INVESTIGATIONS FOR ENHANCEMENT OF MECHANICAL PROPERTIES WITH REINFORCEMENT SIZE VARIATION IN METAL MATRIX COMPOSITES

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

OF

MASTER OF TECHNOLOGY

IN

[**PRODUCTION ENGINEERING**]

Submitted by:

[**VIBHU SINGH**]

(**Roll No. 2K17/PIE/19**)

Under the supervision

of

Dr. M. S. NIRANJAN

(Associate Professor)

DEPARTMENT OF MECHANICAL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

CANDIDATE'S DECLARATION

I, VIBHU SINGH, 2K17/PIE/19 student of M.Tech, PRODUCTION AND INDUSTRIAL ENGINEERING hereby declare that the project Dissertation entitled "**INVESTIGATIONS FOR ENHANCEMENT OF MECHANICAL PROPERTIES WITH REINFORCEMENT SIZE VARIATION IN METAL MATRIX COMPOSITES**", which is submitted to the **Department of MECHANICAL ENGINEERING**, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title or recognition.

Place: Delhi VIBHU SINGH

Date: 2K17/PIE/19

<u>CERTIFICATE</u>

I herby certify that the Project Dissertation entitled "**INVESTIGATIONS FOR ENHANCEMENT OF MECHANICAL PROPERTIES WITH REINFORCEMENT SIZE VARIATION IN METAL MATRIX COMPOSITES**" which is submitted by **Ms. VIBHU SINGH**, **2K17/PIE/19, Mechanical Engineering,** Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this university or elsewhere.

Place: Delhi — Supervisor

Date: — Dr. M. S. Niranjan

(Associate Professor)

ACKNOWLEDGEMENT

It is a matter of great pleasure for me to present my major project report on "**INVESTIGATIONS FOR ENHANCEMENT OF MECHANICAL PROPERTIES WITH REINFORCEMENT SIZE VARIATION IN METAL MATRIX COMPOSITES**". First and foremost, I am profoundly grateful to my guide **Dr. M. S. NIRANJAN, Associate Professor, Mechanical Engineering Department, DTU** for their expert guidance and continuous encouragement during all stages of report. I feel lucky to have an opportunity to work with them. Not only was their understanding towards the subject, but also their interpretation of the results drawn from the graphs very thought provoking. I am thankful to the kindness and generosity shown by them towards me, as it helped me morally in completing the project before actually starting it.

Date: VIBHU SINGH

Place: Delhi (2K17/PIE/19)

ABSTRACT

Metal matrix composites are emanating as advance engineering and structural materials and their demands are continuously growing in various sectors with higher pace. Among all the metals matrix composite, aluminum matrix composite are coming out as a tough potential competitor for the conventional materials for having large number of applications in aerospace, manufacturing, transportation, defence, sports and count goes on. The driving force for the usage of AMC over other is due to its ductility, toughness, strength and being less expensive. In this investigation, AMC has been fabricated using aluminum alloy Al 6063 T6 as base matrix material as aluminum characterizes the property of being light weight, durable, corrosion resistance and good strength and strengthening it by adding hard ceramic particle Boron Carbide (B_4C) as reinforcement which the third hardest material known. Three different micro sizes of B_4C have been incorporated viz.104µm, 74µm, 53µm. Stir casting technique has been used to synthesize aluminum metal matrix composite. Though several other techniques are available for the composite preparation, stir casting is preferred because of being simple, cost-effective, convenient to use, suitable for mass production and one of the proven processes. Micro-structure and mechanical behaviour of the Al alloy and prepared composites has been analyzed. Through optical microscopy, uniform and proper distribution of B_4C particle is observed in the developed composites. It was observed that hardness of reinforced composite has been more than that of base alloy, in which composite with particle size 104µm has maximum hardness. Ultimate tensile strength of the prepared composite has found to be less as compared to base alloy which further shows a decreasing trend in tensile strength as the particle size decreases from to 104µm to 53µm.

Keywords-Al alloy 6063-T6, Boron Carbide, Stir Casting, Micro-structure, Micro-Hardness, Ultimate Tensile Strength

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

In current framework, there is a demand of a material that has superior and unusual combinations of properties which can satisfy the need of large sector industries like automobile, production, construction etc which can't be met by the metal alloys, ceramics, and polymeric materials. For example, aircraft engineers are increasingly searching for materials that have low densities, are strong, compact and impact resistant, and are light weight. The best material created by researches in order to fulfil the above requirement is composite. Recording a massive demand, one can consider composite as a next generation materials.

Defining composite as materials which are made by combining two or more components such that the final properties of which are different from the properties of individual components from which it is made.

It is a material in which the mixing of components is homogenous at macroscopic scale but gets heterogeneous at microscopic scale. Each of the components should have distinct properties from the prepared composite.

To annotate a certain materials as a composite, following requirements should be fulfilled.

1. Combination of materials should result in notable property changes
2. Amount of each constituent should be generally more than 10 %
3. In general, property of one constituent is much greater (≥ 5) than the other

Generally a composite comprise of two components-one is known as reinforcement and the other one is known as matrix. Reinforcement is that component which is discontinuous in nature, stronger and harder. The main functions that are performed by the reinforcements are that it imparts the desired propertied into the composite, helps in bearing the load that is applied over the composite and transfers the required strength to the matrix. Reinforcing constituents in composites, as the word indicates, provide the strength that makes the composite what it is.

The other component matrix is continuous in nature and perform functions such as it help to hold the reinforcement fibres together and protects it from environment and abrasion (among itself). It also helps to maintain the dispersion of fibres and distributes the loads evenly between fibres. There are some properties in respect of material and structure such as impact resistance, better finish and transverse strength of the lamina that cannot be imparted by the reinforcement itself, hence in that case matrix plays a significant role. Now there are some of the reasons that provide an edge to composites over other materials during selection of materials at any industrial level like-low weight, stiffness and strength, low coefficient of expansion, resistance against fatigue, ease in manufacturing complex shapes, simple repair of damaged structures, resistance to corrosion.

The biggest advantage of modern composite materials is that they are light as well as strong. By picking a proper combination of reinforcement and matrix material, a new composite can be made that unequivocally meets the necessities of a particular application despite of the fact that the resulting product is progressively proficient, the raw materials are regularly costly

1.1CLASSIFICATION OF COMPOSITES

There are two category according to which composite are classified-

The first classification is made on the basis of the type of matrix material used in the composite. The main materials that are being used as matrix are- Metal, Ceramics and Polymers and Carbon. So according to these matrixes, various composites can be prepared such as Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is commonly expected to incorporate two classes of composites, in particular Polymer Matrix Composites (PMCs) and carbon matrix composites generally known to as carbon-carbon composites.

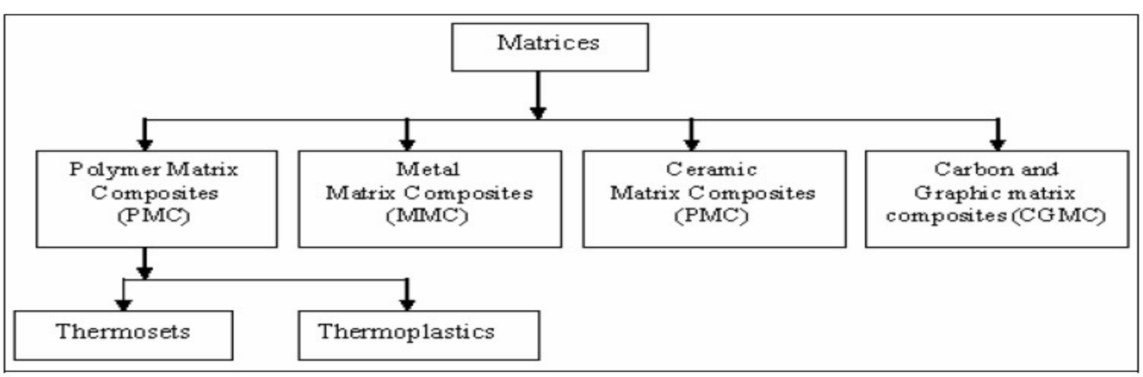


Figure 1-1 Classification on the basis of matrix material[2]

- The second classification is done on the basis of reinforcement form which can be of fibre, laminar or particle form. According to this various composites are prepared such as fibre reinforced composites, laminar composites and particulate composites. Fibre Reinforced composites (FRP) can be further sub classified into those containing discontinuous or continuous fibres.

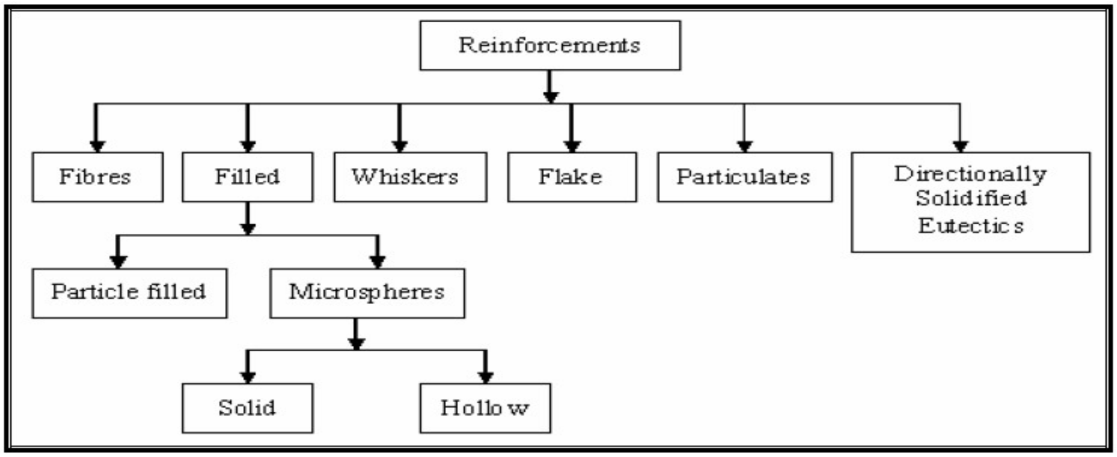


Figure 1-2 Classification on the basis of reinforcement [2]

Fibre Reinforced Composites are made of fibres that are embedded in matrix material. Fibre composite can further be divided into continuous and discontinuous fibres. Continuous fibres reinforced are those in which any further increase in length of the fibre does not affect the elastic modulus of the composite while discontinuous fibres reinforced are those in which its properties vary with the change in the length of the fibre. Fibres are small in diameter and when pushed axially, they bend easily although they have very good tensile properties. These fibres must be supported to keep individual fibres from bending and buckling.

- **Laminar Composites** are composed of layers of materials that are held together by matrix. Sandwich structures come under this.
- **Particulate Composites** are the composites in which reinforcements are present in the form of particles such that they are distributed all over the matrix. The particles may be flakes or in powder form. Concrete and wood particle boards are some good example of this.

  Taking about composite prepared from metal matrix and containing reinforcement in particle form-

Metal Matrix Composites (MMC)

Metal network composites, at present however producing a wide enthusiasm for research society, are not as broadly being used as their plastic partners. High quality, break durability and solidness are offered by metal frameworks than those offered by their polymer partners. They can withstand raised temperature in destructive condition than polymer composites. Most metals and alloys could be used as matrix and they require proper reinforcement materials which should be steady over a scope of temperature and non-receptive as well. Anyway the directing angle for the decision depends basically on the matrix material. Light metals form the matrix for temperature application and the reinforcements in addition to the aforementioned reasons are characterized by high moduli.

Most metals and alloys provide great frameworks for matrix. In any case, for all intents and purposes, the choices for low-temperature applications are very few. Only light metals are responsive, with their low density demonstrating a favorable position. Titanium, Aluminum and magnesium are the prominent network metals as of now in vogue, which are especially helpful for aircraft applications. If metallic matrix materials have to offer high strength, they require a reinforcement that has high value of modulus. The strength-to-weight ratios of resulting composites can be higher than most alloys.

The melting point, physical and mechanical properties of the composite at various temperatures determine the temperature of composites at which fulfill desired needs or applications. Most metals, ceramics and compounds can be used with matrices of low melting point alloys. The selection of reinforcement turns out to be increasingly hindered with increment in the liquefying temperature of matrix materials.

