation . Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials . The most useful compound of aluminium where least weight is required and can be combined to make oxides and sulphates .

1.2 Physical Characteristics

Aluminium is a relatively soft , durable , lightweight ,ductile and malleable metal with appearance ranging from silvery to dull gray , depending on the surface roughness . It is nonmagnetic and does not easily ignite . A fresh film of aluminium serves as a good reflector of visible light and an excellent reflector of medium and far infrared radiation,The yield strength of pure aluminium is 7-11 Mpa, while aluminium alloys have yield strengths ranging from 200 – 600 Mpa . Aluminium has about one-third the density and stiffness of steel .It is easily machined ,cast ,drawn and extruded.

Aluminium atoms are arranged in a face centered cubic (FCC) structure. Aluminium is a good thermal and electrical conductor, having 59% the conductivity of copper, both thermal and electrical, while having only 30% of copper's density. Aluminium is capable of being a superconductor, with a superconducting critical temperature of 1.2 kelvin and a critical magnetic field of about 100 gauss (10 milli teslas).

1.3 Chemical Characteristics

Corrosion resistance can be excellent due to a thin surface layer of aluminium oxide that forms when the metal is exposed to air to prevent further oxidation. The strongest aluminium alloys are less corrosion resistant due to galvanic reaction with alloyed copper. This corrosion resistance is also often greatly reduced by aqueous salts in the presence of dissimilar metals.

In highly acidic solutions aluminium reacts with water to form hydrogen and in highly alkaline to form aluminates which protect passivation. Chlorides such as common sodium chloride are well known source of corrosion of aluminium and are among the main reason that household plumbing is never made from this metal.

However its resistance to corrosion generally aluminium is one of the few metals that retains silvery reflectance in finely powdered form, making it an important component of silver colored paints. Aluminium mirror finish has the highest reflectance of any metal in the 200-400 nm (UV) and the 3,000 – 10,000 nm. Aluminium is oxidized by water at temperatures below 280 °C to produce hydrogen, aluminium hydroxide and heat.

1.4 Advantages of Aluminium

physically, chemically and mechanically aluminium is a metal steel, brass, copper, zinc, lead or titanium and silicon. It can be melted, cast, formed and machined much like these metals and it conducts electric current. In fact the same equipment and fabrication methods are used as for steel.

1.4.1 Light Weight

Aluminium is a very light metal with a specific weight of 2.7 g/cm^3 , about a third that of steel. For example, the use of aluminium in vehicles reduces dead weight and energy consumption while increasing load capacity. Its strength can be adapted to the application required by modifying the composition of its alloys.

1.4.2 Corrosion Resistance

Aluminium naturally regenerates a protective oxide coating and is highly corrosion resistant. Different types of surface treatment such as anodizing, painting or lacquering can further improve this property. It is particularly useful for applications where protection and conservation are required.

1.4.3 Electrical and Thermal Conductivity

Aluminium is an excellent heat and electricity conductor and in relation to its weight. It is almost twice as good as thermal and electrical conductor as copper. This has made aluminium the most commonly used material in major power transmission lines.

1.4.4 Reflectivity

Aluminium is a good reflector of visible light as well as heat, and that together with its low weight makes it an ideal material for reflectors in, for example, light fittings or rescue blankets.

1.4.5 Ductility

Aluminium is ductile and has a low melting point and density. In a molten condition it can be processed in a number of ways. Its ductility allows products of aluminium to be basically formed close to the end of the product's design.

1.4.6 Impermeable and odourless

Aluminium foil can be rolled up to .007 mm thickness even then it is still completely impermeable and neither light, aroma nor taste or substances come out of the rolled foil. The metal itself is non-toxic and releases no aroma or taste.

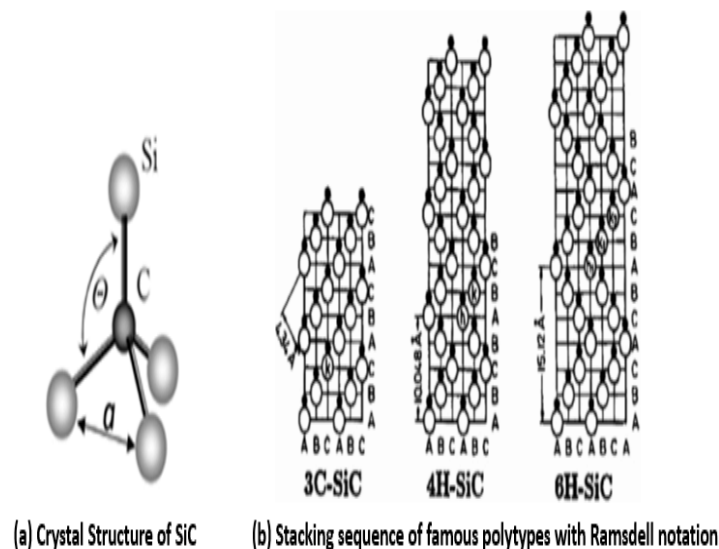
1.4.7 Recyclability

Aluminium is 100 percent recyclable with no downgrading of its qualities. The re-melting of aluminium requires little energy. Only about 5 percent of the energy required to produce the primary metal initially is needed in the recycling process.

1.5 Silicon Carbide (SiC)

Silicon carbide (SiC) also known as carborundum a compound of silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissanite. Silicon carbide powder has been mass produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. Electronic applications of silicon carbide as light-emitting diodes (LEDs) and detectors in early radios were first demonstrated around 1907. Today SiC is used in semiconductor electronics applications that are high temperature, high-voltage or both. Large single crystals of silicon carbide can be grown by the Lely method: they can be cut into gems known as synthetic moissanite. Silicon carbide with high surface area can be produced from SiO₂ contained in plant material, exceedingly hard, synthetically produced crystalline compound of silicon and carbon. Its chemical formula is SiC. Since the late 19th century silicon carbide has been an important material for sandpaper, grinding wheels, and cutting tools. More recently, it has found application in refractory linings and heating elements for industrial furnaces, in wear-resistant parts for pumps and rocket engines, and in semiconducting substrates for light emitting diodes.

1.5.1 Structure



Silicon carbide exists in about 250 crystalline forms. The polymorphism of SiC is characterised by a large family of crystalline structures called polytypes. They are variations of the same chemical compound that are identical in two dimensions and differ in the third. Thus, they can be viewed as layers stacked in a certain sequence.

Alpha silicon carbide (α -SiC) is the most commonly encountered polymorph, it is formed at temperature greater than 1700 °C and has a hexagonal crystal structure. The beta modification (β -SiC), with a zinc blende crystal structure similar to diamond, is formed at temperatures below 1700 °C. The beta form has few commercial uses, although there is now increasing interest in its use as a support for heterogeneous catalysts, because of its higher surface area compared to the alpha form. Pure SiC is colorless. The brown to black color of industrial product results from iron impurities. The rainbow like luster of the crystals is caused by a layer of silicon dioxide that forms on the surface.

The high sublimation temperature of SiC (approximately 2700 °C) makes it useful for bearings and furnace parts. Silicon carbide does not melt at any known pressure. It is also highly inert chemically. There is currently much interest in its use as a semiconductor material in electronics, where its high thermal conductivity, high electric field breakdown strength and high maximum current density make it more promising than silicon for high powered devices. SiC also has a very low coefficient of thermal expansion ($4 \times 10^{-6}/\text{K}$) and experiences no phase transitions that would cause discontinuities in thermal expansion.

1.5.2 Properties

- Low density
- High strength
- High thermal expansion
- High hardness
- High elastic modulus
- Excellent thermal shock resistance
- Superior chemical inertness

1.5.3 Applications

- Abrasives and cutting tools
- Structural material
- Automobile parts
- Electrical systems
- Electronic circuit elements
- LEDs
- Astronomical telescopes
- Heating elements
- Steel production
- Nuclear fuel particles
- Catalyst supporter

1.6 ALUMINIUM ALLOYS

Selecting the right alloy for a given application entails considerations of its tensile strength, density, ductility, formability, workability, weld ability and corrosion resistance. Aluminium alloys are alloys in which aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminium is used for wrought product, for example rolled plate, foils and extrusions. Cast aluminium alloy yields cost effective products due to its low melting point, although they generally have lower tensile strength than wrought alloys. The most important cast aluminium alloy system is Al-Si, where the high levels of silicon (4.0% to 13%) contribute to give good casting characteristics. Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required.

Wrought aluminium alloys are used in the shaping processes: rolling, forging, extrusion, pressing, stamping. Cast aluminium alloys come after sand casting, permanent mould casting, die casting, investment casting, centrifugal casting,

squeeze casting and continuous casting .



Fig 2 Aluminium Alloy

Table.1 Designation for wrought Aluminium alloys

Alloying Elements	Designations
None (99%+ Aluminium)	1XXX
Copper	2XXX
Manganese	3XXX
Silicon	4XXX
Magnesium	5XXX
Magnesium + Silicon	6XXX
Zinc	7XXX
Lithium	8XXX

Source :- Dieter,G.E.(1998),Mechanical Metallurgy, S.I. Metric , Ed.,p.358. Mcgraw Hill, Singapore.

1.7 Metal Matrix Composites

A metal matrix composite (MMC) is composite material with a least two constituent parts, one being a metal necessarily and the other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite. An MMC is complementary to a cermet. Metal composite materials have found application in many areas of daily life for quite some time. Often it is not realized that the application makes use of composite materials. These materials can be produced in every situation from the conventional production and processing of metals. Here, the Dalmation sword with its meander structure, which results from welding two types of steel by repeated forging, can be mentioned. Materials like cast iron with graphite or steel with a high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials. For many researchers the term metal matrix composite is often equated with the term light metal matrix composites (LMCs). Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications. In traffic engineering, especially in the automobile industry, MMCs have been used commercially in fiber reinforced pistons and aluminium crank cases with strengthened cylinder surfaces as well as particle strengthened brake disks. These innovative materials open up unlimited possibilities for modern material science and development; the characteristic of MMCs can be designed into the material, custom-made, dependent on the application. From this potential, metal matrix composites fulfill all the desired conceptions of the designer. This material group becomes interesting for use as constructional and functional materials, if the property profile of conventional material either does not reach the increased standards of specific demands, or is the solution of the problem. However, the technology of MMCs is in competition with other modern materials technologies, for example powder metallurgy. The advantage of the composite material is only realized when there is a reasonable cost performance relationship in the component production. The use of a composite material is obligatory if a special property profile can only be achieved by application of these materials. The possibility of combining various material systems gives the opportunity for unlimited variation.

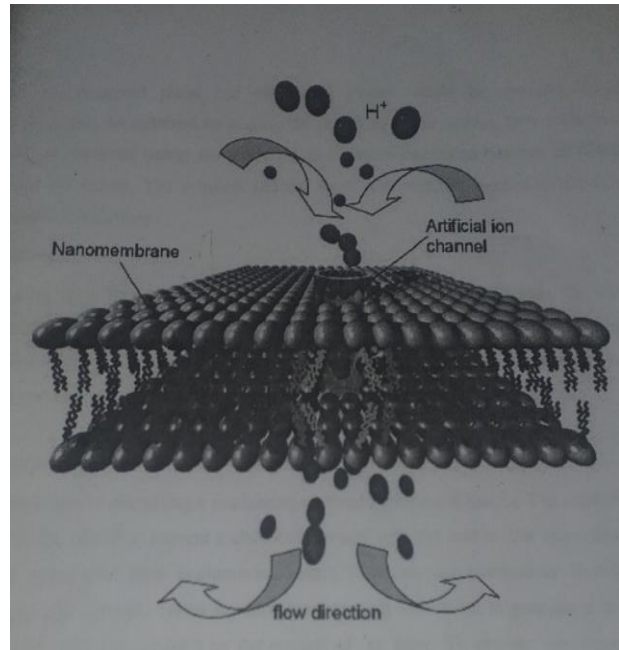
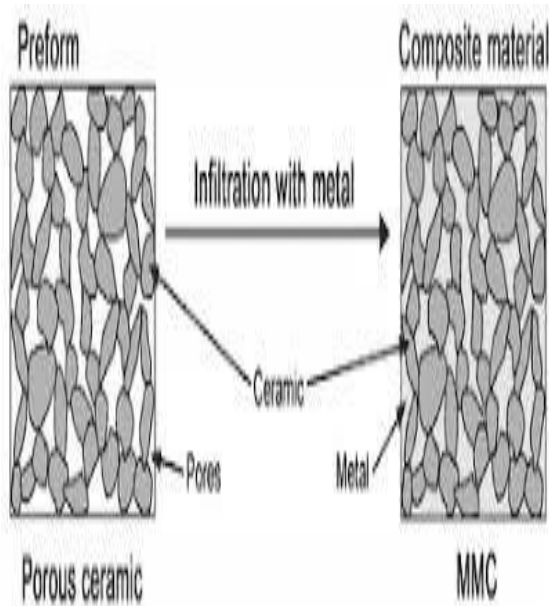


Fig.3 Formation of metal matrix composites

Source:- D.M. Skibo, D.M. Schuster, L.Jolla(1988),process for preparation of composite material containing nonmetallic particals in a metallic matrix , and composite materials made by, US patent No. 4 786 467.