Particulate Reinforced Composites

Microstructures of metal and ceramics composites, which show particles of one phase strewn in the other, are known as particle reinforced composites.

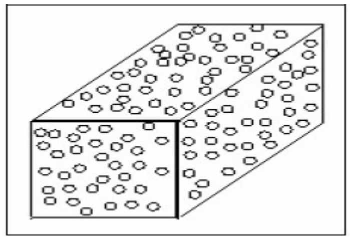


Figure 1-3 Particulate Composite [2]

CHAPTER 2

LITERATURE REVIEW

This study investigated the microstructure and mechanical properties of aluminium matrix composite using boron carbide as reinforcement. The main purpose was to enhance the tensile strength and hardness for the composite. For this Al-6061 was taken and reinforced with boron carbide particulates of 37, 44, 63, 105, 250µ sizes respectively using stir casting techniques. There was a homogenous dispersion of the boron carbide particles in the composite. The hardness and tensile strength of the composite was found to be increased with the increase with size of the boron carbide particles and increase in the weight percentage of the reinforcement. [1]

In this, it was investigated how the mechanical properties and failure mechanism of aluminum composite reinforced with silicon carbide changes under compression with strain rates from .001 to 5200 per second. For this the weight percentage of SiC was taken 65% and sizes were 10 µm and 50 µm. Quasi static and dynamic compression tests were performed for both composites. The results showed that on increasing strain rate the yield strength of the two composites increases in which the yield strength of composites having smaller SiC size has higher than larger one. Similarly the composite with smaller size of SiC act superior than the larger size of SiC under the compression loading due to the more compact interface and larger tension for movements of dislocations.[2]

In this investigation, work is carried out in which a composite was prepared of the AA6351 using silicon carbide as reinforcement. Different weight fractions were used for SiC which vary from 0% to 20%.The prepared composite was examined for density, hardness, yield strength, impact strength and under optical microscope. The optical microscope showed uniform distribution of SiC in the aluminium composite and mechanical properties shows an increasing tendency with the increase in the weight percentage of the reinforcement. [3]

This study investigated the wear rate in terms of weight per unit load and wear volume of a composite that was prepared using aluminum 356 as a matrix material and boron carbide as a reinforcement. The composite was prepared using stir casting technique and the weight percentage of the boron carbide was changed as 3%,6%,9% and 12% respectively. As the weight percentage of B_4C and load increases, the wear rate and wear volume increase such the wear rate was maximum for 9% B_4C composite but decreases as % comes to 12%.[4]

In this research work, fabrication of a composite having aluminum 6161 as base matrix metal and boron carbide (B_4C) as the reinforcement was done. The weight percentage of B_4C were 6,8,10 and 12% and various sizes of B_4C were taken as 37µ,44µ,63µ,105µ,250 µm. Mechanical properties and microstructure were studied. Optical microscopy and XRD revealed the homogeneous distribution of B_4C in the AL composite. The hardness was maximum for 250µm size and weight percentage of 12%.And tensile strength comes maximum for size 105 µm and weight percentage of 8%.[5]

In this investigation, preparation of an aluminium 2024 based composite having B_4C as reinforcement using stir casting technique was performed. The two weight percent of B_4C were taken as 5% and 10%.Tensile and hardness test were conducted on both the composites. Tensile strength comes maximum for 10% B_4C and Rockwell hardness comes maximum for 5% B_4C. [6]

In this study boron carbide with size 30µm and of different weight percentage as 2.5%,5 and 7.5% was used for the preparation of composite having aluminum-silicon alloy(LM6) as matrix using stir casting technique. Hardness and ultimate compression strength of the composite increase but density decrease with the increase in weight % of B_4C.SEM show uniform distribution of B_4C in the composite. [7]

In this investigation, fabrication of a composite having aluminum 2024 alloy as matrix and B_4C as reinforcement was done .Different size of B_4C were used for the preparation of the composite such as 0%,1%,2%,3%,4% and 5%.XRD and optical microscopy showed uniform distribution of B_4C in the composite. The tensile and hardness comes maximum for 5% B_4C in the composite. [8]

In this work, it was studied the effect of B_4C on the mechanical and tribological behaviour of the Al 7075 based composite which was produced using stir casting technique. For this various sizes and percentages of B_4C were used such as -5,10,15 and 20 volume % and size from 16µm to 20µm.Hardness,tensile,compression, flexural strength and wear behaviour were studied for each of the prepared composite. Results revealed that hardness, tensile, compression and flexural strength increase on increasing the volume fraction of B_4C and higher than the base alloy. Wear resistance increases on increasing the B_4C particle content.[9]

In this investigation, an aluminum based composite containing B_4C as the reinforcement was used .Two sizes of B_4C were used –micro (70μm)and nano(100 nm) and different weight percentages were used-2,4,6,8 and 10%.The composite were prepared using stir casting and ultrasonic cavitations-assisted stir casting techniques. Mechanical and wear behaviour were studied.SEM and X-Ray show uniform distribution of B_4C in the composite. According to size , nano composite were stronger, have high impact energy and were more ductile than the micro composites. Increasing the weight percentage increases the tensile strength of the composite but decrease the ductility. Hardness of micro and nano composites increases with weight % upto 8% and then decreases. [10]

In this research work, it was found the improvement in the mechanical properties of the aluminum composites AL-Si12Cu/B_4C using B_4C as reinforcement with size 33μm and varying weight percentages of 2,4,6,8 and 10%.The composite was prepared using stir casting technique. Results showed that hardness increase as weight 5 of B_4C increase due to the resistance offered by the B_4C particle to the plastic deformation while tensile strength increase mainly up to 8% greatly and then level of increase reduce due to the clustering of B_4C particles.[11]

In this paper, fabrication an aluminium composite containing boron carbide and graphite as the reinforcements with various volume fractions of B_4C particles viz.2.5%,5% and 7.5% ,keeping graphite at 2% constant using stir casting technique was used. Mechanical behaviour and wear test were performed. The conclusions drawn that optical microscopy and SEM show uniform distribution of B_4C in the composite. Hardness of composite increase by 48% if volume fraction of B_4C increases from 2.5% to 5% and increases by 11.83% if B_4C content increase from 5% to 7.5%.Tensile strength increases up to 5% and then decreases. Compression strength comes higher for 5% reinforcements of B_4C in the Al composite. Wear rate show an increasing tendency on increasing the content of B_4C in the composite. [12]

In this research work, it was examined aluminum 6061 matrix which was reinforced with B_4C particles with various weight percentages viz.6,8,10,12 wt% respectively using stir casting technique. Microstructure and mechanical properties were analyzed for each composite.XRD and optical microscopy revealed uniform distribution of B_4C in the composite. Micro Vickers hardness comes maximum for 12% wt B_4C and tensile strength comes maximum for 8% wt B_4C.[13]

In this paper, it investigated the effect of boron carbide different sizes on the abrasive wear behaviour of the Al-5083 composite. Micro, sub micro and nano size of B_4C were used and the composite was prepared using cryogenic mechanical alloying and dual mode dynamic forging. Abrasive wear resistance comes maximum for nano size B_4C due to its high hardness and more interfacial area and decrease as the size increases.[14]

In this investigation, preparation of composite using Aluminum-LM13 grade as base metal and B_4C as reinforcement using sand casting technique was used. The weight percentage of the B_4C was varied from 3% to 9% and cooling rate was measured using k type thermocouple at point 1mm away from the mould cavity. Cooling rates and mechanical properties of the prepared composites were studied. Results showed that cooling rates and mechanical properties such as hardness, tensile strength increases with increase in the percentage of B_4C.[15]

In this study, fabrication of a composite using Aluminum A356.1 as the base metal and boron carbide (30µm) as the reinforcement was done. The manufacturing was done using stir casting technique .Mechanical and physical properties test were performed after solidification of the specimens. The conclusions drawn were that as the volume fraction of B4C increase, the tensile strength and hardness of the composite also increases. On increasing the temperature from 800 °C to 1000°C, wettability and mechanical properties enhances.[16]

In this work,it was studied the effect of reinforcement particle size and number of passes in friction stir processing in the composite prepared from aluminum as base matrix material and boron carbide as the reinforcement. The two sizes of reinforcement taken were micro (20µm)

and nano size(30-60 nm).The effects were studied on micro structure ,micro hardness , tensile strength and wear strength of the composite. The microstructure revealed that composite with nano size B_4C particle and having three passes have fine grains size, high hardness, and tensile strength and wear rate than base alloy. And as the number of passes increase, there is an increasing tendency shown by all the above mechanical properties. Wear properties and wear rate of nano sized B_4C composite is better than the micro sized B_4C composite.[17]

In this work, development of two composite, one was Al 6061 having boron carbide(with 10% wt,20-50 µm size) as reinforcement and other was Al 6061 having boron carbide (10% wt,20-50 µm) and graphite(3,20 µm size) as reinforcement was done. Dry sliding wear behaviour and hardness of Al 6061 base alloy and above two composites were studied. Scanning electron microscope revealed the uniform distribution of B4C and graphite in the composite. The hardness of hybrid composite was less than the B_4C composite by 21%.Th wear rate of hybrid composite that is Al 6061-B_4C-Gr hybrid composite is higher than that of B_4C composite and is much higher than the Al -6061.[18]

In this paper ,it was studied that by modifying the design of the stirrer of the stir casting equipment like the geometry of the stirrer and increase in the stirring force helps in getting homogenous distribution of the reinforcement particle and reduce the formation of cluster respectively. By modifying the feeding mechanism improves in the uniformity of the reinforcements and controlled spraying of particulates helps in enhancing the properties of composite.[19]

In this study, fabrication of composite of Al 6061 as base matrix and TiC as reinforcement by enhancing some of the factors that affect in the mechanical properties of the final prepared composite was done. In order to have a proper melting of the base alloy, the temperature of the furnace was initially increased to 30°C above the melting temperature of the base alloy and during stirring the temperature was further increased to 50°C in order to compensate for the cooling effect of the stirring. The reinforcement was wrapped in the aluminum foil in order to insert into the molten base alloy present in the crucible. To increase the wettability of TiC with the aluminum alloy, magnesium was added to it and to avoid the oxidation of the composite, inert gas argon was passed. After enhancing all the above factors, SEM shows the proper distribution of the reinforcement in the composite and hence a defect free composite was prepared.[20]

In this investigation, fabrication of a composite using LM24 Aluminum alloy as base matrix and B_4C_p as the reinforcement. Different weight percentage of B_4C_p ahs be considered-1%,2% and

3%.Particle size of 10 m of B4CP has been taken. Microstructure and mechanical properties were evaluated. Results revealed a uniform distribution of B_4C particles in the molten melt of LM24 Al alloy. Hardness of AMC with 3% B4C was found to be maximum using Brinell hardness test and base alloy has more tensile strength than AMC's.[21]

RESEARCH GAP

There are several challenges related to the development, commercial viability and wide spread usage of MMCs. Increased processing cost, lack of theoretically predicted properties, lack of available design data, doubted recyclability, reclamation and secondary processing capability, compromised ductility and toughness are few of the reasons that limit the uses of MMCs in various sectors in spite of their superior characteristics.

In order to enhance the usage of composites in various industries, following problems that are encountered while making of composites has to be solved-

- During preparation of composites, there is a non uniformity in the mixing of the rein enforcement into the metal matrix. Hence it’s needed to optimize the mixing of the reinforcement into the matrix. Mechanisms behind different processing techniques is to be understood thoroughly in order to achieve uniform dispersion of reinforcement, strong interfacial bonding and improved wettability without affecting the micro structural integrity of the composites.
- Occurrence of Porosity-Blow holes during the stir casting of the metal matrix composites where blow holes can be define as gases entrapped by solidifying metal on the surface of the casting, which results in a rounded or oval blowhole as a cavity, frequently associated with slag's or oxides

OBJECTIVE OF PROJECT

- Fabrication of MMCs by using stir casting method
- Various sizes of same reinforcement can be used to get the various combinations of metal matrix composites.
- Size variation will be of different mesh size but at same micro-level.
- Microstructure of the prepared composite is studied under microscope of desired resolution.
- Mechanical properties of fabricated composites are studied by using micro hardness test, tensile test.

CHAPTER 3

RESEARCH METHOLOGY

3.1 ALUMINIUM

Aluminium is a silvery-white metal which comes at the 13^{th} place in the periodic table. Aluminium is the most widespread metal on Earth, present at level more than 8% of the Earth's core mass. After oxygen and silicon it is the third most common chemical element on earth. Due to its binding nature with other elements, it is pure form cannot be found in nature. The most common form of aluminium that is found in nature is aluminium sulphates which are minerals that combine two sulphuric acids: one based on an alkaline metal (lithium, sodium, potassium rubidium or caesium) and one based on a metal from the third group of the periodic table, primarily aluminium.

The origin if the name aluminium was from aluminium sulphates which stands for alumen in Latin. Aluminum offers an uncommon blend of profitable properties. Since aluminum can easily form compounds with other elements so a wide variety of its alloy can be developed. In order to achieve the required properties to be used in new areas, even a small amount of mixture can provide that. A large amount of such examples cab be seen in daily life such as the mixture of silicon and magnesium with aluminium can be seen on the road in the form of aluminium alloy wheels, in the engines, chassis and other parts of modern vehicles.

It is impossible to imagine big industries like construction, automotive, aviation, energy, food and other industries without aluminium. In addition to this, aluminium has become a symbol of development: all cutting edge devices and vehicles are made from it.

There are many ways to combine aluminum with other materials in order to form a new material that is known as composite (hybrid materials made from two or more materials that retain their identity without chemically combining or mixing). In most of the composite, aluminum is used as a base matrix material and is reinforced with particles of different properties in order to produce a material, which are strong, light weight and can be used in wide applications.

3.1.1 The Benefits of Aluminum and its alloy

1. Light metal
2. Has good corrosion resistance to common atmospheric and marine atmospheres.
3. Has high reflectivity and can be used for decorative applications.
4. Some aluminum alloys can match or even exceed the strength of common construction steel.
5. Retains its toughness at very low temperatures, without becoming brittle like carbon steels.
6. A good conductor of heat and electricity.
7. Readily worked and formed using a wide variety of forming processes including deep drawing and roll forming.
8. Non-toxic and is commonly used in contact with foodstuffs.
9. Can be readily recycled.

3.2 WROUGHT ALUMINUM ALLOY DESIGNATION SYSTEM

6xxx series-Magnesium and Silicon

6XXX Series Alloys -These are aluminium alloy containing silicon and magnesium up to 1% and have wide applications in welding fabrication industry, used predominantly in the form of extrusions, and in many structural components. Adding magnesium and silicon to aluminum forms a compound of magnesium-silicide, that provides this material its ability to become solution heat treated which increase its strength. These alloys are naturally solidification crack sensitive and this is the reason that they are not arc welded autogenously (without filler material).Adding sufficient amounts of filler material while arc welding process is essential in order to provide dilution of the base material, in order to prevent the hot cracking problem. They are welded with both 4xxx and 5xxx filler materials, dependent on the application and service requirements.

3.2.1 THE BASIC TEMPER DESIGNATIONS

While designating the aluminium alloys, T stands for Thermally Treated means the products that are being heat treated in order to produce stable temper where “T” is always followed by one or more digits like **T6** here it stands for solution that is heat-treated and artificially aged.

3.3 ALUMINIUM ALLOY 6063 T

AA 6063 is an aluminium alloy, in which magnesium and silicon are main alloying elements. Aluminium alloy 6063 is an alloy having medium and commonly known to as an architectural alloy. It is normally used in intricate extrusions. It has a decent surface completion, high corrosion resistance, is promptly fit to welding and can be effectively anodized. It has commonly great mechanical properties and is heat treatable. Most generally accessible as T6 temper.

3.3.1 COMPOSITION OF AA 6063 T6-

Table 3-1Composition of Al-6063 [29]

Element	% Present
Magnesium (Mg)	0.45 - 0.90
Silicon (Si)	0.20 - 0.60
Iron (Fe)	0.0 - 0.35
Others (Total)	0.0 - 0.15
Chromium (Cr)	0.0 - 0.10
Copper (Cu)	0.0 - 0.10
Titanium (Ti)	0.0 - 0.10
Manganese (Mn)	0.0 - 0.10
Zinc (Zn)	0.0 - 0.10
Other (Each)	0.0 - 0.05
Aluminium (Al)	Balance

3.3.2 SUPPLIED FORMS

Alloy 6063 is can be found in various forms such as-

- Extrusions
- Tube
- Bar

• Rod

3.3.3 PROPERTIES OF AA 6063-T6

Table 3-2 General Physical Properties [29]

Property	Value
Density	2.70 g/cm^3
Melting Point	655 °C
Thermal Expansion	23.5 x10^{-6} /K
Modulus of Elasticity	69.5 GPa
Thermal Conductivity	201 W/m.K
Electrical Resistivity	52 % IACS
Electrical Resistivity	0.033 x10^{-6} Ω .m

Table 3-3Mechanical Properties [29]

Rod & Bar Up To 150mm Dia. & A/F	
Property	Value
Proof Stress	170 Min MPa
Tensile Strength	215 Min MPa
Elongation A50 mm	8 Min %
Hardness Brinell	75 HB
Elongation A	10 Min %

3.3.4 APPLICATIONS

6063 has wide applications in

- Rail and road transport
- Extreme sports equipment
- Architectural applications
- Extrusions
- Window frames and Doors

- Shop fittings
- Irrigation tubing

3.4 BORON CARBIDE

Boron carbide is an extremely hard boron–carbon ceramic and covalent material utilized in tank defensive layer, impenetrable vests, motor damage powders and various other mechanical applications. With a Vickers Hardness of >30 GPa, it is one of the hardest known materials, behind cubic boron nitride and precious stone diamond.

Nickname - Black diamond for its extreme hardness.

Chemical Formula - B_4C

Preparation-

In order to prepare boron carbide, boron trioxide is treated with carbon or magnesium in an electric furnace having a presence of carbon. While using carbon, reaction take place at temperature higher than the melting point of boron carbide and carbon monoxide is liberated.

$2\ B_2O_3 + 7\ C \rightarrow B_4C + 6\ CO$

After granulating, the dark powder is hardened by squeezing at temperatures surpassing 2,000° C (3,630° F).

Some of the properties of B_4C are-

- At normal state, it is a dark black powder
- Have no odour
- Insoluble in water
- Have molar mass equal to 55.255 g/mol
- Hardness of about 9 to 10 oh mohs scale
- Melting and Boiling point are 2763°C and 3500°C respectively.
- Density of around 2.52 g/cm^3
- Specific gravity is 2.52.
- Have a rhombohedral crystal structure.

Uses-

- Having a good hardness along with very low density, it is used as reinforcement with aluminum in military armor and high-performance bicycles

- Used in wear and tear resistant coatings as being a wear resistant ceramic.
- It is a grating substance utilized for forming and cleaning work-pieces produced using metal and other hard materials.
- This artistic substance is utilized in Metal Matrix Composites.
- Boron Carbide is utilized in ballistic missile destroying plating of body reinforces for human and vehicles. These defensive layer plates can oppose the effect of weapons like projectiles, shrapnel and rockets.

Table 3-4 Particle Size / Mesh Conversion Chart [23]

Particle Size		U.S. Std. Sieve		Tensile Bolt Cloth			Market Grade		
Inches	Microns	Std Sieve	Opening In Inches	Mesh TBC	Opening Inches	Opening Microns	Mesh MG	Opening Inches	Opening Microns
0.0083	210	70	0.0083	84	0.0084	213			
0.0079	200			88	0.0079	201			
0.0076	193			90	0.0076	193			
0.0070	177	80	0.0071	94	0.0071	180	80	0.0070	178
0.0065	165			105	0.0065	165			
0.0059	149	100	0.0059	120	0.0058	147	100	0.0055	140
0.0049	125	120	0.0049	145	0.0047	119	120	0.0046	117
0.0041	105	140	0.0042	165	0.0042	107	150	0.0041	104
0.0035	88	170	0.0035	200	0.0034	86	170	0.0035	89
0.0029	74	200	0.0030	230	0.0029	74	200	0.0029	74
0.0025	63	230	0.0025				250	0.0024	61
0.0021	53	270	0.0021	300	0.0022	56	270	0.0021	53
0.0017	44	325	0.0018				325	0.0017	43
0.0015	38	400	0.0015				400	0.0015	38
0.0010	25	500	0.0010				500	0.0010	25
0.0008	20	635	0.0008				635	0.0008	20

3.5 STIR CASTING TECHNIQUE

3.5.1 Processing of metal matrix composites

There are lot of advantages that are provided by the metal matrix composite as compared to metals. To manufacture metal matrix composite, a lot of process are available which are classified in the basis of temperature of the metallic matrix during the preparation of composite. Mainly these process are classified into five categories –

(1) Liquid-phase processes,

(2) Solid–liquid processes

(3) Deposition techniques and

(4) In situ processes.

(5) Two- phase (solid–liquid) processes.

Focusing on the first and the most common one-

Liquid state fabrication of Metal Matrix Composites – In this process, the reinforcement is added into the molten metal matrix in the form of dispersed phase then after solidification takes place. Due to the addition in the form of dispersed form, a good mechanical properties and interfacial bond is achieved between the dispersed phase and molten matrix.

In order to improve wettability, coating is done on the dispersed particle as coating not only lessens the interfacial energy but also prevent chemical interaction between the dispersed phase and the matrix.

Various methods of liquid state fabrication of Metal Matrix Composites:

- Stir casting,
- Infiltration like gas pressure infiltration ,
- Squeeze casting infiltration or Pressure die infiltration.

For the preparation of the composite, stir casting technique is being used, hence following paragraph mainly focuses on it.

3.5.2 STIR CASTING

This technique comes under the category of liquid-state method and is one of the most common and cost-effective for the preparation of the composite .In this technique, reinforcement is mixed with the molten metal with the help of a mechanical stirrer which is, made to run by a motor. After mixing of the reinforcement, liquid composite material is casted by the other conventional casting method and processed by metal forming technologies, if required.

3.5.2.1 Process parameters of stir casting process

Stir casting stand apart from many methods to prepare composites because of the following reason –

- Highly economical method as require only one-third of cost to prepare as compared to other methods.
- High volume of production is possible
- Large sizes product can be fabricated.

While preparing metal matrix composite using stir casting technique, various factors play an important role such as-

(a) Non -uniform distribution of the reinforcement material

(b) Mixing or Wettability between the reinforcement and the molten metal

(c) Occurrence of Porosity while casting metal matrix composites and

(d) Occurrence of chemical reactions between the main substances.

(a)**Proper distribution of reinforcement materials in matrix**

While adding reinforcement into the molten metal, it is important that proper mixing must occur. But some time due to density difference among the reinforcement and molten metal, on uniform or cluster type distribution occur. Hence in order to avoid this, vortex method is used during stir casting. In this method, after melting the metal, its is stirred continuously to form vortex at the surface of the melt. And then reinforcement is added at the side of the vortex. Then stirring continues for few minute before slurry is cast.

Wettability should be proper among the reinforcement and molten metal which means liquid must spread properly on the solid ceramic reinforcement surface. Good wettability helps to attain quality metal matrix composite

(b) **Porosity in cast metal matrix composites**

Some of the reasons due to which pores occur in the casting are- entrapment of gas during mixing, hydrogen evolution and shrinkage during solidification. These problems can be minimized by proper mechanical stirring.

The nature of samples which are casted in stir casting procedure relies upon different procedure parameters like mixing speed, mixing time, holding time, pouring temperature and the size and position of impeller. By controlling these parameters the porosity, wettability in cast metal lattice composites can be improved.

Following components which influence the stir casting process the most. They are

1. Speed of mixing/stirring

2. Time length of mixing/stirring

3. Mixing temperature

A. SPEED OF STIRING

In order to achieve the desired properties, there must be proper and uniform distribution of reinforcement in the molten metal matrix. Now if the RPM of the stirrer is low, a low shear force will act on molten metal and no space will be there for the reinforcement to get uniformly distributed and rather they start forming clusters.. All this occur due to the absence of the required force to resist it. As the speed of the stirrer is increased, this increases the force on the molten metal, which creates a passage for the reinforcement particle to move in the vortex created by the stirrer as energy provided by increasing the RPM, helps to attain uniform distribution of the reinforcement particle. But the limitation of increasing the rpm is that porosity occurs due to entrapment of the gas particle.