1.7.1 Prepration of MMCs

There are several methods used for fabrication of MMCs ,but the most suitable process which is used in liquid phase technique.

Liquid Phase Technique

Liquid state fabrication of Metal Matrix Composite 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 it should have good interfacial bonding between the dispersed phase and the liquid matrix should be obtained . Bonding improvement may be achieved by coating the dispersed phase particles. 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.

Stir Casting

Stir casting is a liquid state method of composite material fabrication, in which a dispersed phase (ceramic particles) is mixed with the other molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies.

1.8 Composites

MMCs are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix. For example, carbon fibers are commonly used in aluminium matrix to synthesize composites showing low density and high strength. However, carbon reacts with aluminium to generate a brittle and water soluble compound Al_4C_3 on the surface of the fiber. To prevent this reaction, the carbon fibers are coated with nickel or titanium boride.



Fig 4 Composite material

1.9 Matrix

The matrix is the monolithic material into which the reinforcement is embedded and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications of matrix is usually a lighter metal such as aluminium, magnesium and titanium are used to provide support for the reinforcement. In high temperature application cobalt and cobalt-nickel alloy matrices are used commonly. The selection of suitable matrix alloys is mainly determined by the intended application of the composite material.

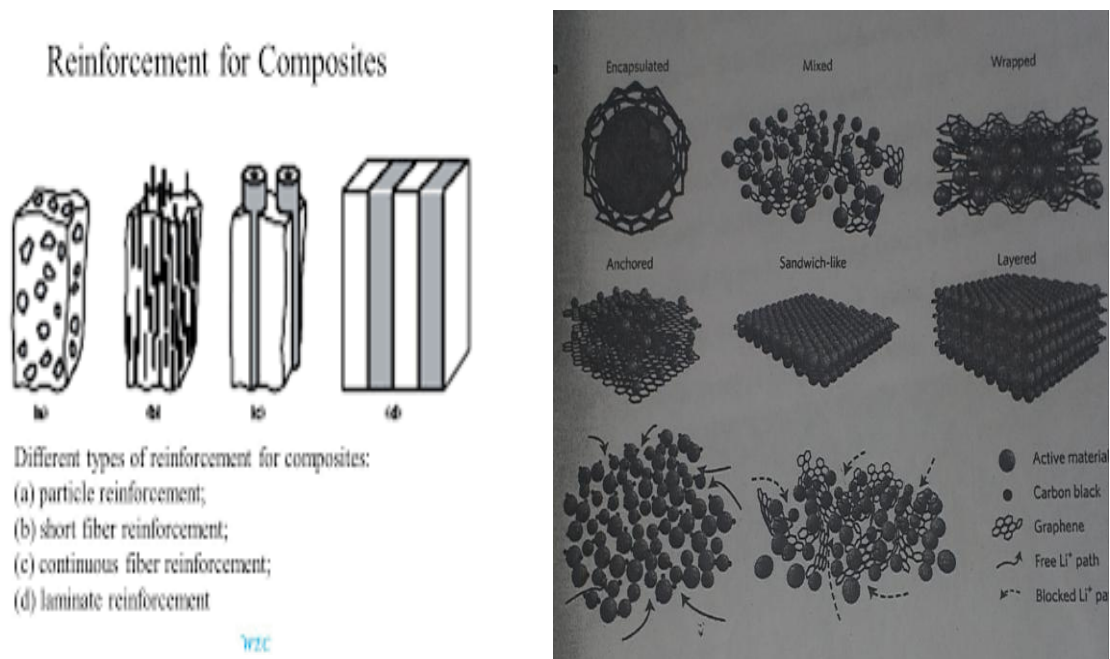


Fig.5 Formation of matrix

Source:- Singla, M.Chawla, V. Dwivedi, D.D. And Lakhvit, S.(2009) “Development of aluminium based SiC particulate metal matrix composite”, J. Miner. Matls Charac. Eng., 8(6),pp.455-467.

For the development of light metal composites material that are mostly easy to process, conventional light metal alloys are applied as matrix materials. Mainly aluminium alloys are used for light weight composites. The matrix is the monolithic material into which the reinforcement is embedded completely continuous. This means that there is a path through the matrix to any point in the material sandwiched together.

1.10 Reinforcement

The reinforcement material is embedded into a matrix . The reinforcement does not always serve a purely structural task (reinforcing the compound), or thermal conductivity . The reinforcement can be either continuous, or discontinuous. Discontinuous MMCs can be isotropic, and can be worked with standard metalworking techniques, such as extrusion, forging, or rolling . In addition , they may be machined using conventional techniques, but commonly would need the use of polycrystalline diamond tooling .

Continuous reinforcement used continuous filament wires or fibers such as carbon fiber or silicon carbide . Because the fibers are embedded into the matrix in a certain direction , the result is an anisotropic structure in which the alignment of the material affects its strength . One of the first MMCs used boron filament as reinforcement . Discontinuous reinforcement uses whiskers, short fibers or particles. The most common reinforcing material in this category are alumina and silicon carbide.

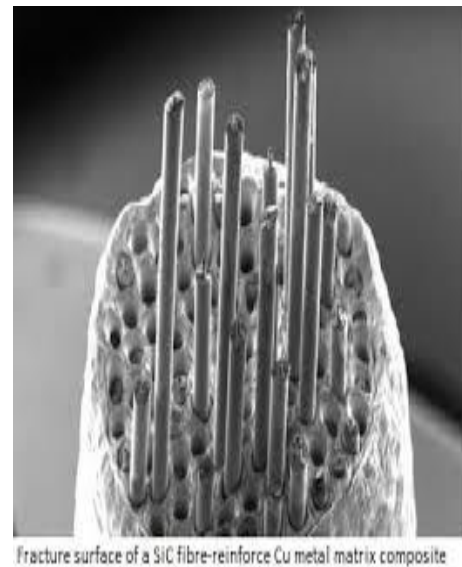
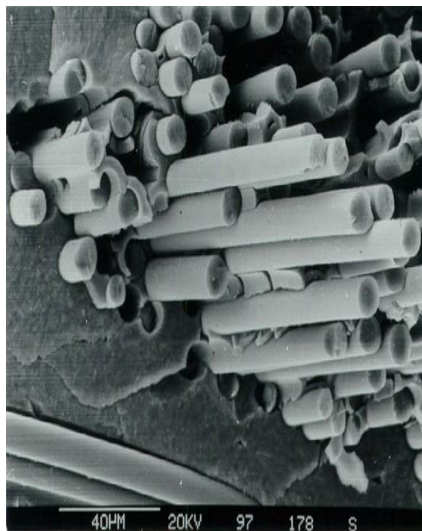


Fig.6 Reinforcement

Source:- Lucas , J.P. Stephens, J.J.and Greulich, F.A. (1991), “the reinforcement of compistion redistribubtion in cast aluminium metal matrix composites”, Materials Science and Engineering , Vol . 131 (2), pp. 221-230

1.11 Aluminium silicon Carbide (AlSiC)

AlSiC is a metal matrix composite consisting of aluminium matrix with silicon carbide particles. It has high thermal conductivity (180-200 W/m K) and isothermal can be adjusted to match other materials like silicon and gallium, arsenide chips and various ceramics. It is chiefly used in microelectronics as substrate for power and high density multi-chip modules, where it aids with removal of waste heat. AlSiC composites are suitable replacements for copper-molybdenum (CuMo) and copper tungsten (CuW) alloys. They have about 1/3 the weight of copper, 1/5 of CuMo and 1/6 of CuW which makes them suitable for weight sensitive application. They are also stronger and stiffer than copper. They are tough, light weight and strong.

AlSiC parts are typically manufactured by near net shape approach by creating a SiC performed by metal injection molding of SiC binder slurry is fired to remove the binder then infiltrated under pressure with molten aluminium. The material is fully densified without voids and is hermetic. High stiffness and low density appears making larger parts with thin wall and manufacturing large fins of heat dissipation. AlSiC can be plated with nickel and nickel – gold or by other metals by thermal spraying. Ceramic and metal insets can be inserted into the preform before aluminium infiltration results in a hermetic seal.

AlSiC can also be prepared by mechanical alloying. When lower degree of SiC contents are used parts can be stamped from AlSiC sheets.

The aluminium matrix contains high amount of dislocations responsible for the strength of the material. The dislocations are appeared during cooling of the SiC particles due to their different thermal expansion coefficient. A similar material is Dymalloy with copper-silver alloy instead of aluminium and diamond instead of silicon carbide. Other materials are copper reinforced with carbon fiber, diamond reinforced with aluminium and pyrolytic graphite with silicon

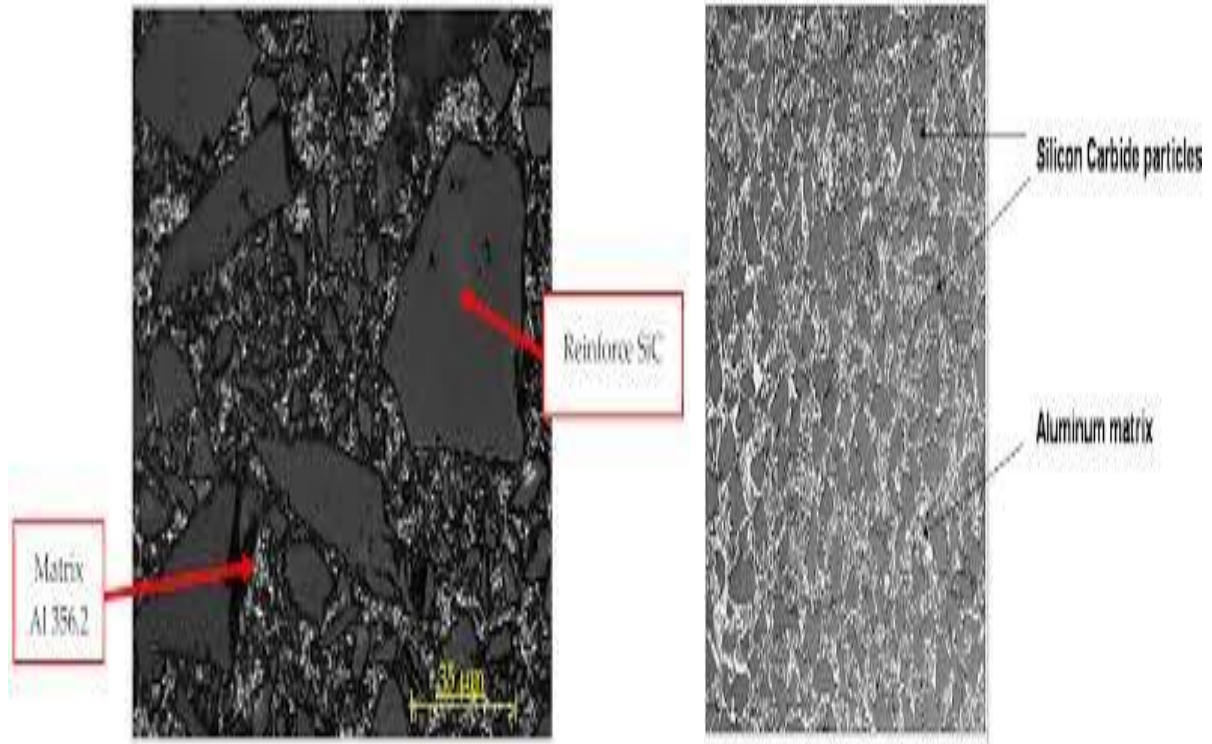


Fig.7 Microscopic view of AlSiC

Source :- Nesarikar, A.R. Tiwari, S.N and Graham, E.E (1993),”Al₂O₃- particle-reinforced aluminium alloy composite”,Materials Science and Engineering A ,Vol . 147 (2), pp. 191-199.