B. TIME DURATION OF STIRRING

This factor plays an important role in the uniform distribution of the reinforcement in the molten metal matrix. If stirring is done for less time, it cause agglomeration of reinforcement particles and maybe possible, some portion of metal matrix do not contain any reinforcement. On increasing the stirrer time, reinforcement get properly distributed in the molten matrix and help in enhancing the mechanical properties of the composite.

C. STIRRING TEMPERATURE

This is one of the most important factors affecting the stir casting process. As temperature increases, viscosity of the molten metal also increases and due to this, mixing of reinforcement get affected. Increase in the temperature of the melt, also enhances the chemical reaction between the reinforcement and the metal matrix.

3.5.3 Fabrication of AMC's

Al 6063 –T6 alloy was used as the matrix and B_4C of mesh size 150,200 and 270 at 6 wt% were used as reinforcement in the AMCs.

Liquid metallurgy stir casting method was adopted for composite fabrication, which essentially included following steps, i.e. melting of matrix alloy, preheating of reinforcement particulates, mixing of preheated particulates into molten alloy, solidification

Step 1-A graphite crucible of cylindrical in shape, having a maximum working temperature of 2700°C and required dimension, 3-phase electrical resistance furnace (maximum working temperature 1500°C) was used for melting of the matrix alloy and composite slurry preparation. It was mounted with a K-type thermocouple with a maximum range of 1200°C and speed regulated motorized stirring system.

Step 2-The B_4C was heated to 350°C for 45 min using muffle furnace and, before mixing with the molten alloy. Preheating of B_4C is necessary to oxidize their surface remove moisture and improve wettability in matrix material

Step 3-Before addition of preheated B_4C, vortex was created on the surface of molten alloy by motorized stirring at stirring speed of 400rpm. The particulates were added at slow rate (approximately 10 g/min) using a funnel and rod, into the vortex of molten alloy. The stirrer speed was then slowly increased to 220 rpm and stirring was continued for 10 minutes more. The stirrer blades were positioned at one-third of the depth of the molten slurry from its surface, to enable proper mixing.

Step 4-After mixing the reinforcement for about 15 min with the help of stirrer ,stirrer is taken out and composite slurry is allowed to get cool and solidify and then the cast AMC was removed out of the graphite crucible

3.6 MUFFLE FURNACE

A muffle heater is a heater with a remotely warmed chamber, the dividers of which brilliantly heat the substance of the chamber, so the material being warmed has no contact with the flame. Muffle heaters are frequently used in research facilities as a minimal method for making incredibly high-temperature environments. They are utilized to test the attributes of materials at amazingly high and precise temperatures. A muffle furnace is also known as a retort furnace**.**

3.6.1 CONSTRUCTION OF MUFFLE FURNACE

Furnace mainly consists of

- A vented warming chamber

- ➢ A temperature controller
- ➢ a door safety switch for the safety of the operator

3 .6.2 WORKING OF MUFFLE FURNACE

A muffle furnace is a bit of oven-type equipment that can achieve high temperatures. It more often works by putting a high-temperature warming loop in a protected material. The protecting material successfully goes about as a muffle, keeping heat from getting away.

Furnace is usually heated to desired temperatures by-

- Conduction
- Convection
- Blackbody radiation from electrical-resistance heating elements

A valuable metal thermocouple detects the temperature in the chamber and transmits this data to the temperature control in mill volts. The control segment comprises of a temperature controller, a current controller, a transformer, a contactor (relay), an electrical switch. The temperature controller detects the heater temperature (by methods for the thermocouple) and changes power to the warming components by methods for the present controller. The flow controller controls power to the warming components by changing the extent of the electrical flow (as opposed to turning the power totally on or off). This is the favored technique for controlling power to molybdenum di silicide warming components. At the point when all the fundamental work is done and the current is controlled at that point sample gets warmed to the ideal temperature and after that expelled.

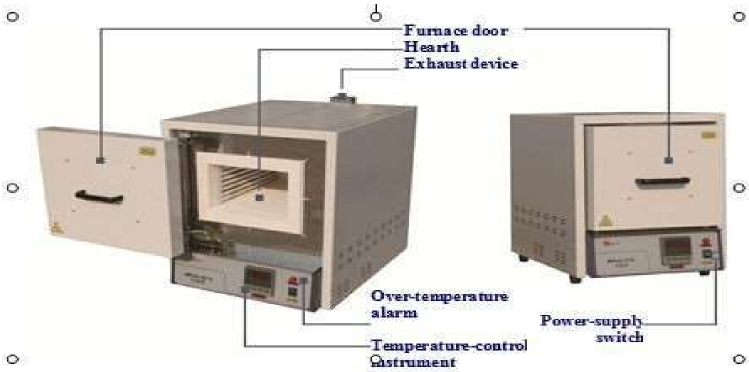


Figure 3-1Muffle Furnace[22]

There is typically no combustion engaged with the temperature control of the framework, which takes into account a lot more prominent control of temperature consistency and guarantees confinement of the material being warmed from the results of fuel combustion.

3.6.3 Applications

Use for high temperature applications such as-

- Creation of enamel coatings
- Ceramics
- Soldering and Brazing
- Fusing glass

They are additionally utilized in many research areas, for instance by scientific experts so as to figure out what extent of a sample is non-burnable and non-volatile. Advances in materials for warming components encourage increasingly complex metallurgical applications.

3.7 WIRE CUT ELECTRIC DISCHARGE MACHINING (WEDM)

The Wire Electric Discharge Machining (WEDM) is a variety of EDM and is generally known as wire-cut EDM or wire cutting. In this procedure, a slender metallic wire is fed on to the workpiece, which is submerged in a tank of dielectric liquid, for example, de-ionized water. This procedure can likewise cut plates as thick as 300mm and is utilized for making punches, tools and dies the bucket from hard metals that are hard to machine with different techniques. The wire, which is continually encouraged from a spool, is held among upper and lower diamond aides. The aides are generally CNC-controlled and move in the x–y plane. On most machines, the upper guide can move autonomously in the z–u–v hub, giving it an adaptability to cut decreased and changing shapes (model: square at the base and hover on the top). The upper guide can control pivot developments in x–y–u–v–I–j–k–l–.This aide in programming the wire-cut EDM, for cutting unpredictable and fragile shapes.

In the wire-cut EDM process, water is ordinarily utilized as the dielectric liquid. Channels and de-ionizing units are utilized for controlling the resistivity and other electrical properties. Wires made of brass are commonly liked. The water helps in flushing ceaselessly the waste from the cutting zone. The flushing likewise decides the feed rates to be given for various thicknesses of the materials.

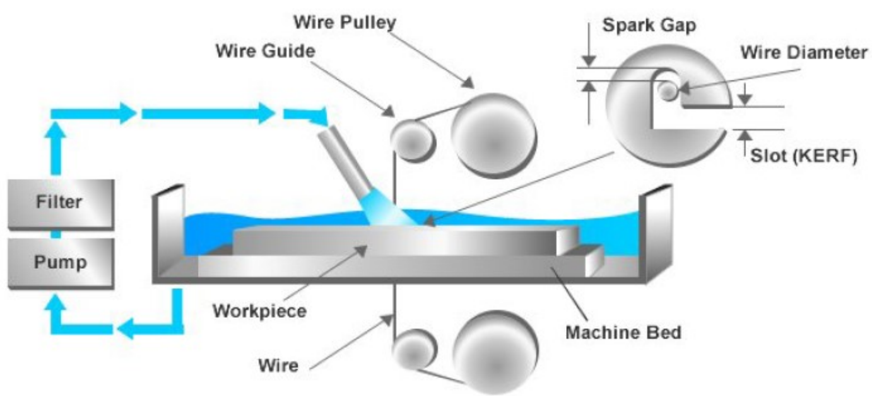


Figure 3-2 Schematic diagram of wire –EDM machine [23]

The WEDM procedure requires lesser cutting powers in a material evacuation; thus it is commonly utilized when lower value of residual stress in the work piece is desired. If the vitality/control per heartbeat is generally low (as in completing activities), little changes in the mechanical properties of the material are relied upon because of these low residual stresses. The materials which are not pressure relieved before can get misshaped in the machining procedure.
The choice of procedure parameters is essential, as now and again the work piece experiences noteworthy thermal cycles that can be extreme. These thermal cycles can frame recast layers and prompt residual stress weights on the work piece which are undesired.

3.7.1 Process of Material Removal in Wire-Cut EDM

In the WEDM procedure, the movement of wire is moderate. It is sustained in the modified way and material is cut/expelled from the workpiece as needs be. Electrically conductive materials are cut by the WEDM procedure by the electro-warm systems. Material expulsion happens by a progression of discrete releases between the wire cathode and workpiece within the sight of a di-electric fluid. The di-electric liquid gets ionized between the apparatus cathode hole along these lines making a way for each release. The zone wherein release happens gets warmed to extremely high temperatures to such an extent that the surface gets softened and expelled. The cut particles (debris) escape by the persistently streaming dielectric liquid.

3.7.2 Applications of Wire-Cut EDM

Wire EDM is utilized for cutting aluminum, metal, copper, carbides, graphite, steels and titanium. The wire material differs with the application prerequisites. Examplel: for snappier cutting activity, zinc-covered metal wires are utilized while for progressively precise applications, molybdenum wires are utilized.

The process is used in the following areas-

- Aerospace, Medical, Electronics and Semiconductor applications
- Tool & Die making industries
- For cutting the hard Extrusion Dies
- In making Fixtures, Gauges & Cams
- Cutting of Gears, Strippers, Punches and Dies
- Manufacturing hard Electrodes
- Manufacturing micro-tooling for Micro-EDM, Micro-USM and such other micro machining applications.

The Subsystems of Wire EDM

- Power supply.
- Dielectric system.
- Wire feeding system.

- Positioning system.

The power supply and di-electric framework utilized in WEDM is fundamentally the same as that of the traditional EDM. The primary distinction lies just in the sort of dielectric utilized. In wire cut EDM, a moving wire anode is utilized to cut complex diagrams and fine subtleties the required work piece. The wire is twisted on a spool and is kept in consistent strain. The drive framework consistently conveys the crisp wire on-to the work region. New wire is constantly presented to the work piece thus the wear of the wire (instrument) isn't the major issue in WEDM process The wire encouraging framework comprises of an enormous spool of wire and rollers which direct the wire through the machine. The nearness of metal contact gives capacity to the wire and aides it further so as to keep it straight all through the cutting process.

Different parts are the squeeze rollers which give drive and wire strain, a framework to string the wire from the upper to the lower manage and a sensor to identify when the wire runs out or breaks.

3.7.3 Process Parameters in WEDM

The procedure parameters that can influence the nature of machining or cutting or penetrating in WEDM procedure are as per the following:

- Electrical parameters: Peak flow, beat on schedule, beat off time and supply voltage and extremity
- Non-electrical parameters: Wire speed; work feed rate, machining time, increase and rate of flushing.
- Electrode based parameters: Material and size of the wire.
- Dielectric System: Type, thickness, and other stream qualities.

3.7.4 Advantages of Wire EDM Machining

- Accuracy
- Multifaceted nature
- Shorter lead times
- Less set up time
- Tapers
- Exact inner cuts

- Better outcomes
- Fine opening boring

3.8 TENSILE TEST

Tensile test is also known as tension test. This is one of the most common type of test that is performed on a material to test its properties and comes under the category of destructive test. In this test, a tensile load is applied on a specimen which is of the desired shape and then its response is calculated. This test gives the measure of strength of the material in various terms such as ultimate tensile strength, yield strength etc under different loading and how ,much it can elongate. These types of test are helpful in finding the breaking point of composites or plastics and the limit up to which the specimen can stretch by plotting stress-strain graph.

This test is performed on machine named as-Universal Testing Machine(UTM).UTM machine is also known as tensile tester or compression tester or bend tester It name “Universal “is derived from the fact that it can perform various type of test like-Tension, Compression, Bend, Peel, Puncture.

With the help of tensile testing of a specimen a lot of properties of a material can be known or evaluated. With this test, a stress-strain of a material can be plotted and lot of values like young’s modulus, yield strength, ultimate tensile strength can be calculated.

Some important definition related to tensile test.

Ultimate Tensile Strength

It is defined as the maximum value os tress or load that can be sustain by the specimen during tensile loading.

Hooke's Law

Also known as law of elasticity .When a load is applied on a material within the elastic limit, stress induced in the material is directly proportional to stain produced. The ratio of stress and strain gives a constant known as modulus of elasticity or Young’s modulus (E).

Modulus of Elasticity

The modulus of elasticity can be defined as a quantity that measures a material’s stiffness which only applies in the initial linear region of the curve. In this region, when the load is removed, specimen return to its original state as it was earlier before applying the load.

Yield Strength

It is that stress which when applied to the material, plastic deformation start taking place.

Strain

Strain can be defined as how much a material elongates or stretches when subjected to tensile loading.

Strain can be of two types-

1) Engineering Strain which is the ratio of change in length t the original length of the specimen.
2)) True Strain (ε) which is defined as a ratio of change in length to the instantaneous length of the specimen under tensile loading.

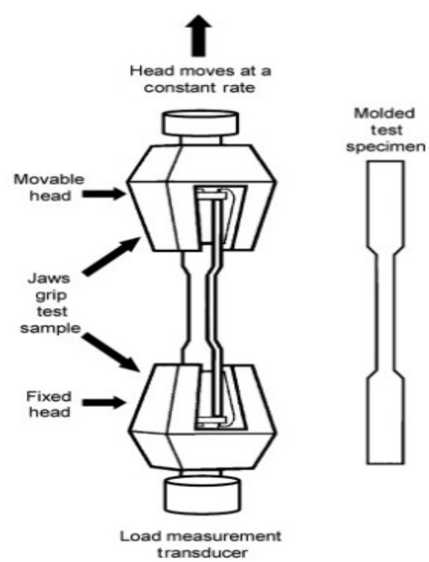


Figure 3-3 Schematic diagram of specimen on UTM machine [25]

3.9 HARDNESS TEST

Hardness is a characteristic in which material shows resist to the indentation, scratches or deformation while application of load. While measuring hardness, a fixed load is applied on the materials and then by measuring the permanent depth, hardness is evaluated. The size of indentation give the measure of hardness as smaller the indentation harder the material and vice versa. Indentation hardness value is obtained by measuring the depth or the area of the indentation using various methods.

Micro hardness test basically means applying a load not more than 1kgf in order to get a static indentation. Vickers diamond pyramid or the Knoop elongated diamond pyramids are the indenters that are used in micro hardness test. In this the procedure for conducting the testing is similar to that of the standard Vickers hardness test, only difference is that this test is done on microscopic scale. Proper metallographic finish is required on the surface of the sample. This directly connected to the load. Lesser is the load, more the surface finish is required.

The **Vickers hardness test method**, known as a micro hardness test method, is mostly used for small parts, thin sections, or case depth work and is based on an optical measurement system.

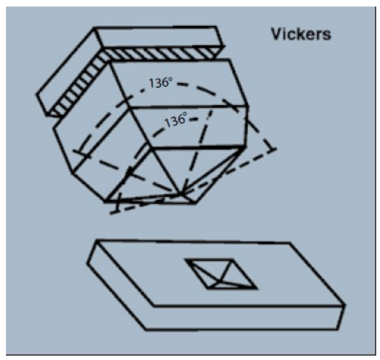


Figure 3-4 Vickers hardness Test Diagram [25]

The Vickers hardness test technique comprises of indenting the test material with a diamond indenter, as a correct pyramid with a square base and a point of 136 degrees between inverse faces exposed to a force of 1 to 100 kgf. The full burden is typically connected for 10 to 15 seconds. Microscope is used to calculate the average of two diagonals which were indented on the surface of the material and along with this, area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient which is kgf load / mm^2 area of indentation.

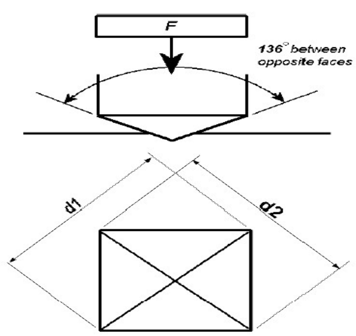


Figure 3-5 Diagram for calculation of hardness value[25]

F= Load in kgf

d = Arithmetic mean of the two diagonals, *d1* and *d2*in mm

HV = Vickers hardness

$$HV = \frac{2F\sin\frac{136^\circ}{2}}{d^2} \qquad HV - 1.854\ \frac{F}{d^2} \text{ approximately}$$

The Vickers hardness should be represented like 700 HV/10, in which 700 is Vickers hardness , obtained by using a load of 10 kgf . A few diverse load settings give for all intents and purposes indistinguishable hardness numbers on uniform material, which is greatly improved than the arbitrary changing of scale with the different hardness testing strategies. The benefits of the Vickers hardness test are that very exact reading can be taken, and only one sort of indenter is utilized for a wide range of metals and surface treatment. Altogether versatile and exact for testing the gentlest and hardest of materials, under differing loads.

Vickers hardness provide few advantage like-

- Can be utilized with any materials and test samples, from delicate to hard, as the methodology covers the whole hardness run.
- There is just one sort of indenter, which can be utilized for all Vickers techniques.
- Non-destructive testing is conceivable, so the test sample can be utilized for different purposes.

Vickers method has the following disadvantages:

- Proper polishing and grounding of the specimen is required before testing as indent is measured optically.
- Slow process
- Require hardness testers equipped with an optical system, which makes them more expensive

3.10 MICROSTRUCTURE

- Examination of the microstructure of material gives data used to decide whether the auxiliary parameters are inside sure particulars. The examination results are utilized as a measure for acknowledgement or dismissal.
- Micro structural examination is by and large performed utilizing optical or scanning electron magnifying lens to amplify highlights of the material under investigation.
- The sum or size of these highlights can be estimated and measured, and contrasted with acknowledgement criteria. These examinations are regularly utilized in failure investigation to help recognize the kind of material being referred to and decide whether the material got the best possible handling treatment. Metallurgical examinations may assess.
- extent of decarburization and carburization, grain estimate, inter granular attack or erosion
- depth of alpha case in titanium composites
- percent spheroidization
- inclusion appraisals
- volume division of different stages or second stage particles in metals sample preparation

so as to distinguish and assess the microstructure of material, it is essential to set up the test cautiously and appropriately.

The different steps in test planning for micro structural examination include:

- Selecting a delegate sample of the materials
- Sectioning the sample to abstain from adjusting or decimating the structure of intrigue
- Mounting the area without harm to the sample
- Grinding to accomplish a level sample with a base measure of harm to the sample surface
- Polishing the mounted and ground sample \
- Etching in the best possible etchant to uncover the micro structural subtleties.

3.10.1 PROCESS

Selecting

Choosing a delegate sample to appropriately portray the microstructure or the highlights of intrigue is a significant initial step. For instance, grain size estimations are performed on transverse segments, though broad microstructure assessments are performed on longitudinal areas.

Sectioning

Test sample are painstakingly segmented to abstain from adjusting or obliterating the structure of the materials. Be that as it may, regardless of how cautiously abrasive sawing or electric discharge machining is played out, a modest quantity of distortion happens on the sample surface. This miss happening must be evacuated during consequent readiness steps.

Mounting

After the test is segmented to an advantageous size, it is mounted in a plastic or epoxy material to encourage taking care of and the crushing and cleaning steps. Mounting media must be perfect with the sample as for hardness and scraped area obstruction. Typical mounting materials are thermosetting phenolics, for example, Bakelite, and thermoplastic materials, for example, methyl methacrylate (lucite). Mounting includes putting the sample in a shape and encompassing it with the suitable powder. At the point when the form is warmed and pressurized at the right dimensions, setting or restoring of the media happens. The mounted sample is expelled from the shape. On the off chance that the utilization of warmth or weight may adjust the structure of the sample of intrigue, at that point cast able cold mounting materials, for example, epoxies are utilized.

Grinding

Grinding pursues mounting to expel the surface harm that happened during the segmenting step and to give a level surface. Grinding by and large includes the utilization of abrasive wheel which was lubricated with water and progression of dynamically better abrasive grits.
This methodology gives a level surface that is almost free of exasperates or twisted metal that has been presented by the past sample planning steps.

Polishing

The cleaning step expels the last slim layer of the twisted metal. It leaves an appropriately arranged sample, prepared for examination of the un-etched qualities, for example, consideration content or any porosity that may exist.

Etching

The last advance that may be utilized is etching to demonstrate the microstructure of the sample. This progression uncovers highlights, for example, grain limits, twins and second stage particles not found in the un etched sample.

CHAPTER 4

EXPERIMENTATION

4.1 FABRICATION OF COMPOSITES

Al 6063 –T6 alloy was used as the matrix and $B_4C$of mesh size 150 (104µm), 200 (74µm) and 270 (53µm) at 6 wt% were used as reinforcement in the AMCs.

Liquid metallurgy stir casting method was adopted for composite fabrication, which essentially included following steps, i.e. melting of matrix alloy, preheating of reinforcement particulates, mixing of preheated particulates into molten alloy, solidification

Step1-A graphite crucible of cylindrical in shape, having a maximum working temperature of 2700°C and required dimension, 220 V, 3-phase electrical resistance furnace (maximum working temperature 1500°C) was used for melting of the matrix alloy and composite slurry preparation. It was mounted with a K-type thermocouple with a maximum range of 1200°C and speed regulated motorized stirring system.

Step 2-The B_4C powder was heated to 350°C for 45 min using muffle furnace and, before mixing with the molten alloy. Preheating of B_4C is necessary to oxidize their surface remove moisture and improve wettability in matrix material.

Step 3-Before addition of preheated B_4C; vortex was created on the surface of molten alloy by motorized stirring at stirring speed of 400rpm. The particulates were added at slow rate (approximately 10 g/min) using a funnel and rod, into the vortex of molten alloy. The stirrer speed was then slowly increased to 220 rpm and stirring was continued for 10 minutes more. The stirrer blades were positioned at one-third of the depth of the molten slurry from its surface, to enable proper mixing.

Step 4-After mixing the reinforcement for about 15 min with the help of stirrer, stirrer is taken out and composite slurry is allowed to get cool and solidify and then the cast AMC was removed out of the graphite crucible After casting out the composite out of the crucible, before cutting at wire EDM machine, proper turning and finishing is done on its outer surface on the lathe machine using carbide tip cutting tool.

After getting the required surface, required specimen are being cut on the transverse section using wire EDM machine. Two specimens are being cut, one for tensile test and other for micro structure and micro hardness.

Prepared specimen of casted specimens-

Figure 4-1Casting of Base alloy

Figure 4-2Casting of AMC with B4C MS 150

Figure 4-3Casting of AMC with B4C MS 200

Figure 4-4Casting of AMC with B4C MS 270

4.2 MICROSTRUCTURE ANALYSIS

To study the microstructure of the specimens, they were cut and prepared as per the following standard metallographic procedure.

- **Sectioning**

Sectioning means cutting of required size specimen form the large sample with least damage to the micro structure with the help of wire EDM machine.

- **Mounting**

If the size of cut out specimen is larger than 25mm square or more, then no mounting is required as no problem occur during polishing. Mounting basically helps in handling of the specimen during preparation and further handling and avoid any damage to the polishing wheels..In case of smaller cut out specimens, mounting are done in two forms-one is known as hot mounting and other is known as cold mounting. In hot mounting, Bakelite is used while in cold mounting epoxy is used to encapsulate the specimen.

- **Sample surface polishing**

The main purpose of this step is to achieve a surface free from scratches, defects or any unwanted material which can be introduced during above process. This process can further be divided into three steps- grinding, coarse polishing, and final polishing.