Silicon can be added to aluminium alloys in quantities sufficient to cause a substantial lowering of the melting point . For this reason this alloy system is used entirely for welding wire and brazing filler alloys are non heat treatable but in general they pick up enough of the alloy constituents of the parent metal to respond to a limited degree of heat treatment.

1.11.1 Properties

- Low density
- High strength
- Low thermal expansion
- High thermal conductivity
- High hardness
- High elastic modulus
- Excellent thermal shock resistance
- Superior chemical inertness

1.12 Objective of Research Work

1. To prepare the sample of metal matrix composite of Aluminium and Silicon Carbide of different compositions.
2. To study the properties of Aluminium Silicon Carbide metal matrix composites for different composition of SiC.
3. To test the sample of Aluminium Silicon carbide metal matrix composites to evaluate the modulus of rigidity.

CHAPTER-2
REVIEW OF LITERATURE

CHAPTER-2

REVIEW OF LITERATURE

This chapter presents a review of the literature data available on the effect of various reinforcement types, their sizes and volume fraction, ageing behavior with Al based MMC's. Metal matrices composites are a combination of two phases, matrix and the reinforcement. Matrices can be selected from a number of Aluminum alloys e.g. AA 2000, 6000, 7000, A356 and many reinforcement types SiC, Al₂O₃, AlN and cobalt etc. are available in different sizes, morphologies (particulates, short fibers and platelets) and volume fraction. These reinforcement can be combined with the different matrices, resulting in large composite systems. Furthermore, several different processing routes, such as powder metallurgy, stir casting; squeeze casting, hot extrusion etc.

Ramula and Taya et .al (1989) has presented paper on Al / SiCw / 15 and 25% one fractionate a- time experiments MRR, increased with % of reinforcement, surface was soften and absence of SiCw on it. They found that MRR increased with an increase in power. The MRR obtained with brass electrode was greater compared to that with copper electrode. Micro hardness variations in the 25% reinforcement MMC was significantly varied with the process parameters. The surface was soften and indicates absence of ceramic reinforcement on the surface.

Roux et al. (1993) has observed that Al/SiCp is one of the best light weight and having good strength proved by experiments recast layer with protruding ceramic particles and blow holes were observed, recast layer thickness increased with current.

Poon and Lee (1993) has studied the effect of various process parameters in EDM of Al/SiCp composites. MRR was found to be higher with low percentage of reinforcement. It has reported that relative tool wear was also increased with the increase in discharge current and reduced percentage of ceramic reinforcement. The surface finish was found to be better at lower values of discharge currents. It has found that copper was most suitable tool materials among the used tools such as graphite and tungsten copper. Besides, positive polarity was found to be associated with better performance in all respects.

Hung et al. (1994) has studied the effect of four two-level factors in electro-discharge machining of Al/SiCp/10% and 20% MMCs. It has found that fine grains of aluminum were present in the recast layer due to rapid cooling. The sub-surface was found to be softened .Higher percentage of ceramic particles contributed to low MRR. Discharge current was found to be the only significant factor for surface finish. Tool damaging was 28 found due to abnormal arcing. There was no provision of electrode reciprocation in this study.

Felloni et al. (1994) has studied into wire electro-discharge machining of Al/SiCp/25% MMC. The cutting rates in machining of unreinforced alloy were found to be higher than the composite materials. However, surface finish of MMC was better than the aluminum alloy. No significant micro hardness variations and

heat affected zone were found. Besides, recast layer up to 20 μm was found to be present. Monno et al. (1994) found the need of more discharge current in machining of Al/SiC composites than that required for unreinforced alloy. Kerf and surface finish of MMCs were found to be superior to that of unreinforced alloy.

D.J Lloyd (1994) has primarily been concerned with the factors influencing the micro structural, mechanical properties relationship of composites shows the effect of different reinforcement. In this author study different reinforcement effect on different alloy are considered. Conclusions of this paper are elongation of composites decreases as increases percentage of reinforcement and tensile strength are increase.

Lau et al. (1995) has found wire electro-discharge machining of metal matrix composites difficult due to frequent wire breakages. It has been concluded that this material is possibly machined by WEDM of Al/Al₂O₃ composites using one factor at a time experiments. Surface finish of MMC was found to be poor than the unreinforced alloy under fine machining conditions. Further, the values of surface roughness were found to be unchanged under fine and rough mode of machining in MMCs. Wire shifting was evident and resulted into banding marks on the machined surfaces.

Yue et al. (1996) have studied in WEDM of Al/Al₂O₃ composites using one factor at a time experiments. Surface finish of MMC was found to be poor than the unreinforced alloy under fine machining conditions. The sizes of particles were found to be significant in banding and surface finish. The fiber reinforced composites were found to be machined to a better surface finish compared to particle reinforced MMC.

Hocheng et al.(1997) have done the fundamental analysis of EDM of SiC/Al metal matrix composite. The material removal rate was found to be proportional to the applied current and the on -time. The crater size was larger in single discharge. The MRR was thus higher at the beginning and was retarded afterwards. This may be because of shielding of the molten metal due to the SiC particles as observed in the earlier studies. Due to this he has recommended high current and short on time as a good combination for EDM of SiC/Al composites.

Gatto and Iuliano (1998) have worked on wire EDM of metal matrix composites. They especially studied the surface features of the wire EDMed machined composites. In this study, two composites viz. 15% SiCw/Al alloy and 20% SiCp/Al alloy were compared. It has been found that the cutting rate in both these cases were almost same which does not agree with the previous work by Ramulu and Taya. The surface roughness values of the wire EDM machined surfaces of the SiC particle reinforced composites were slightly greater than those of the composite reinforced with SiC whiskers. The surface roughness was greater in both the cases was greater in roughing conditions than those in finishing conditions. The roughness value of the 20% SiCp/ Al alloy composite wire EDMed machined surfaces and then glass bead peened were less than the corresponding values for the 15% SiCw/Al alloy composite. Cracks on the machined surfaces were not observed. There was no evidence of the SiC reinforcement on the machined surface up to certain depth of the layer. This made the layer softer than that of the composite material. Hence to reduce the depth of this 30 outer layer without SiC reinforcement the low current and short pulse on time were suggested so that it could be under 5 μm . the glass bead peening caused the disappearance of the soft layer.

Yan and Wang et al. (1999) has used rotary EDM with a hollow tube electrode to drill $\text{Al}_2\text{O}_3/6061$ Al composite. It was found that rotary EDM gives higher cutting feed rate than that of stationary modes. This was due to the superior debris-disposal effect of the rotating electrode. This is attributed to the combined effect of injection pressure and the centrifugal force due to rotation. The electrode wear and surface roughness were higher than that of stationary electrodes. The peak current and volume fraction have shown significant effect on the material removal rate, electrode wear rate and the surface roughness. The rotating speed and the flushing pressure had shown minor effect as compared to the effect of peak current and volume fraction of the reinforcement. The important finding was that the time required for deionization of the dielectric after the spark was high as compared to other conventional materials like steel, which implies unstable wave form. This may be attributed to the presence of insulating particles may suppress resistivity and hence prolonged de-ionization duration or decrease in the discharge frequency.

Hashim J, Looney L et al. (1999) has presented their paper on metal matrix composites Production by the stir casting Method in Journal of Material Processing and Technology. They develop an easiest method to make metal matrix composites which was very helpful and reduced the cost of manufacturing.

Daniel B. Miracle (2000) has researched on the behavior of different compositions of AlSiC. In Air Force Research Laboratory he studied 6092/SiC/17.5p & 2009/SiC/15p-T4 for F16 aircraft Door and body purposes. It can be observed that the densities of composites are higher than that of their base matrix, further the density increases with increased percentage of filler content in the composites.

I.A Ibrahim, F. A Mohamed, E. J. Lavernia et al. (2001) has studied the mechanical properties that can be obtained with metal matrix composites by varying reinforcement percentage by 5%, 10%, 15%, 20% and taking different alloy AA 6061, AA 2014, AA 356. Conclusion of this paper is by increasing reinforcement % age yield strength, ultimate strength is increasing but elongation of an alloy decreases.

Rozenek et al. (2001) have worked on the wire electric discharge machining characteristics of metal matrix composites. In this study, SiC particulate aluminum alloy matrix composites as well as Al_2O_3 reinforced aluminum alloy matrix composites were machined by wire EDM. The effects of current, voltage, and pulse -on time much on the cutting speed and surface roughness were investigated. It has been shown that the cutting speed of unreinforced alloy is much greater than that of reinforced alloy. The effect of these parameters on surface roughness was as significant as it is in the EDM of the steel. The main finding of this work which does not agree with any other work in this area is the decrease in surface roughness with the increase in voltage.

P.K Rohtagi, J.K Kim, et al. (2002) has investigated the effect of aging characteristics of aluminum alloy A356 and an aluminum alloy.A356 containing hollow spherical fly ash particles were studied using optical microscopy, transmission electron microscopy (TEM), energy dispersive X-ray (EDX) spectroscopy, hardness tests, and compressive items. As the density of the composite is lower than that of the base alloy due to the presence of hollow particles, the composites have a higher specific strength and specific hardness compared to the matrix. Even though the hardness of the as-cast composite was higher than that of the base alloy, no significant change in the aging kinetics was observed, due to the presence of spherical fly ash particles in the matrix. Aging times of the order of 104 to 105 seconds were required to reach the peak hardness (92HRF) and compressive strength (376MPa) in both the A356-5wt. % fly ash composite and the matrix alloy. The possible effect of shape and hollowness of particles, the interface between the matrix and the particles, the low modulus of the particles, and the micro cracks formed on the surface of hollow fly ash particles on the kinetics of the age hardening of aluminum alloy A356.

A. Daouda, W. Reif (2002) have studied the influence of Al_2O_3 particulates on the precipitation and hardening behavior of the A356 MgAl_2O_3 spinel Al_2O composites. It was found that the formed at the interface led to Mg depletion in the matrix and subsequently to lesser age hardening in the composites. Therefore, it was necessary for the composite matrix to have a higher Mg concentration prior to casting to achieve the same level of hardening in the composite as in the unreinforced. The hardening kinetics is enhanced by Al_2O particulates because the precipitation preferentially develops on the dislocation lines that increased due to coefficient of thermal expansion mismatch between the matrix and reinforcement.

Guo et al.(2002) have studied experimentally in wire EDM of particle reinforced composites. In his study, high speed wire EDM machine tool was used for machining of Al_2O_3 reinforced aluminum alloy. In high speed wire EDM the wire travelling speed could be in the range of 10m/s , where as it is in the range of about 10 to 15m/min in conventional wire EDM machine tools .In this study the effect of electrical parameters on cutting rate and surface roughness was investigated. With the increase in voltage, cutting rate was increased which is also observed in other unreinforced materials like steel. Surface roughness decreased with the increased voltage, which does not happen while machining of steel or other unreinforced metals. The reason for this decrease in roughness may be the removal of non-conductive Al_2O_3 particles at higher energy, which would otherwise remain on the machined surface to increase the surface roughness.

N. Chawla, J.J. Williams, et al. (2003) has investigated the tensile strength processes in discontinuously reinforced aluminum (DRA). In this experiment author varies the average particle size (6-23 micro meter), Heat treatment is also given. Conclusion of this paper is that as particle size increases tensile strength decreases .Heat treatment increases the tensile strength.

Miyajima et al. (2003) have reported that the density of Al_{2024} -SiC particle composites is greater than that of Al_{2024} -SiC whisker reinforced composites for the same amount of volume fraction. From the above the increase in density can be reasoned to the fact that the ceramic particles posses higher density. Further, the increase volume fraction of these particles contribute in increasing the density of the composites, also they have stated that the theoretical and measured density values of these composites match to each other. Additionally, the above discussions can be reasoned to the fact that the ceramic particles posses higher density. (YU Xiao-dong et al 2007) studied the effect of Al_{5210} alloy reinforced with SiC metal matrix composites with a high volume fraction and various particle size. It was concluded that, the bending strength of SiCp/5210 Al composites with a high volume fraction (50%) increases with decreasing particle size, but the fracture toughness increases with the increasing particle size.

S.V. Prasad and R. Asthana (2004) has presented this paper which gives an overview of the tri biological behavior of Al MMCs reinforced with hard particles, short fibers, and solid lubricants, and the technologies for producing automotive parts from these novel materials. The emphasis has been on developing affordable Al MMCs, reinforced with SiC and Al_2O_3 , that will reduce the weight and increase the engine efficiency, and there by reduce fuel consumption and vehicle emissions. Considerable reduction in wear and friction is achieved by use of these particulates. Furthermore, increased cylinder pressures (and therefore higher engine performance) are possible because Al MMCs can withstand high mechanical and thermal loads, and reduce heat losses by permitting closer fit that can be achieved because of lower thermal expansion coefficient of Aluminum MMCs.