➢ **Grinding**

After the specimens are being mounted, in order to make them flat, a belt grinder is being used. After that, wash the sample properly. Slowly start moving the specimen in the back and forth direction across thee the abrasive grit of size 400 by applying uniform. Once done with 400 size, check if the surface if the specimen is flat and contains the scratches only in one direction, After this wash the sample and start rubbing it on the next size abrasive grit that is 600.Repeat this procedure for 600 grit abrasive, checking after each step to be sure that only those scratches remain that are due to the smallest grit.

➢ **Course polishing**

Before proceeding to the first polishing wheel (leftmost wheel), wash sample with water.

1) After cleaning the wheel with fingers, apply little water over it and start the motor at 240rpm. Cautiously place sample on the wheel while holding it firmly. Gradually move the sample in a round movement against the revolution of the wheel. Utilize a moderate and even pressure. Ensure to keep the sample level on the wheel with the goal that the last surface will be totally planar.

2) Following a few minutes on the wheel, hold the example in one spot for a minute. This will give loads of parallel scratches that can use to decide whether damage has been removed from the grinding steps.

Repeat steps above on the right polishing wheel.

Now, the sample will be smooth to the eye and even the oils and dirt on fingers will scratch it with bigger scratches than the abrasive. Try not to touch the sample surface from this point on.

The last step in the process is to etch the sample to bring out the microstructure.

- **Etching**
- For etching purpose, cotton swab and a Petri dish are used. Keller's reagent (HCl+HF+HNO3) is used as etchant.
- Gently swab the surface of specimen with the etchant as roughly spreading the etchant will produce a scratch at its surface.
- Keep the etchant on the surface for 10 seconds or so and clean the sample with water to stop the etching.
- Examine the etched specimen under the microscope.
- In case, sample gets over-etched, repeat the final polishing step and re-etch for a shorter time. Samples to be inspected at high magnification for the most part require shorter etching times than those to be seen at lower magnification
- After last polishing stage the sample will have a mirror like finish.
- To see the grains, etching is necessary as cracks, pores and defects can be observed without etching.
- Etchant reacts with atoms and dissolves them as the atoms at grain boundaries dissolve quickly. A dissolved grain boundary looks dark.

Steps-

Apply enchant to polished surface for some time and then rinse it with distilled water.Once the specimen is etched, it is kept under the microscope to see the microstructure under its magnification. High magnification is required for study of phases and Low magnification for study of grain size.

Specimens for microstructure analysis

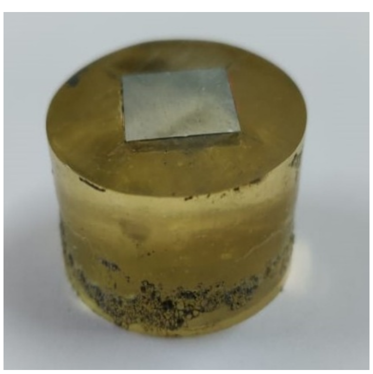


Figure 4-5Base alloy specimen

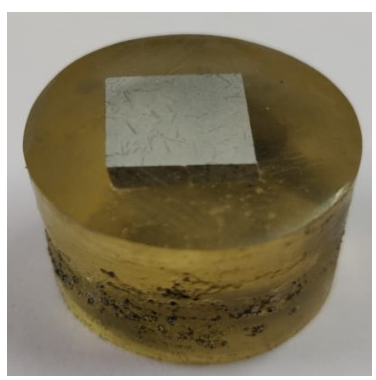
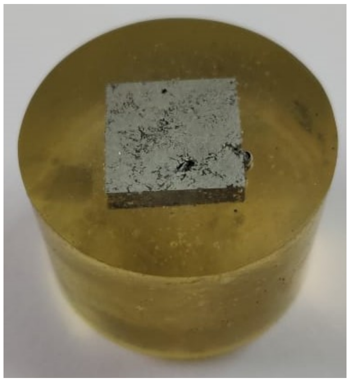


Figure 4-6AMC with B4C MS 150 specimen



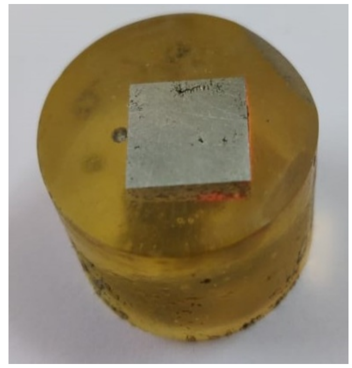


Figure 4-7AMC with B4C MS 200 specimen   Figure 4-8AMC with B4C MS 270 specimen

4.3 MICROHARNESS TEST

1) To perform the micro hardness test on Vickers's hardness test, proper specimen has to be prepared means its surface quality should be free from impurities and good.

2) For this proper polishing is required.

3) After polishing, the specimen should be clamped properly under the indenter of the tester.

4) In order to measure the hardness of the specimens, different location should be chosen on its surface.

5) Now to start with the test, a load of 300 mN is applied for about 20 sec to 40 second the surface of the specimen.

6) Ideally, the value of load is increased from 0 to final value within few seconds and is always in mN.

7) Generally the dwell time is around 10 to 15 seconds.

8) While performing Vickers test, the indent must positioned such that there must be some clearance from the specimen edge and between different indentations on the surface of the specimen.

9) During testing, care must be taken such that no vibration or shock must occur as these will create an error in the final values of hardness.

10) After the test, the value is given in the form of HV value where the numeric value is in between 1 to 3000 and HV stands for "Hardness according to Vickers".

11) In the Vickers hardness test, an optical method, the size of indentation (the diagonals) that is left by the indenter is calculated. The larger the indent left by the indenter at a defined test force in the surface of a work piece (specimen), the softer the tested material.
The formula used to calculate the HV value is-

$$HV = \frac{2F\sin\frac{136^{\circ}}{2}}{d^2} \qquad HV = 1.854\frac{F}{d^2} \text{ approximately}$$

Here F stands for Load in mN and d is the mean of both the diagonal of the pyramid indentation (d_1 & d_2).

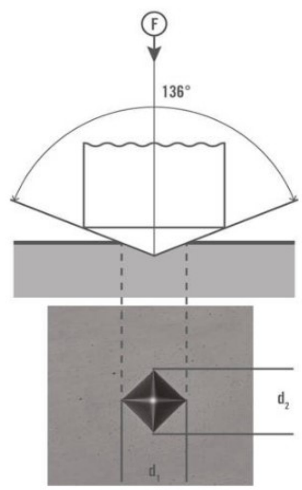


Figure 4-9Schematic diagram of Vickers hardness test [25]

In order to perform above test, Vickers micro hardness machine with model name FISCHERSCOPE HM2000 S has been used. Following are its specifications-

- Design-Standard: Vickers
- Hardness measurement range-.001-120000 N/mm2, near diamond hardness
- Test load range-0.1-2000 mN
- Specimen size-Min diameter 6 mm

- Sample holder-Holder for cylindrical specimen

- Indented use-Nano indentation on lacquer coatings, bulk materials, electroplated coatings, hard material coating, polymers and much more.

- Predefined test parameters-

- F=300,000 mN/20sec

- Creep-5.0 sec

- R=s force increases

4.4 TENSILE TEST

- In order to perform the tensile test on the prepared composites, first of all a specimen is cut in the shape of dumb bell and the ultimate tensile strength was estimated using computerized uni-axial tensile testing machine.
- The dimension of the specimen should be according to the requirements.
- To start with the tensile test, the specimen is install in the testing machine
- Start the machine
- After that, load is applied on the specimen, which increases gradually.
- As the value of load increases, elongation in the specimen also increases and at last necking starts.
- At fracture load level, finally the specimen breaks.
- Remove the specimen from the machine
- Record the data and collect it
- Calculate the values and plot stress strain curve for each specimen and perform comparison.

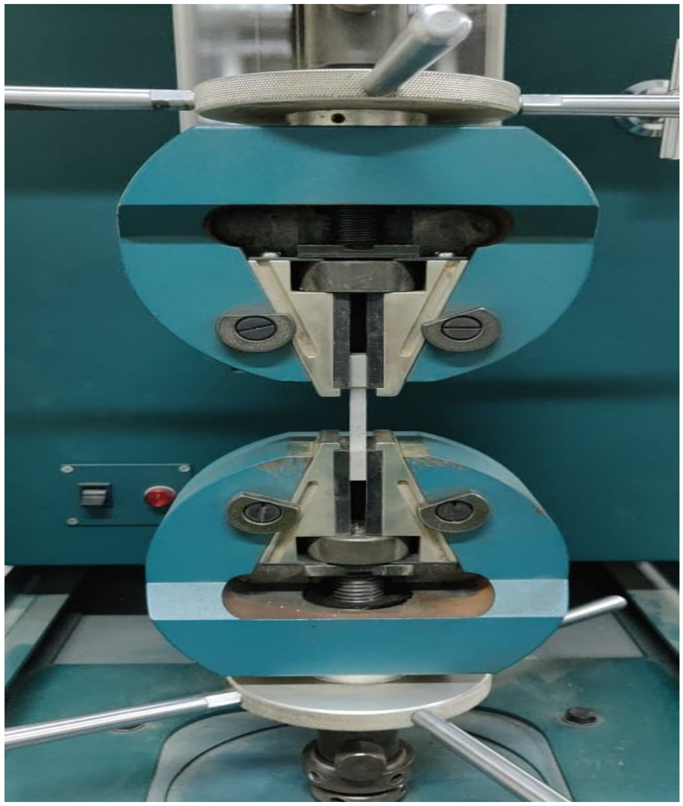


Figure 4-10Specimen subjected to tensile loading

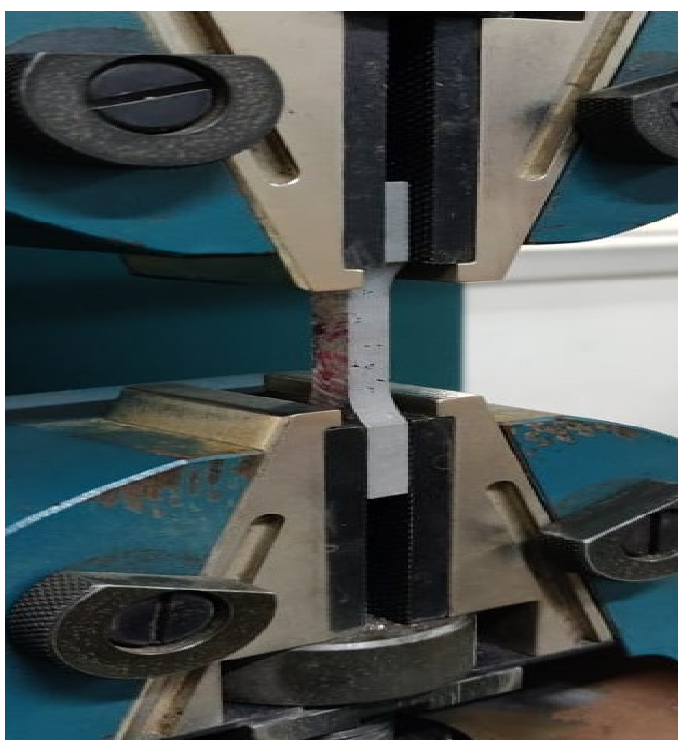


Figure 4-11Closer view of specimen subjected to tensile loading

TENSILE TEST OUTSOMES-

(a)Base alloy Al-6063

Figure 4-12Base alloy specimen before tensile test

Figure 4-13Base alloy specimen after tensile test

(b)AMC with B4C MS 150

Figure 4-14AMC MS 150 specimen before tensile test

Figure 4-15AMC MS 150 specimen after tensile test

(c)AMC with B_4C MS 200

Figure 4-16AMC MS 200 specimen before tensile test

Figure 4-17AMC MS 200 specimen after tensile test

(d)AMC with B_4C MS 270

Figure 4-18AMC MS 270 specimen before tensile test

Figure 4-19AMC MS 270 specimen after tensile test

CHAPTER 5

RESULTS AND DISCUSSION

This chapter deals with the analysis of the data collected for the various tests conducted on the alloy Al-6063 T6 and three composites prepared with different sizes of Boron Carbide powder.

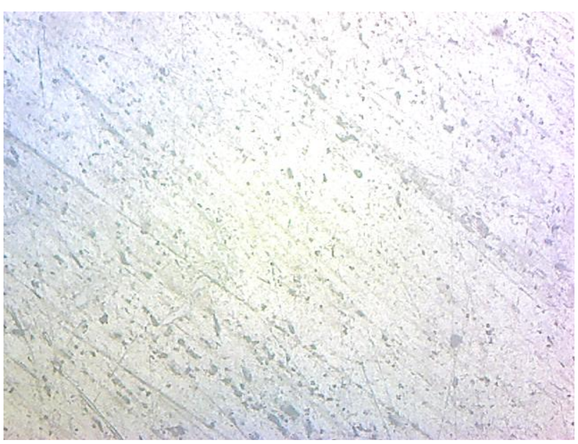
5.1) EVALUATION OF MICROSTRUCTURE

An Aluminium composite has been fabricated using Al-6063 T6 as the base matrix material and three micro sizes of Boron Carbide powder-53µ(Mesh size 270),74µ(Mesh size 200)and 104µ (Mesh size 150) as the reinforcement .Stir casting technique has been incorporated for the preparation of the composite. After the preparation, proper sectioning and mounting has been done and then each Aluminium Matrix Composite with different size of B_4C has been observed under the optical microscope with four magnification level i.e. 10X,20X,50X & 100X in two steps-first before etching and then after etching. Observations have been done through transverse section of the prepared specimen.

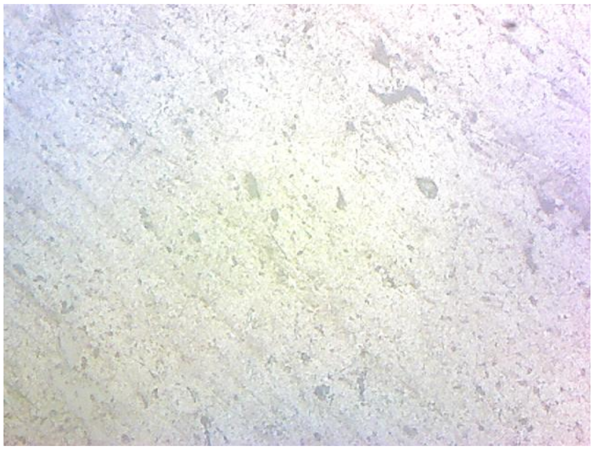
5.1.1 BEFORE ETCHING

As Casted Al-663 T6

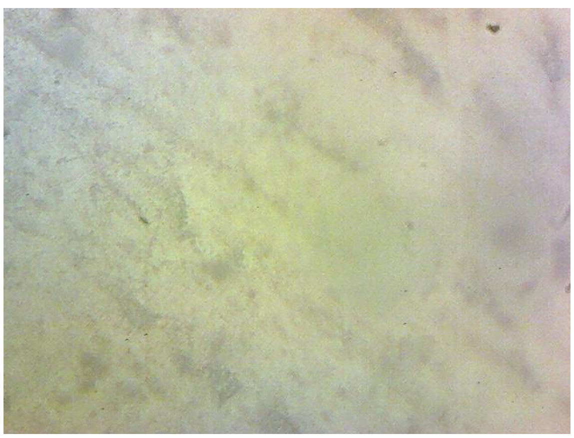
- Under 10X magnification



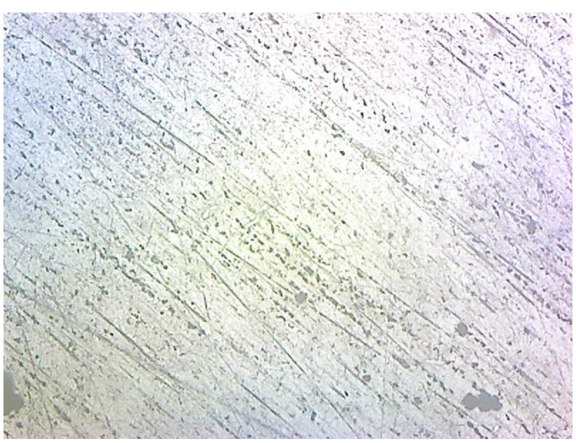
- Under 20X magnification



- Under 50X magnification

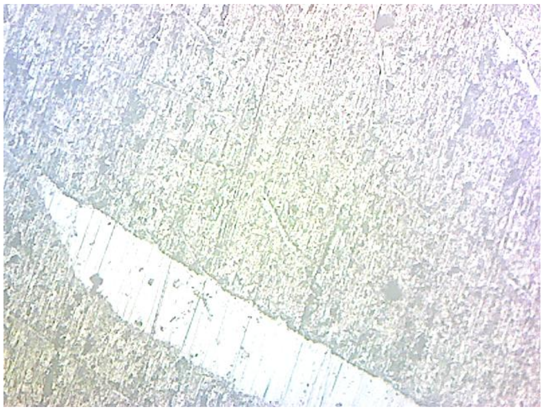


- Under 100X magnification

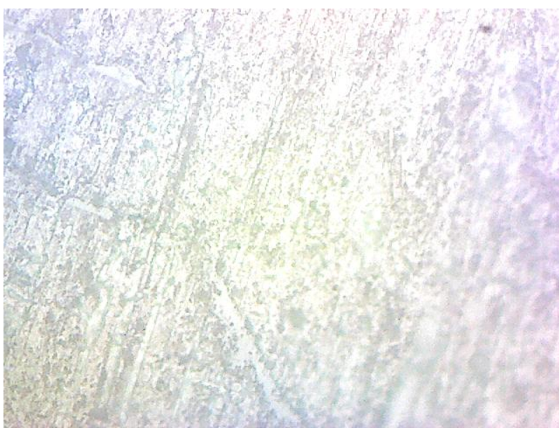


5.1.2 AMC with B_4C (Mesh Size-150)

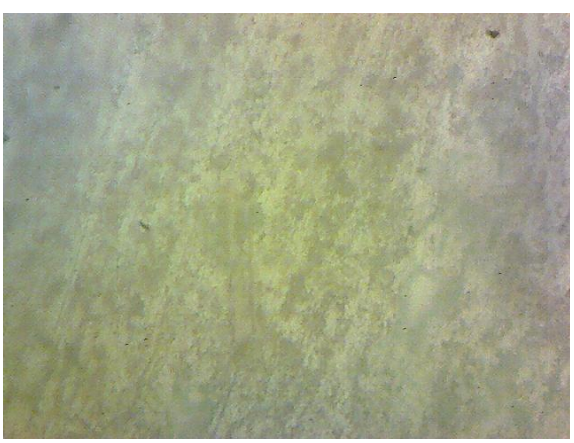
- Under 10X magnification



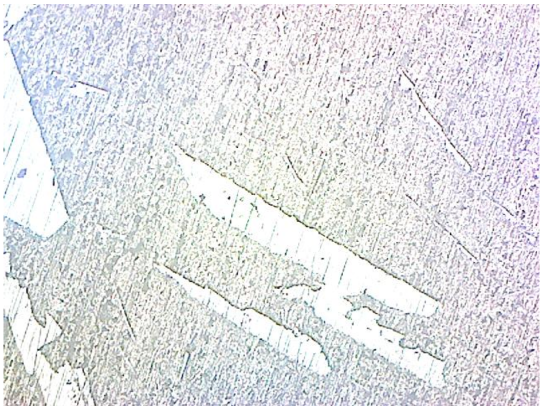
- Under 20X magnification



- Under 50X magnification

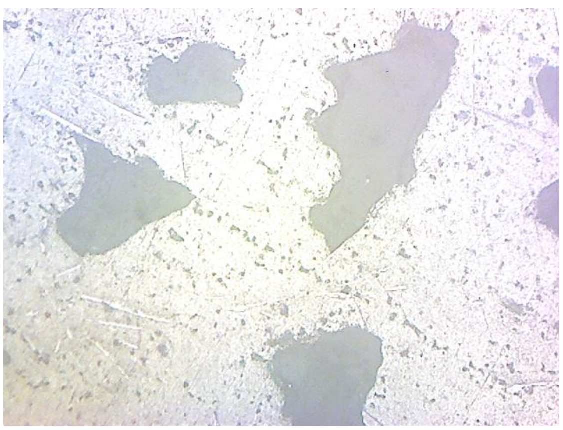


- Under 100X magnification

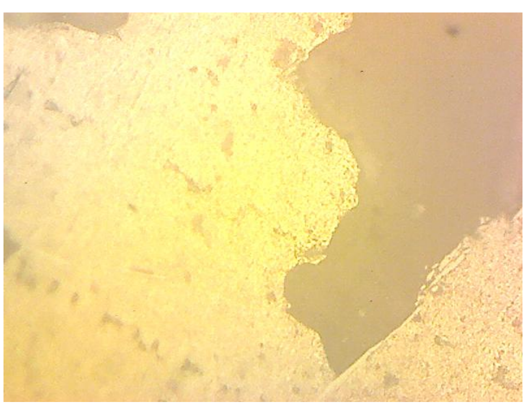


5.1.3 AMC with B_4C (Mesh Size-200)

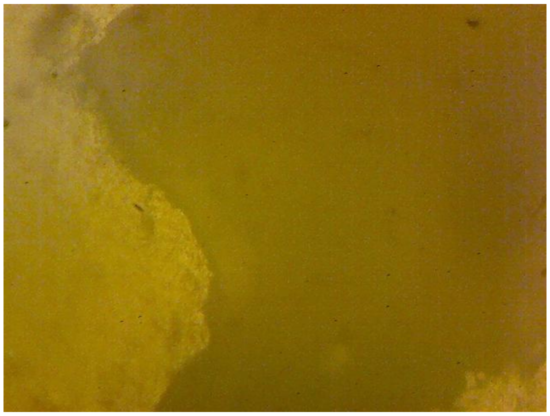
- Under 10X magnification



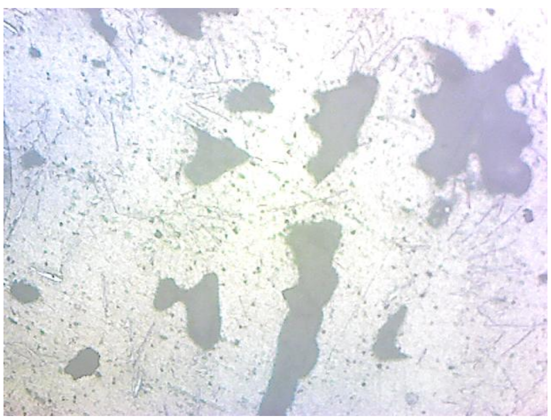
- Under 20X magnification



- Under 50X magnification



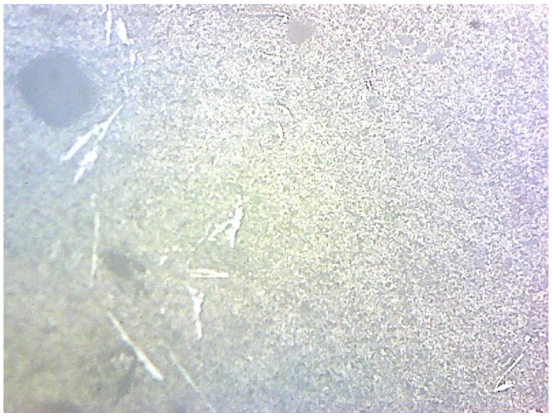
- Under 100X magnification



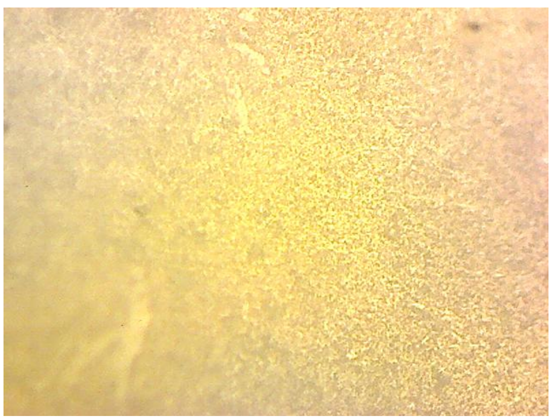
5.1.4 AMC with B_4C (Mesh Size-270)