M. Kok (2004) has examined AA2024 aluminum alloy metal matrix composites (MMMCs) reinforced with three different sizes and weight fractions of Al 203 particles up to 30 wt. % were fabricated by a vortex method and subsequent applied pressure. The effects of Al 203 particle content and size of particle

on the mechanical properties of the composites such as hardness and tensile strength were investigated. Scanning electron microscopic observations on the microstructures revealed that the dispersion of the coarser sizes of particle was more uniform while finer particles led to agglomeration of the particles and porosity. The results show that the hardness and the tensile strength of the composites increased with decreasing size and increasing weight fraction of particles.

L. Ceshini, G.Minak, A.Morri (2005) has presented this paper on the tensile properties and the low-cycle fatigue behavior of the 7005 aluminum alloy reinforced with 10 volume % of Al with O_3 particles and 6061 aluminum alloy reinforced with 20 volume % Al_2O_3 particles were studied by the material in homogeneity, mainly related to the particle size and distribution. No significant variation of the tensile strength and ductility with temperature was observed up to $150^\circ C$, while at $250^\circ C$ strength significantly decreased and ductility increased.

Yan and Tsai (2005) have studied WEDM of Al/ Al_2O_3 p composites. The effect of pulse on –time on cutting speed, surface finish and fire and wire breakage was studied. They showed that surface finish of composites was inferior to that of unreinforced alloy. Further, banding was found to be significant at low wire tension.

S.Balasivanandha Prabhu, L. Karunamoorthy, S. Kathiresan, B. Mohan (2006) has studied high silicon content aluminum alloy-silicon carbide metal matrix composite material, with 10 % SiC were successfully synthesized , using different stirring speed and stirring times. The microstructure of the produced composite was examined by optical microscope and scanning electron microscope. The Brinell hardness test was performed. Increase in stirring speed and stirring time resulted in better distribution of particles.

The hardness test results also revealed that stirring speed and stirring time have their effect on the hardness of the composite. The uniform hardness values were achieved at 600 rpm with 10 min stirring, But beyond certain stir speed the properties degraded again.

Z.M. El-Baradie (2007) has investigated 7020 aluminum alloy unreinforced and reinforced with 5 and 10 % volume fraction SiC particulates. The aging behavior of the unreinforced and reinforced materials was studied for both natural and artificial aging at $170^\circ C$. The results show that the incorporation of 5 and 10 % vol.% of SiCp can be improved considerably by natural and artificial aging. Also, the effect of deformation for both unreinforced and composite alloy was studied. The results show that the deformation altered the aging precipitation sequence significantly the greater the deformation, the higher the dislocation densities and hence, the faster the precipitation. Generally, deformation accelerated aging and hence, peak hardness occurred earlier. Also, appreciable increase in hardness and faster kinetics were obtained by the introduction of thermo chemical processing to these alloys.

Hailong Wang (2008) has investigated SiC particulate reinforced Al composites were prepared by powder metallurgy (PM) method and conventional atmospheric sintering. Scanning electron microscope (SEM), X-ray diffraction (XRD) techniques were used to characterize the sintered composites. The effect of temperature on the density, hardness, strength and microstructure of composites. Detailed failure behavior was analyzed. They have found that the segregation of SiC appeared at higher temperature. The highest micro hardness of 80MPa occurred at $700^\circ C$.The strength tended to increase with the increasing temperature due to the formation of Al_2Cu . Both ductile and brittle fracture feature were observed.

Manoj Singla, D. Deepak Dwivedi , Lakhvir Singh, Vikas Chawala (2009) has studied to develop aluminum based silicon carbide particulate MMCs with an objective to develop a conventional low cost

method of producing MMCs and to obtain homogenous dispersion of ceramic material. To achieve these objectives two methods of stir casting technique has been adopted and subsequent property analysis has been made. Aluminum (98.41% C.P) and SiC (320-grit) has been chosen as matrix and reinforcement material respectively. Experiments have been conducted by varying weight fraction of SiC (5%, 10%, 15%, 20%, 25% and 30%), while keeping all other parameters constant. An increasing trend of hardness and impact strength with increase in weight percentage of SiC has been observed. The best results (maximum hardness 45.5 BHN & maximum impact strength of 36N-m.) have been obtained at 25% weight fraction of SiCp.

Liu et al. (2010) have studied on the mechanism of electrochemical discharge machining of Al/SiC composites. They have reported that the breakdown voltage in electrochemical discharge machining was lower compared to conventional die-sinking EDM. In addition, the formation of Al_4C_3 phase was found on the EDM machined surface but not on the electrochemical discharge machined specimen.

Kenneth K. et. al (2012) has found that the low porosity level (≤ 1.6 % porosity) can be achieved by using borax additive and two –step stir casting technique resulted in the production of Al 6063/SiCp. (Y Sahin et al 2003) investigated the effect of Al2024 alloy reinforced with silicon carbide (SiC) metal matrix composites of various particle sizes by molten metal mixing, because of cost effective. Micro structural examination showed that the SiCp distribution was homogeneous and no interface porosity could be observed. Density of the composite increased almost linearly with the weight fraction of particles. It was found that, increasing amount of porosity with increasing the volume fraction, especially for low particle sizes of composites, because of the decrease in the inner particle spacing. In other words, with increasing the volume fraction of MMCs during the production stage, it is required that the longer particle addition time is combined with decreasing the particle size. The porosity level increased, since the contact surface area was increased.

M.D. Kulkarni, et. al (2012) have studied on the role of percentage volume of SiCp on the tensile properties and fracture behavior oh Al 7075 Al alloys at various test temperatures. The composition of the Al 7075 β -SiCp particles of average size 42 μm is used as reinforcement. About 10, 20 and 30 vol% SiCp were incorporated in the melt by rheocasting and squeeze –cast at a pressure of 235 MPa to form composites billets. These were hot extruded to 12 mm diameter cylindrical rods at an extrusion ratio 17: 1 and rectangular bars of cross- section 11X 22 mm at an extrusion ratio 7: 1.

Mahendra Bhoopati, M et al (2013) have noticed that, since SiC and fly ash particle are having low density compared with aluminum, the experimental density values of the Al-SiC, Al- fly and AlSiC-fly ash content decreased linearly. The decrease in density of composites can be attributed to lower density of SiC, fly ash and SiC-fly ash particles than that of the unreinforced Al. If the theoretical value closely matches with the experimental value indicates the better bonding between the interface between matrix and reinforcement. Similar results were obtained by (Rao et .al. 2010 and Gnjjidi et. al. 2001). It is therefore, to improve the density again, apart from Al-SiC and Al-fly ash composites, the mixture of SiC and fly ash particles were added with aluminum. At higher concentration [Al/(10%SiC +10% fly ash)] , the density is about 54% improvement when compared pure aluminum (Rao , J.B et .al. 2010 and Gnjjidi, Z et. al. 2001).Age hardened condition the result of several investigation regarding the mechanical and physical properties in precipitation/Age hardened condition of silicon carbide (SiC) particles reinforced with Al 6061 and other aluminum alloys can be summarized as follows: (Rafiq A et.al 2000) investigated the mechanical property in under aged, peak aged and over aged condition of Al 6063 alloy. The variation in time and temperature has improved the mechanical properties of Al alloy with reduction in ductility .Aging

at 200 °C for 6 hrs, has produced maximum fatigue fracture resistance. Scanning Electron Microscope (SEM) images investigated facet fatigue surface, in under-aged alloys, whereas the peak-aged and over-aged alloy show a mixed mode of fracture. (J.J. Gracio et . al , 2006) investigated the Jayashree P.K et. al International Journal of current Engineering and Technology, Vol 3. No.3 (August 2013) 1068 artificial aging behavior of Al6022-T4 alloy over a wide temperature. It was shown that 6022-T4 alloy can be substantially hardened through a short aging treatment at temperature excess of 200° C in a time interval of less than 2 hrs. The increase in hardness until the peak –aged condition and finally a decrease in hardness as the specimen becomes over-aged were observed.

CHAPTER – 3
MATERIALS AND METHODS

CHAPTER – 3 MATERIALS AND METHODS

3.1 Properties of Aluminium and Silicon Carbide

Table.2 Properties of Aluminium

Properties of Aluminium	Value
Atomic number	13
Atomic weight(g/mol)	26.98
Valency	3
Crystal structure	FCC
Melting point (°C)	660.2
Boiling point (°C)	2480
Mean specific heat (0 – 100)(cal/g. °C)	0.219
Thermal conductivity (0-100°C)(cal/cm. °C)	.57
Co-efficient of linear expansion(0-100)(x10 ⁻⁶ /°C)	23.5
Electrical resistivity at 20°C(Ω/cm)	2.69
Density(g/cm ³)	2.68
Modulus of elasticity (gpa)	68.3
Poisson's ratio	.34

Table.3 Properties of major SiC polytypes

Crystal structure	3C (β)	4H	6H(α)
Space group	inc blende (cubic)	Hexagonal	Hexagonal
Pearson symbol	T^2_d-F3m	$C^4_{6V}-P6_3mc$	$C^4_{6V}-P6_3mc$
Lattice constants (\AA)	cF8	hP8	hP12
Density (g/cm^3)	4.3596	3.0730; 10.053	3.0810; 5.12
Bandgap (eV)	3.21	3,21	3.21
Thermal conductivity ($\text{Wcm}^{-1}\text{K}^{-1}$)	250	220	220
Bulk modulus (GPa)	2.36	3.23	3.05

3.2 Preparation of specimen

Specimens of aluminium silicon carbide metal matrix composites was made by the stir casting technique. For investigating the mechanical properties of any material it is very important to make the specimen very precise, since our aim isto know the behaviour of AlSiC MMCs with varying percentage of SiC , we have to be very precise in the composition of the material . To achieve this 1000 gm of specimen has been made for each of the material like 5%,10%,15% & 20% of Sic in Al.

Table.4 Equipments used for making specimen

S. No	
1	Muffle Furnace
2	Graphite stirrer
3	Graphite crucible & mould
4	Hacksaw
5	Belt grinder
6	Weight machine
7	Lathe machine

3.2.1 Muffle Furnace

A muffle furnace in historical usage is a furnce in which the subject material is isolated from the fuel and all of the products of combustion including gases and flying ash . After the development of high temperature electric heating elements and widespread electrification in developed countries then new muffle furnce quickly moved to electric designs.

Now a days muffle furnace is usually a front loading box type of oven for high temperature applications, such as fusing glass, creating enamel coatings, ceramics and soldering and brazing articles. They are also used in many research facilities , for example by chemists in order to determine what proportion of a sample is non – combustible and non-volatile. Some digital controller operator to program up to different temperature segments, such as ramping , soaking , sintering etc. Also , advances in materials for heating elements , such as molybdenum can now produce working temperature upto 1,800 degree celsius (3,272 degree Fahrenheit), which facilitate more sophisticated metallurgical applications. There is usually no combustion involved in the temperature control of the system, which allows much greater control of temperature uniformly and assures isolation of material being heated from the byproducts of fuel combustion.



Fig.8 Muffle furnace

Muffle furnace was used to heat the material to desired temperatures by conduction, convection or backbody radiation from electrical resistance heating elements. A muffle furnace (sometimes ,retort furnace) in historical usage in a furnace in which the subject material is isolated from the fuel and all of the products of combustion including gases and flying ash . In our muffle furnace we have maximum temperature of 1300°C was achieved.

3.2.2 Stirrer

The function of a stirrer was to agitate liquids for speeding up reactions. Stirrer was designed to homogenous mixing of liquid, oilment ,solutuion, viscous material and soild-liquid.



Fig. 9 Stirrer

3.2.3 Belt Ginder

Belt ginder was used for resistant technology purpose to give a smooth , shiny finsih to manufactured products(Aluminium composites). Belt grinding is an abrasive machining process used on metals and other materials. It is typically used as a finishing process in industry . A belt is coated in abrasive material made to run over the surface to be processed in order to remove material or product to desired finish.



Fig. 10 Belt grinder

3.2.4 Power Hack Saw

Power hacksaws are used to cut large sizes (sections) of metal such as steel. cutting diameters of more than 10/15 mm is very hard with normal hand held saw. Therefore power hacksaws have been developed to carry out the difficult and time consuming work. The heavy 'arm' (or electric hacksaw) was a type of hacksaw that was powered either by its own electric motor or separate motor. A hacksaw is a fine-tooth saw with a blade under tension in a frame, used for cutting materials such as Aluminium alloy into small pieces so as to keep the alloy into crucible.



Fig. 11 Power hacksaw

3.2.5 Graphite Crucible and Mould

A crucible is a refractory container used for metal, glass and pigment production as well as a number of modern laboratory processes, which can withstand temperature high enough to melt or otherwise alter its contents. Historically, they have usually been of clay, but they can be made of any material with higher temperature resistance than its substances they are designed to hold.

Crucible and their covers are made of high temperature resistant materials usually porcelain, alumina or an inert metal. One of the earliest uses of platinum was to make crucibles. Ceramics such as alumina, zirconium and especially magnesia will tolerate the highest temperatures. More recently metals such as nickel and zirconium have been used. The lids are typically loose fitting to allow gases to escape during heating of a sample inside. Crucible and their lids come in high form and low form shapes and in various sizes. These small size crucible and their covers made of porcelain are quite cheap when sold in quantity to laboratories and the crucibles are sometimes disposed

after use in precise quantitative chemical analysis.



Fig.12 Graphite crucible

3.2.6 Weight Machine

A weight machine is a machine used for measuring weight, this uses gravity as the primary source of resistance. Digital weight machine is used to weight the powder of aluminium and silicon carbide for mixing. Al and SiC is weighted on the machine by its different proportion, mixing should be very accurate. In order to maintain the accuracy level high digital weight machine is used.



Fig. 13 Weight machiine

3.2.7 Lathe Machine

A lathe is a machine tool which rotates the workpiece on its axis to perform various operations such as cutting ,sanding ,knurling,drilling or deformation, facing turning ,with tools that are applied to the workpiece to create an object having symmetry about an axis of rotation

Lathes are used in wood turing ,metal working ,metal spinning ,thermal spraying ,parts reclamation and glass-working. Lathe can be used to shape pottery, the best-known design being the potter's wheel . Most suitably equipped metalworking lathes can also be used to produce most solids of revolution, plane surfaces and screw threads or helices. Ornamental thathes can produce three-dimensional solids of incredible complexity. The workpiece is usually held in palce by either one or two centers,at least one of which can typically be moved horizontally to accommodate varying workpiece lengths . Other work-holding methods include clamping the work about the axis of rotation using a chuck or to a faceplate using clamps.



Fig. 14 Specimen preparation on lathe machine.

3.3 EXPERIMENTAL WORK

It is very important to know the exact properties and behaviour of the metal so that it can be used on appropriate position and to meet the desired requirement. In order to investigate the behaviour of Aluminium silicon carbide metal matrix composites various methods and experiments have been done on different composites of the AlSiC, that is percentage of SiC in Aluminium is 5%, 10%, 15% & 20%.

3.4 Properties to be Investigated are .

1. Density.
2. Hardness.
3. Engineering strain.
4. Elongation percentage.
5. Ultimate tensile strength.
6. Modulus of rigidity.

3.4.1 Density

The density or the volumetric mass density of a substance is its mass per unit volume. The symbol most often used for density is ρ (rho). Mathematically density is defined as mass divided by volume.

$$\rho = m/v$$

Where,

ρ is the density

m is the mass

v is the volume

For a pure substance the density has the same numerical value as its mass concentration. Different materials usually have different densities and density may be relevant to buoyancy, purity and packaging. Osmium and iridium are the densest known elements at standard conditions for temperature and pressure but certain chemical compounds may be denser. To simplify comparison of density across different systems of units, it is sometimes replaced by the dimensionless quantity

“relative density” or “specific gravity”, i.e. The ratio of the density of the material to that of a standard material, usually water. Thus if the relative density is less than one it means that the substance can float on water.

The density of a material varies with temperature and pressure. This variation is typically small for solids and liquids but it is much greater for gases. Increasing the pressure on an object decreases the volume of the object and thus increases its density. Increasing the temperature of a substance, density decreases and thus increases its volume. In most of materials heating the bottom of fluid results convection from the bottom to the top, due to decrease in the density the heated fluid. This causes it to rise relative to more dense unheated material.

the reciprocal of the density of a substance is occasionally called its specific volume, a term sometimes used in thermodynamics. Density is an intensive property so that increasing the amount of a substance does not increase its density but only increases its mass.

Sample of aluminium silicon carbide metal matrix composites is taken by varying the percentage of silicon carbide in aluminium. A square sample having length, width and height (10x10x10)mm is taken for the investigation of density.

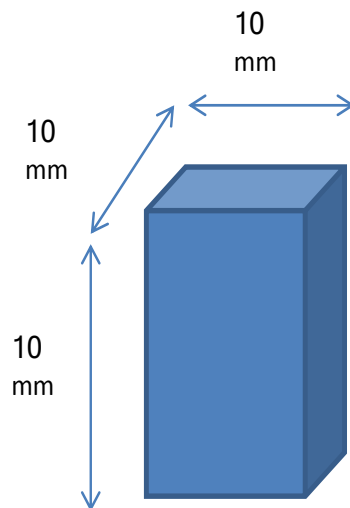


Fig. 15 Dimesion of density sample.

3.4.2 Hardness

The metal's hardness is defined as resistance of metal to plastic deformation, usually by indentation. However, the term may also refer to stiffness or temper or to resistance to scratching, abrasion or cutting. It is the property of a metal which gives it the ability to resist permanent deformation when a load is applied. Hardness of a material is directly proportional to its resistance and inversely proportional to its deformation. The greater the hardness of the metal, the greater resistance it has to deformation. In metallurgy, hardness is defined as the ability of a material to resist plastic deformation. The indentation hardness is the resistance of a material to indentation. This is the usual type of hardness test, in which a pointed or rounded indenter is pressed into a surface under a substantially static load.

Hardness measurement

Brinell's hardness test is done for the investigation of hardness of Aluminium Silicon Carbide metal matrix composites with different compositions. Brinell hardness is determined by forcing a hard steel or carbide sphere of a specified diameter under a specified load into the surface of a material and measuring the diameter of the indentation left after the test. The Brinell hardness number is obtained by dividing the load used in kilograms by the actual surface area of the indentation in square millimeters. The Brinell's hardness test uses a desk top machine to press a 10mm diameter hardened steel ball into the surface of the test specimen. The machine applies a load of 500 kilograms for soft metals such as copper, brass and thin stock. A 1500 kilograms load is used for aluminium casting and a 3000 kilogram load is used for material such as iron and steel. The load is usually applied for 10 to 15 seconds. After the impression is made, the diameter of the resulting round impression is measured. It is measured to plus or minus .05mm using a low-magnification portable microscope. The hardness is calculated by dividing the load by the area of the curved surface of the indentation. The area of a hemispherical surface is arrived at by multiplying the square of the diameter by 3.14159 and then dividing by 2. There is a calibrated chart provided, so with the diameter of the indentation the corresponding hardness number can be referenced. A well structured Brinell hardness number reveals the test conditions, and looks like this, "75 HB 10/500/30" which means that a Brinell Hardness of 75 was obtained using a 10mm diameter hardened steel with a 500 kilogram load applied for a period of 3 seconds. On tests of extremely hard metals a tungsten carbide ball is substituted for the steel ball. The Brinell ball which makes the deepest and widest indentation is more accurately calculated for multiple grain structures, and any irregularities in the alloy.

Hardness measurement methods

There are mainly three types of hardness tests used with accuracy by the metals industry i.e. the Brinell's hardness test, the Rockwell hardness test and the Vickers hardness test. The definition of metallurgical ultimate strength and hardness are approximately similar therefore it can be generally assumed that a strong metal is also a hard metal. The way the three of these hardness tests measure a metal's hardness is to determine the metal's resistance to the penetration of a non-deformable ball or cone. The test determines the depth which such a ball or cone will sink into the metal, under a given load, within a specified period of time. The followings are the most common hardness test methods used in today's available technology:

1. Brinell's hardness test.
2. Rockwell hardness test.
3. Vickers hardness test.

Brinell's Hardness Test

The Brinell hardness test was one of the most widely used hardness test during the World War II. For measuring armor plate hardness, the test is usually conducted by pressing a tungsten carbide sphere 10mm in diameter into the test surface for 10 seconds with a load of 3,000 kg, then measuring the diameter of the resulting depression. The hardness of the material depends on the resistance which it exerts during a small amount of yielding or plastic deformation. The resistance depends on friction, elasticity, viscosity, the intensity and distribution of plastic strain produced by a given tool during indentation.



Fig.16 Brinell's Hardness Testing machine

It is determined by forcing a hard steel or carbide sphere of a specified diameter under a specified load into the surface of a material and measuring the diameter of the indentation left after the test. The Brinell hardness number, or simply Brinell number, is obtained by dividing the load used, in kilograms, by the actual surface area of the indentation, in square millimeters. The result is a pressure measurement, but the units are rarely stated. The BHN is calculated according to the following formula.

$$\text{BHN} = \frac{F}{\frac{\pi}{2} \times (D - (D^2 - D_i^2)^{1/2})}$$

Fig.17 Process of indentation and formula

Where;

BHN = The Brinell's hardness number.

F = The imposed load in kg.

D = The diameter of the spherical indenter in mm.

Di = Diameter of the resulting indenter impression in mm.

Procedure

The specimen is placed securely upon the anvil of Brinell's hardness measuring instrument. Elevate the specimen so that it comes into contact with penetrator and put the specimen under a preliminary or minor load without shock. The major load of 1500 n is applied. Watch the pointer until it comes to rest and wait for 15 seconds. Remove the major load. Read the Rockwell hardness number on the hardness scale. Measure the resulting diameter of indenter impression. Putting the values in the formula and BHN number is found out.

Precaution

1. Brinell's test should be performed on smooth, flat specimens from which dirt and scale have been removed.
2. The test should not be made on specimens that are so thin that the impression penetrates through the metal.
3. Impression should not be made too close to the edge of the specimen.

3.4.3 Engineering Strain

The engineering strain is expressed as the ratio of total deformation to the initial dimension of the material body in which the forces are being applied. To investigate the engineering strain of AlSiC MMCs net elongation and percentage of elongation should be known. In order to the elongation percentage of AlSiC MMCs universal testing is done on the universal testing machine.

Universal testing machine

The tensile test is conducted on UTM . It is a hydraulically pump operated , it has oil in oil sump, a load dial indicator and central buttons. The left has upper ,middle and lower cross heads i.e; specimen grips (or jaws). Idle cross head can be moved up and down for adjustment . The pipes connecting the lift and right parts are oil pipes through which the oil is pumped under pressure which flows towards the left parts to move the coss-heads.



Fig. 18 Universal Testing Machine.

Various machine and structure components are subjected to tensile loading in numerous applications. For safe design of the components , there ultimate tensile strength and ductility can be determined before actual use. Tensile test can be conducted on UTM . A material when subjected to a tensile load it resists the applied load by developinf internal resisting forces. These resistance comes due to atomic bonding between atoms of the material.the resisting force for unit normal cross-section area is known as stress . The value of stress in material goes on increasing with increase in applied tensile load,but it has a certain maximum limit also. The minimum stress , at which a material fails, is called ultimate tensile strength. The end of elastic limit is indicated by the yield point(load). This can be seen during experiment as expalined later in procedure with increase in loading beyond elastic limit original cross-section area (A_0) goes on decreasing and finally reduced to its minimum value when the specimen breaks.

Procedure

Measure the original length and diameter of the specimen . The length may either be length of gauge section which is on the specimen with a preset punch or the total length of the specimen Insert the specimen into grips of the testing machine and attach strain- measuring device to it . Begin the load application and record load versus elongation data. Take readings more frequently as yield point is approached . Measure elongation values with the help of dividers and ruler. Continue the test till fracture occurs. By joining the two broken halves of the specimen together , measure the final length and diameter of specimen.

Precautions

1. The specimen should be prepared in proper dimensions.
2. The specimen should properly fit between the jaws.
3. Take readings carefully
4. After breaking of specimen stop the machine.

The engineering normal strain or engineering extensional strain or normal strain (e) of a material line element axially loaded is expressed as the change in length ΔL per unit of the original length L of the line element or fibers. The normal strain is positive strain if the material fiber is stretched and negative if they are compressed . Thus , we have

$$e = \Delta L/L = (L^1 - L)/L$$

Where ,

e is the engineering normal strain.

L is the original length.

L^1 is the final length.

The engineering shear strain is defined as the tangent of that angle, and is equal to the length of deformation at its maximum divided by the perpendicular length in the plane of force application which sometimes makes it easier to calculate. A strain is a measure of deformation representing the displacement between particles in the body relative to a reference length . A strain is generally a tensor quantity. Physical insight into strains can be gained by observing that a given strain decomposed into normal strain , and the amount of distortion associated with the sliding of plane layers over each other is the shear strain,

within a deforming body. This could be applied by elongation, shortening or volume changes or angular distortion. Universal testing machine is generally used to find the engineering strain of a material so it is also used for the AlSiC MMCs. It is very precise and gives accurate value.

3.4.4 Elongation Percentages

Elongation percentage is found out to know the real deformation taking place along the radius and length with the different percentage composition of SiC in the aluminium silicon carbide MMCs. It is found that as the percentage of SiC increases in aluminium the percentage of elongation decreases as it results that the material is getting harder and more stiff.

3.4.5 Ultimate Tensile Strength (UTS)

Ultimate tensile strength is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. Tensile strength is not the same as compressive strength and the values can be quite different. Some materials will break sharply, without plastic deformation which is called as brittle fracture or failure. Some are more ductile, including most metals, which will experience some plastic deformation and possibly necking before fracture.

The UTS is usually found by performing a tensile test and recording the stress versus strain values. The highest point of the stress-strain curve is the UTS. It is an intensive property therefore its value does not depend on the shape and size of the specimen. However, it depends on other factors, such as the preparation of the specimen, the presence of surface defects and the temperature of the test environment and material.

Tensile strength are rarely used in the design of ductile members but they are important in brittle members. They are tabulated for common materials such as alloys, composite materials, ceramics, plastics and wood. Tensile strength is defined as a stress, which is measured as force per unit area. For some non-homogenous materials or for assembled components, it can be recorded just as a force or as a force per unit width. In the International System of Units (SI), its unit is written as pascal(Pa).

The tensile test is most applied one, of all mechanical tests. In this test ends of the test piece are fixed into the grips connected to a straining device and to a load measuring device. If the applied load is small enough, the deformation of any solid body is entirely elastic. An elastically deformed solid will return to its original form as soon as the load is removed. However, if the load is too large, plastic deformation will occur and the material can be deformed permanently. The initial part of the tension curve which is recoverable immediately after unloading is termed as elastic and the rest of the curve which represents the manner in which solid undergoes plastic deformation is termed as plastic. The stresses below which the deformation is essentially entirely elastic is known as the yield strength of the material. In some material the onset of plastic deformation is denoted by a sudden drop in load indicating both an upper and a lower yield point. However, some materials do not exhibit a sharp yield point. During plastic deformation, at larger extensions strain hardening cannot compensate for the decrease. This stage the "ultimate strength" which is defined as the ratio of the load on the specimen to original cross-sectional area, reaches a maximum value. Further loading will eventually cause 'neck' formation and finally rupture.

Procedure

Measure the original length and diameter of the specimen. The length may either be length of gauge section which is marked on the specimen with a preset punch or the total length of the specimen. Insert the specimen into grips of the test machine and attach strain-measuring device to it. Begin the load application and record load versus elongation data. Take readings more frequently as yield point is approached. Measure elongation values with the help of a divider and a ruler. Continue the test till fracture occurs. By joining the two broken halves of the specimen together measure the final length and diameter of specimen.

Precautions

1. If the strain measuring device is an extensometer it should be removed before necking begins.
2. Measure deflection on scale accurately and carefully.

3.4.6 Modulus of Rigidity

A torsion test is done to measure the modulus of rigidity of any material by maximum twisting forces. It is an extremely common test used in material mechanics to measure how much of a twist a certain material can withstand before cracking or breaking. This applied pressure is referred to as torque. Materials typically used in the manufacturing industry, such as metal fasteners and beams, are often subjected to torsion testing to determine their strength under stress.

There are three broad categories under which a torsion test can take place: failure testing, proof testing and operational testing. Failure testing involves twisting the material until it breaks. Proof testing observes whether a material can bear a certain amount of torque load over a given period of time. Operational testing tests specific products to confirm their elastic limit before going on the market.

It is critical for the results of each torsion test to be recorded. Recording is done through creating a stress-strain diagram with the angle of twist values on the X-axis and the torque values on the Y-axis. Using a torsion testing apparatus, twisting is performed at quarter-degree increments with the torque that it can withstand recorded. The strain corresponds to the twist angle, and the stress corresponds to the torque measured.

The elastic limit of any material is the point at which it can no longer return to its original shape and size. The elastic limit determined by a torsion test is equal to the slope of the line from the start of testing to the proportional limit. This relationship was first measured by Sir Robert Hooke in 1678. Hooke's law states that stress is directly proportional to strain until the proportional limit is reached, at which point the object tested will begin to show signs of stress. After testing, metal materials are categorized as being either ductile or brittle. Ductile metals such as steel or aluminium have high elastic limits and can withstand a great deal of strain before breaking. Brittle materials such as cast iron and concrete have low elastic limits and do not require much strain before rupturing.

Without performing a torsion test, materials would not be properly vetted before being released for industrial use. It is of

paramount importance that the ability for a material to bear certain amount of twisting is accurately measured . Otherwise ,structures and machines that depend on such materials could break down causing instability, work flow interruption or even significant damage and injury.



Fig. 19 Torsion testing machine

A torsion test is quite instrumental in determining the value of modulus of rigidity of a metallic specimen . The value of modulus of rigidity of a metallic specimen. The value of modulus of rigidity can be found out through observations made during the experiment by using the torsion equation.

$$T / I_p = . (C \times \theta) / l = q / r$$

$$I_p = \Pi/32 \times 10^4$$

Where ,

T = Torque applied (N-m).

I_p = Polar moment of inertia (m^4).

C = Modulus of rigidity (N/m^2).

θ = Angle of twist (radian).

l = Length of the shaft (m).

q = shear stress (N/m^2).

r = Distance of element from center of shaft (m).

Procedure

Select the driving dogs to suit the size of the specimen and clamp it in the machine by adjusting the length of the specimen by means of a sliding spindle. Measure the diameter at about three places and take average value . Choose the appropriate range by capacity change lever . Set the maximum load pointer to zero. Set the protector to zero for convenience and clamp it by means of knurled screw . Carry out straining by rotating the hand wheel in either direction . Load the machine in suitable increments . Then load out to failure as to cause equal increments of strain reading. Plot a torque – twist ($T - \theta$) graph . Read off co-ordinates of a convenient point from the straight line portion of the torque twist ($T - \theta$) graph and calculate the value of C by using relation.

Precaution

1. Measure the dimension of the specimen carefully.
2. Measure the angle of twist accurately for the corresponding value of Torque.

Chapter - 4

TEST RESULTS AND DISCUSSION

Chapter – 4

RESULTS AND DISCUSSION

4.1 Density

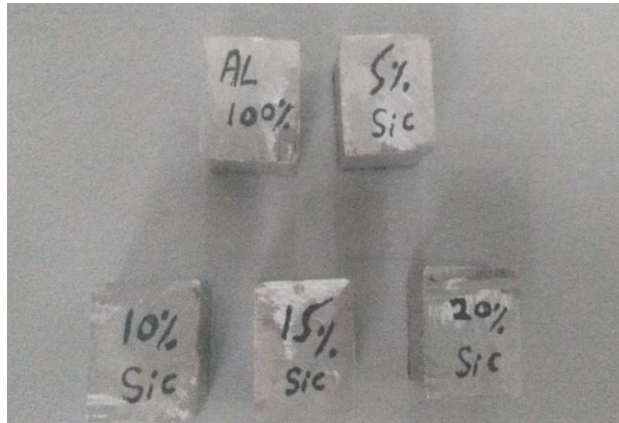


Fig.20 Specimen of AlSiC MMCs for density test

Table.5 Density of AlSiC MMCs with different compositions

AlSiC	Al(100% +SiC(0%))	Al(95% +SiC(5%))	Al(90% +SiC(10%))	Al(85% +SiC(15%))	Al(80% +SiC(20%))
Density(g/cm ³)	2.65	2.72	2.75	2.79	2.82

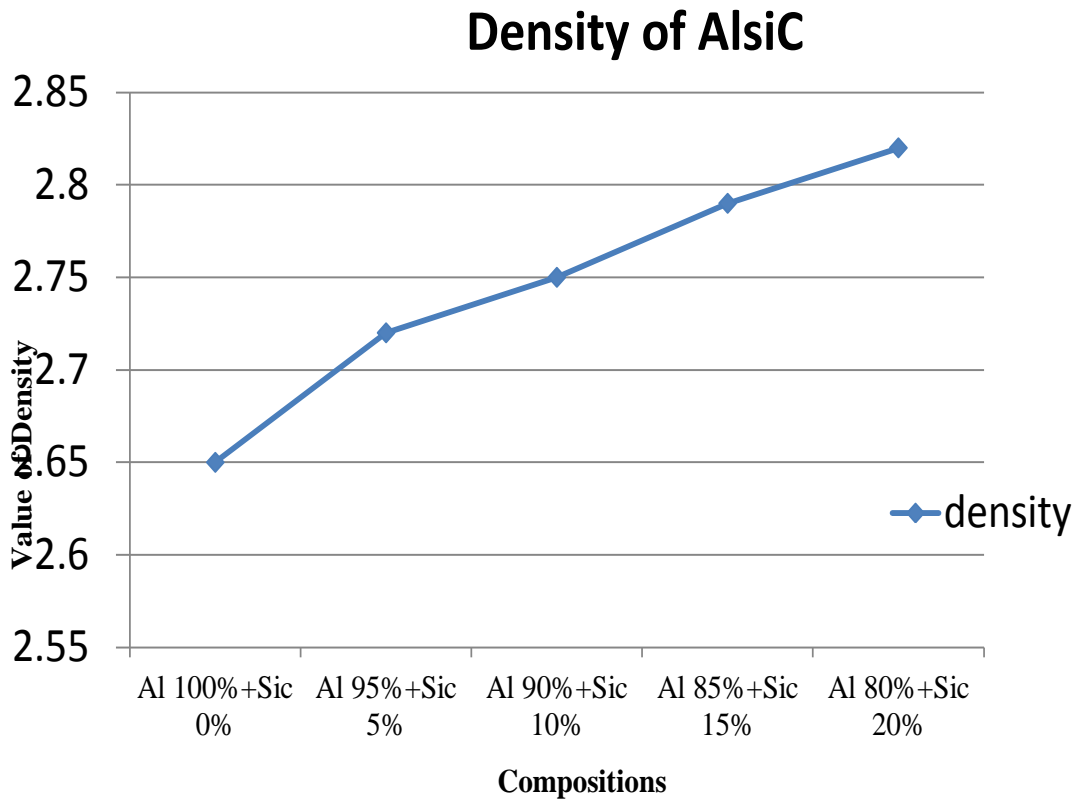


Fig.21 Density of AlSiC MMCs with different composition

It is found that the density increases gradually with increase in percentage of SiC in Aluminium. Silicon having less density than aluminium but due to presence of carbide in the metal matrix composites the weight increases.

4.2 Hardness

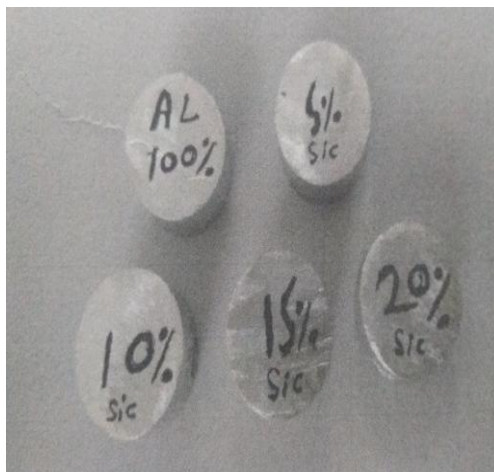


Fig 22 Specimen of AlSiC MMCs for hardness tes

Table.6 Brinell's hardness of AlSiC MMCs with different compositions

AlSiC	Al(100% +SiC(0%))	Al(95% +SiC(5%))	Al(90% +SiC(10%))	Al(85% +SiC(15%))	Al(80% +SiC(20%))
Hardness(BHN)	38	40.3	41.2	44	45.4

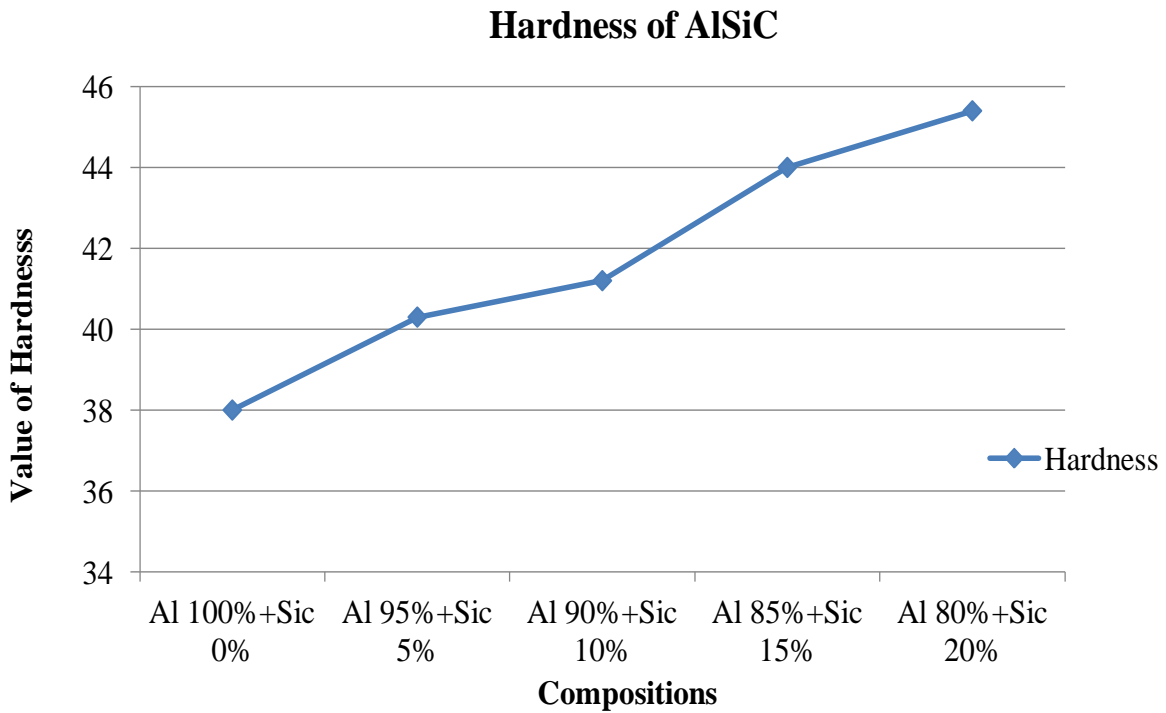


Fig.22 Hardness of AlSiC MMCs with different composition

It is found that the hardness of Aluminium silicon carbide metal matrix composites increases gradually in increase in the % of SiC in the composition. Addition of very small percentage of silicon carbide in Aluminium gives much increase in hardness which result a harder material with low density .

4.3 Engineering strain

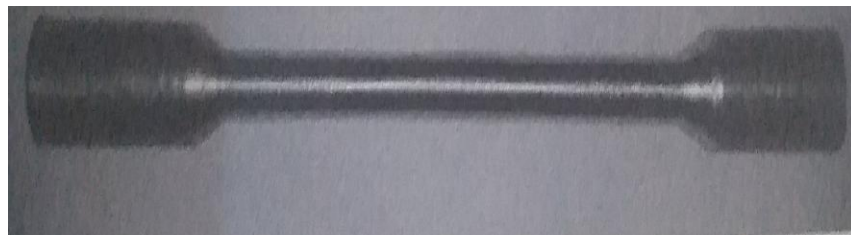


Fig 24 Specimen of AlSiC MMCs for tensile test

Table.7 Engineering strain of AlSiC MMCs with different composition

AlSiC	Al(100% +SiC(0%))	Al(95% +SiC(5%))	Al(90% +SiC(10%))	Al(85% +SiC(15%))	Al(80% +SiC(20%))
Strain e $\Delta L/L$.2	.193	.185	.177	.169

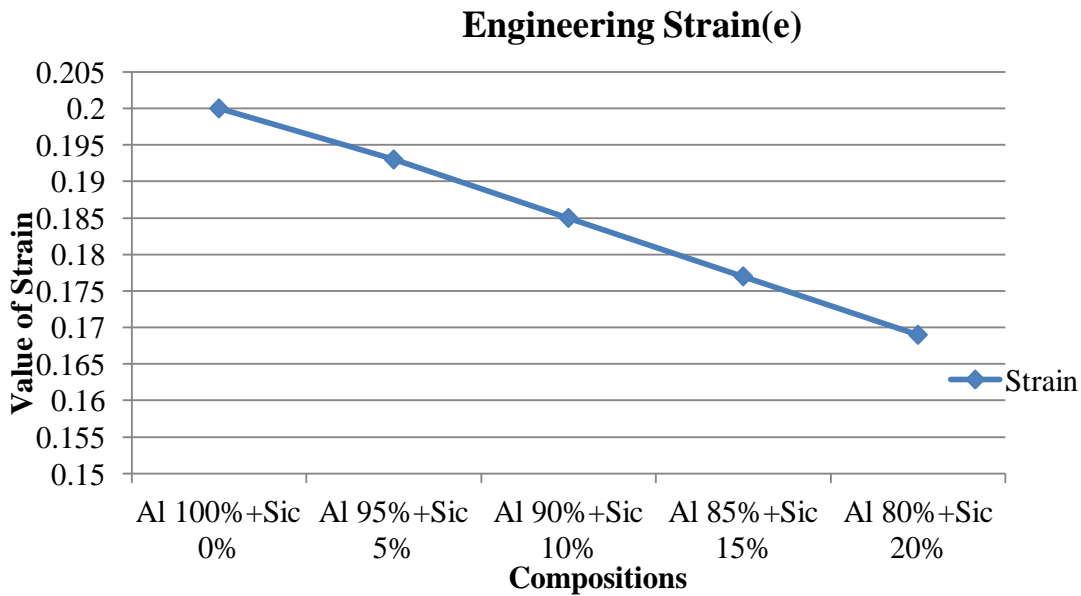


Fig.27 Strain of AlSiC MMCs with different composition

It is found that the strain of Aluminium silicon carbide metal matrix composites decreases respectively with increase in the % of SiC in Aluminium. This also proves that the elasticity and ductility of the AlSiC MMCs is decreasing respectively

4.4 Ultimate Tensile Strength (UTS)

Table.8 Ultimate tensile strength of AlSiC MMCs with different compositions.

AlSiC	Al(100% +SiC(0%))	Al(95% +SiC(5%))	Al(90% +SiC(10%))	Al(85% +SiC(15%))	Al(80% +SiC(20%))
UTS (Mpa)	174.43	195.62	212.15	221.23	187.55

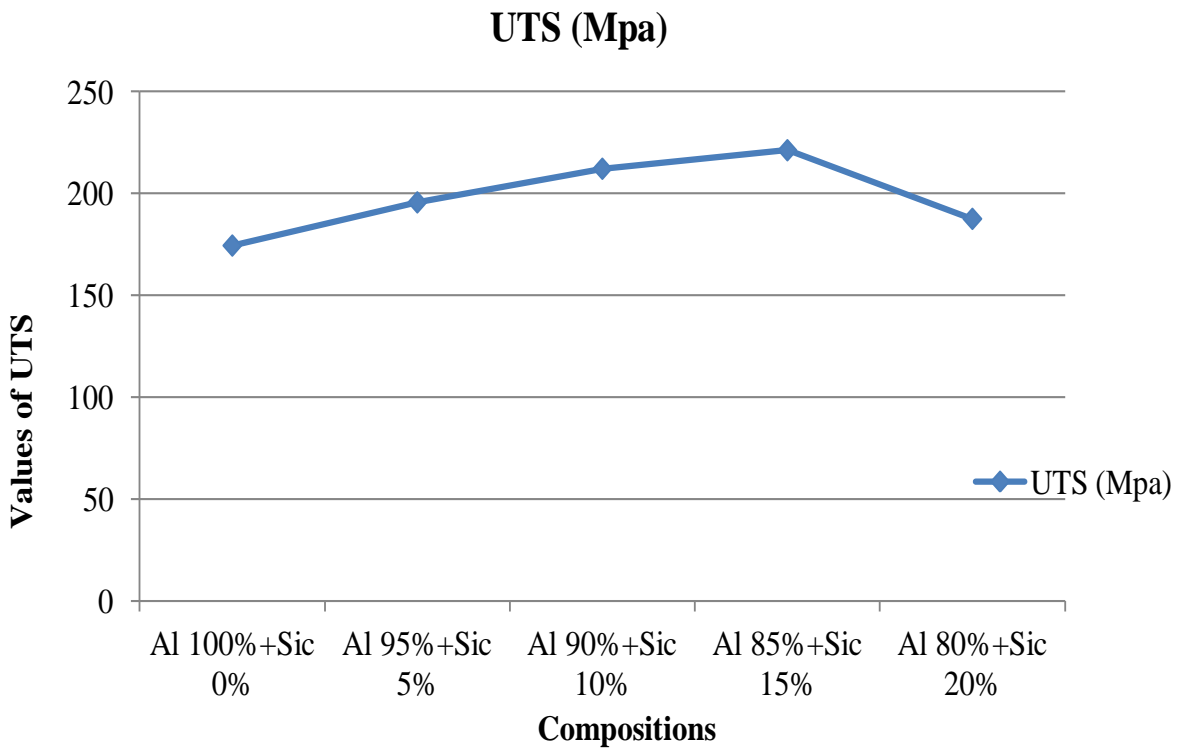


Fig.26 Ultimate tensile strength of AlSiC MMCs with different composition

It is found that the ultimate tensile strength of AlSiC MMCs increases with increase in the wt% of the SiC. But at 20% of AlSiC it decreases with respect to 15% of AlSiC, this proves that the strength increases up to 15% and it shows brittle property as the composition of SiC gets higher.

4.5 Modulus of Rigidity

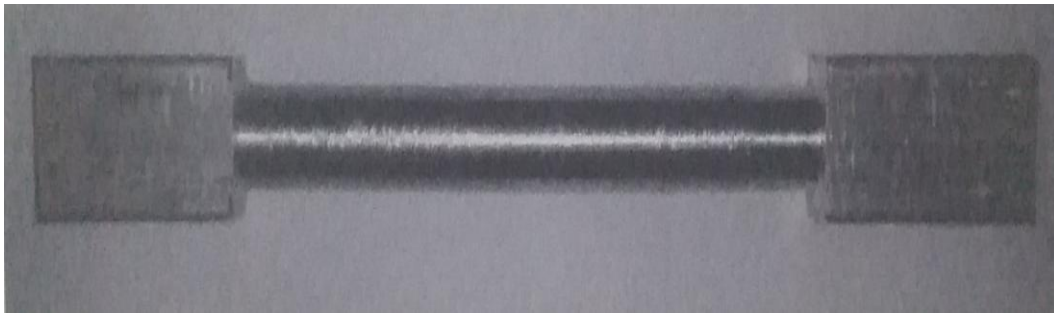


Fig 27 Specimen of AlSiC for Torsion test

Table. 9 Torsion test of AlSiC MMCs with different compositions

AlSiC	Al(100% +SiC(0%))	Al(95% +SiC(5%))	Al(90% +SiC(10%))	Al(85% +SiC(15%))	Al(80% +SiC(20%))
Modulus of rigidity(C) N/mm ²	19.80	25.79	33.87	43.99	60.05

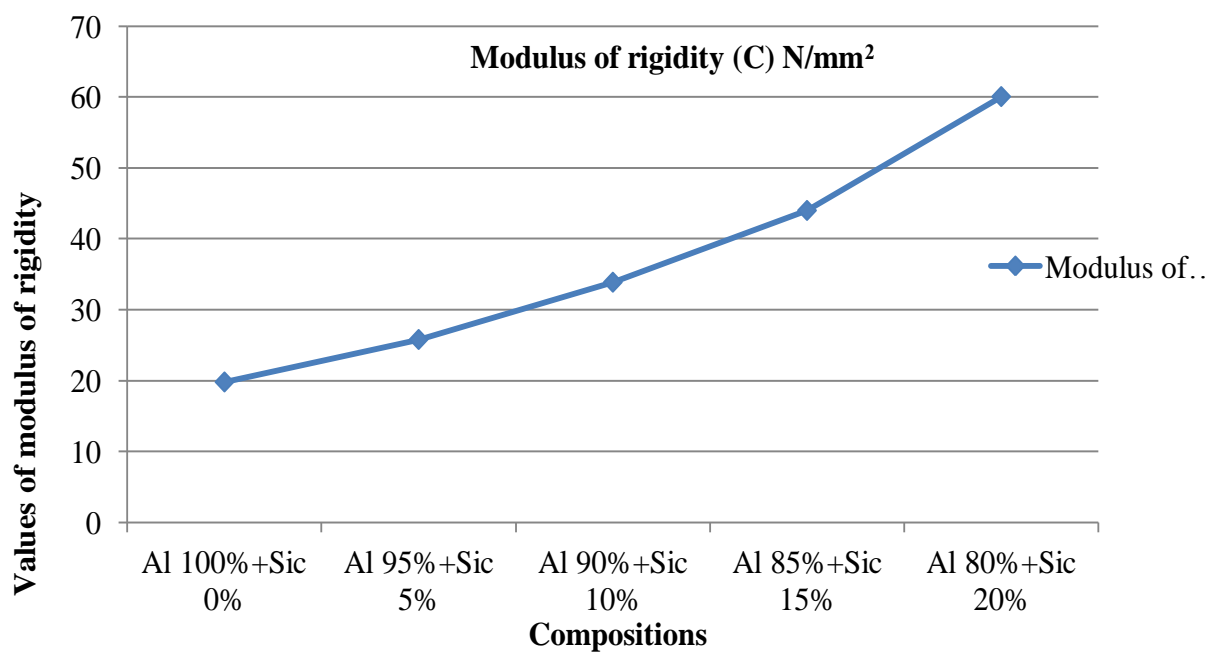


Fig.28 Ultimate tensile strength of AlSiC MMCs with different composition

It is found that the modulus of rigidity increases with increase in % of SiC in AlSiC MMCs .Torque is also increases to break the specimen .With the relation of torsion ,modulus of rigidity is calculated .

Chapter 5

Summary And Conclusion

CHAPTER-5

SUMMARY AND CONCLUSION

5.1 Summary:

Aluminum Silicon carbide alloy composite materials are widely used and applications like engineering structures, industry and electronic applications, sporting goods etc. The properties of aluminum metal matrix composite mostly depend on the processing method which is capable of producing good properties to meet the industrial need. Study of wear properties Al-SiC composite is found that wear rate decreases linearly with increasing of SiC content. Mechanical properties of Al-SiC MMCs like hardness, density, engineering strain, elongation percentage, ultimate tensile strength and modulus of rigidity were evaluated. With the improved value of coefficient of thermal expansion of Aluminum composites is one of the reasons they are widely used by electronic industries and it has been found that the particles reinforcement of aluminum matrix composites can improve considerably the strength and hardness of aluminum and its alloys. Mechanical properties of Aluminum silicon carbide by mass fraction of SiC (5%, 10%, 15%, and 20%). Mechanical and Corrosion behavior of Aluminum Silicon Carbide metal matrix composites are suitable for spur gear, aerospace material, structural material, automobile parts, and astronomical telescopes.

5.2 Conclusion:

Following are the conclusion from present work:-

1. Mechanical properties of AlSiC metal composites are investigated.
2. Density of the AlSiC with different composition of SiC metal matrix composites is investigated. Very little increase in density, but very high increase in strength and hardness.
3. It appears that the hardness increase results in elongation % of AlSiC metal matrix composites. It is also found that the elongation tends to decrease according to the increase in weight percentage of silicon carbide and hence it leads to increase in hardness.

4. Ultimate tensile strength of the aluminum silicon carbide metal matrix composites increases gradually at the increased composition of the silicon carbide in it, but at 15% of SiC in Al give the best tensile strength as per the weight percentage ratio.
5. Modulus of rigidity is increased with increase in % of SiC in Aluminium, Torque also increases as the % increases but the twisting angle decreases respectively results that the AlSiC getting rigid with the pressure of SiC.

Scope of Future Work:-

1. This can further be extended by varying the % of SiC and by varying the composition of AlSiC metal matrix composites
2. Heat treatment can be done to improve the properties.
3. Results can be varied by varying reinforcement grain size.

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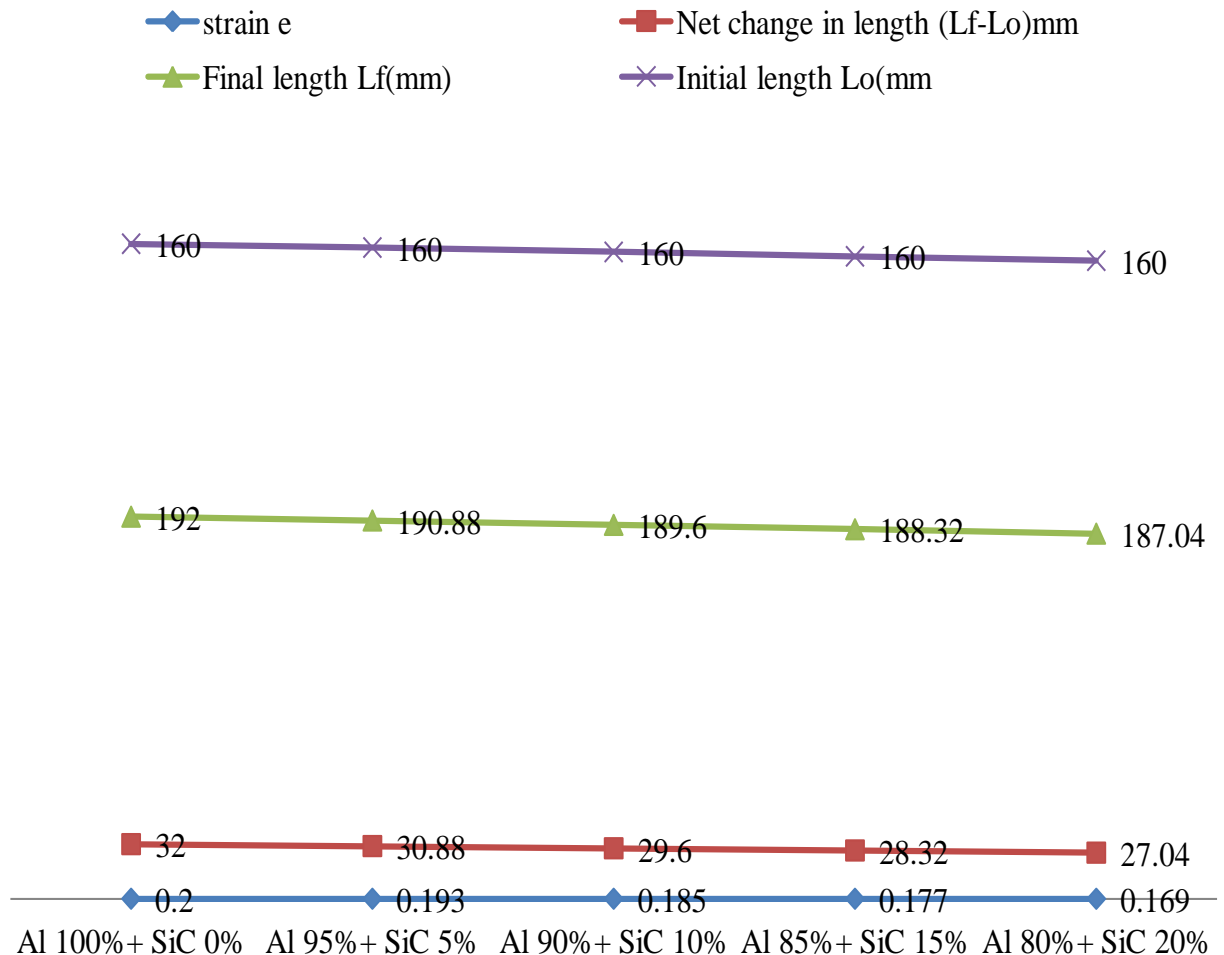
APPENDIX

Engineering strain:

Table.10 Engineering strain of AlSiC MMCs with different compositions

AlSiC	Al 100%+SiC 0%	Al 95%+SiC 5%	Al 90%+SiC 10%	Al 85%+SiC 15%	Al 80%+SiC 20%
Initial length L_0 (mm)	160	160	160	160	160
Final length L_f (mm)	192	190.88	189.60	188.32	187.04
Net change in length (L_f $- L_0$)	32	30.88	29.60	28.32	27.04
Strain e $\Delta L/L$	0.2	0.193	0.185	0.177	0.169

Fig 29 Strain of the AlSiC MMCs with different composition



Modulus of rigidity

Table.11 Torsion test of AlSiC MMCs with different compositions

AlSiC	Al 100%+SiC 0%	Al 95%+SiC 5%	Al 90%+SiC 10%	Al 85%+SiC 15%	Al 80%+SiC 20%
Torque (Nm)	1561	1802	2041	2265	2530
Angle of twist In degree	690	612	528	451	369
Angle of twist in radian(θ)	12.04	10.68	9.21	7.87	6.44
Modulus of rigidity(C) N/mm ²	19.80	25.79	33.87	43.99	60.05

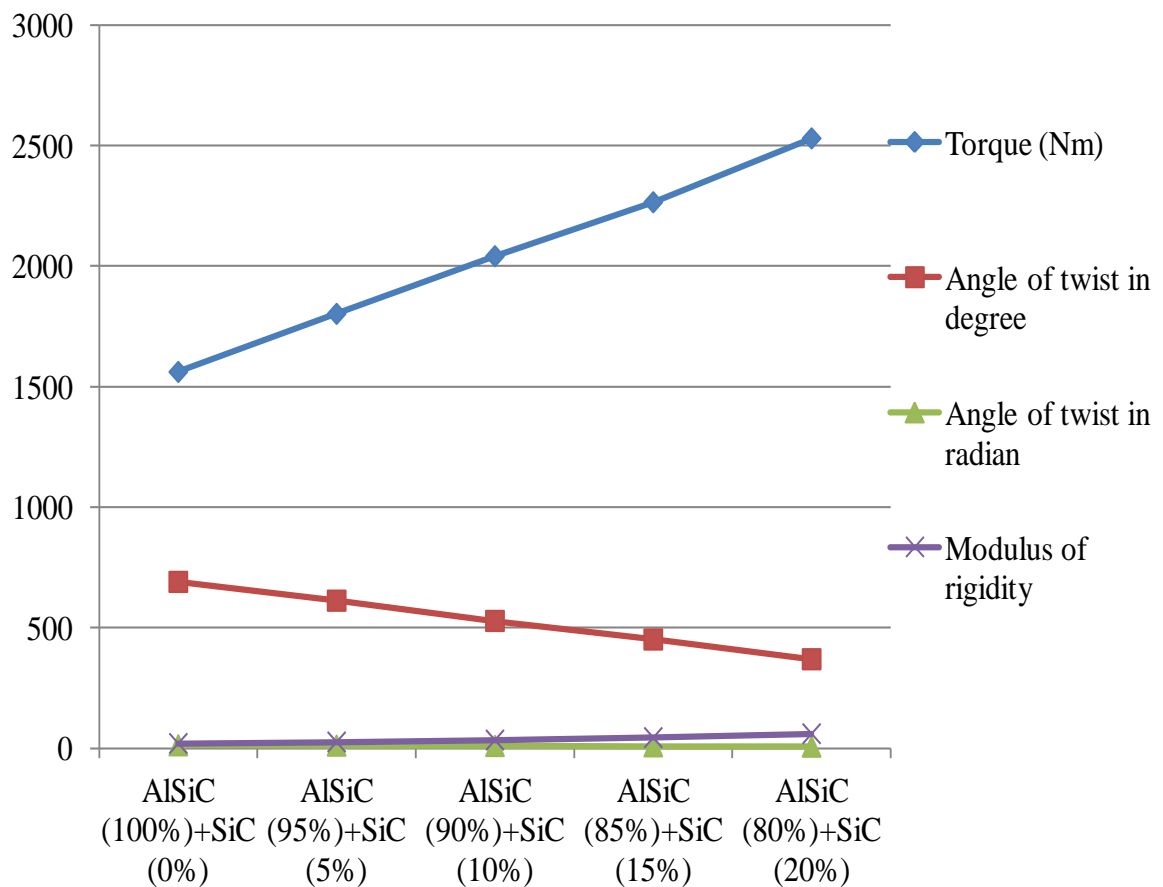


Fig 30 Torsion test of AlSiC MMCs with different composition