- Under 10X magnification

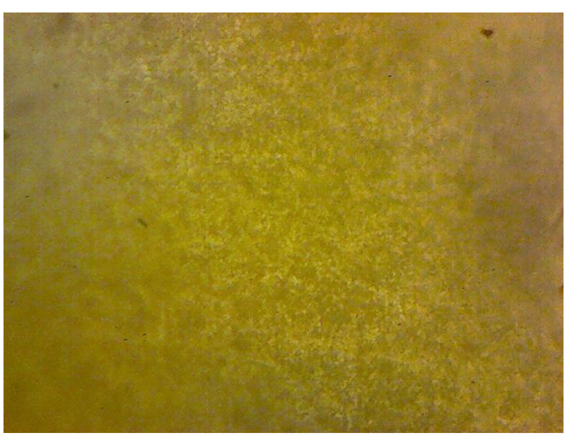
- Under 20X magnification



- Under 50X magnification



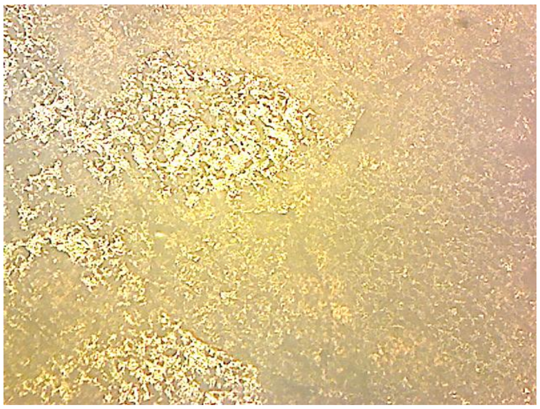
- Under 100X magnification



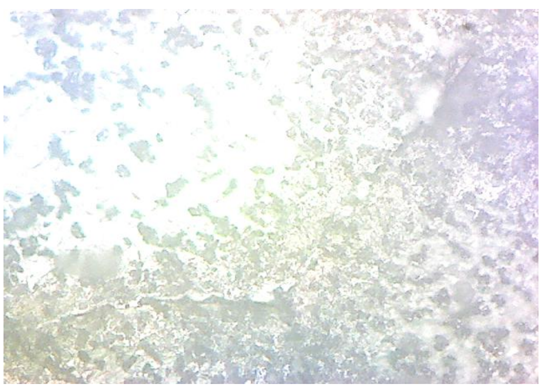
5.2 AFTER ETCHING

5.2.1 As Casted Al-6063 T6

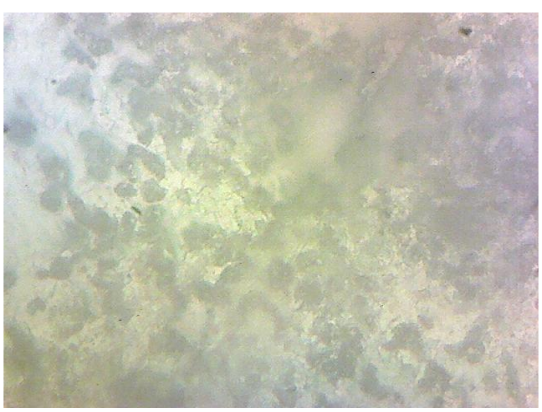
- Under 10X magnification



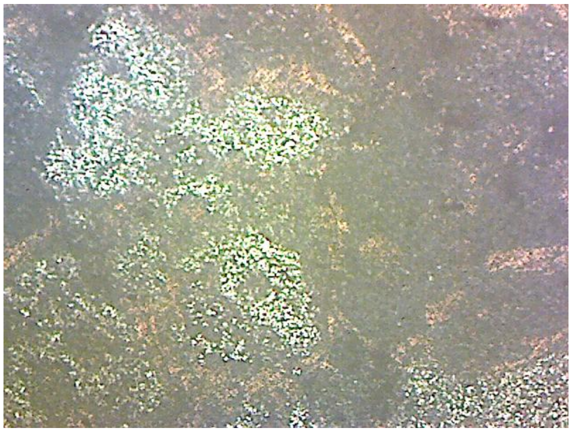
- Under 20X magnification



- Under 50X magnification

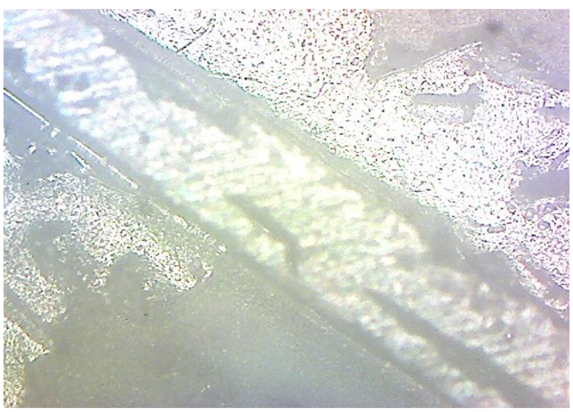


- Under 100X magnification



5.2.2 AMC with B_4C (Mesh Size-150)

- Under 10X magnification



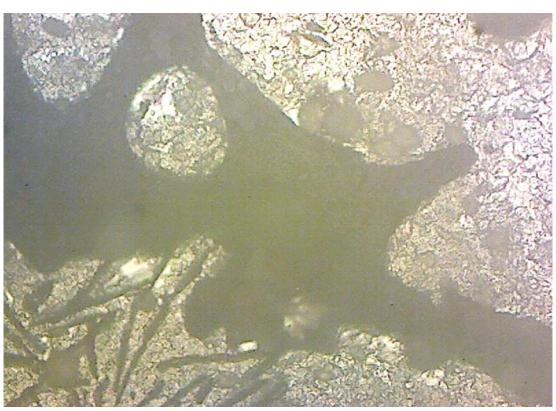
- Under 20X magnification

- Under 50X magnification

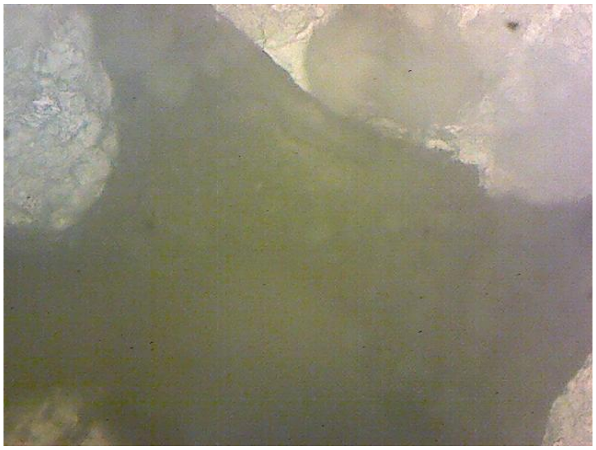
- Under 100X magnification

5.2.3 AMC with B_4C (Mesh Size-200)

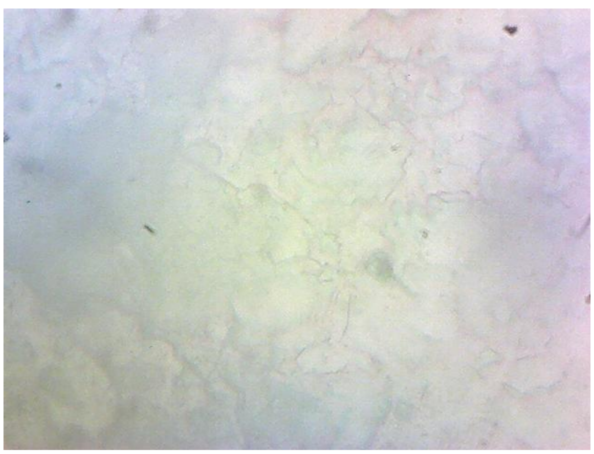
- Under 10X magnification



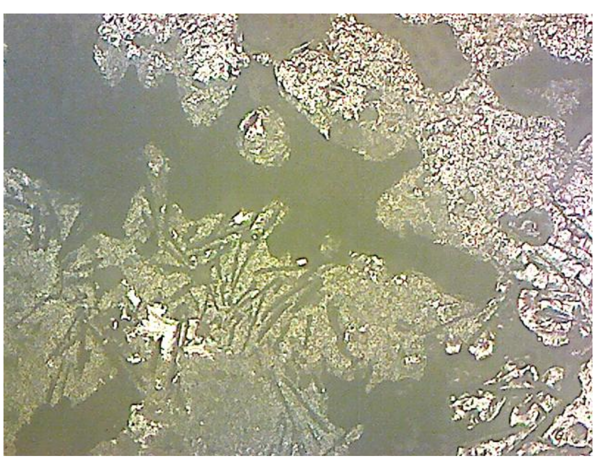
- Under 20X magnification



- Under 50X magnification

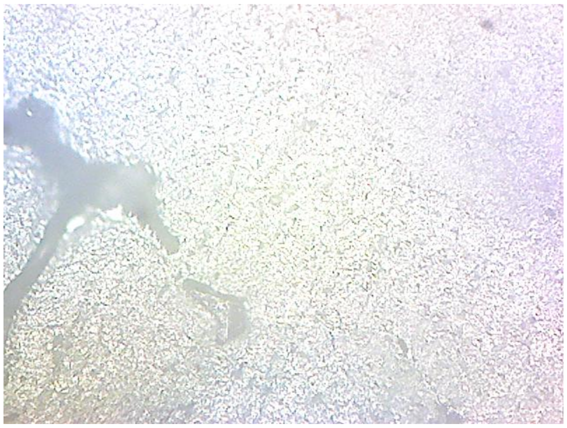


- Under 100X magnification

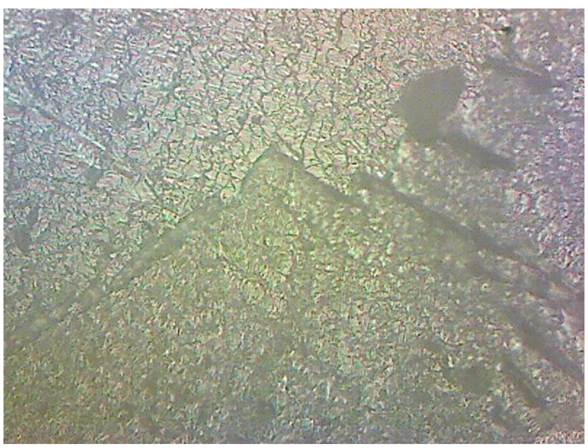


5.2.4 AMC with B_4C (Mesh Size-270)

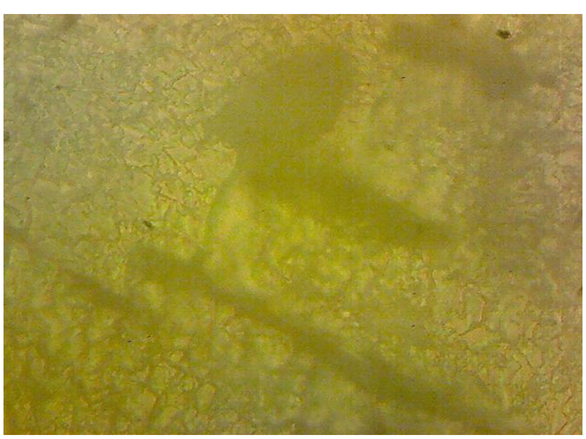
- Under 10X magnification



- Under 20X magnification



- Under 50X magnification



- Under 100X magnification

From the above micrographs, it was observed that the Boron Carbide powder with different sizes has fairly uniform distribution in maximum portion of the molten matrix of Al-6063 T6 and only some areas can be seen having cluster formation. Level of porosity is also less. Uniformity of reinforcement has been achieved by using appropriate process parameters and stirring action.

5.2 EVALUATION OF HARDNESS

Hardness is the measure of the resistance of a material to indentation or damage on the surface. In this experiment, hardness of each alloy and three composite has been calculated using Vickers's Micro Hardness test at different points of prepared transverse section of composite and represented in terms of HV value.

- Hardness for As casted Al-6063 T6

		HM		EIT/ (1-vs^2)		HV
Mean value	x. :	381.91	N/mm²	50.97	GPa	41.78
Confid.interval	q :	------	N/mm²	------	GPa	------
Standard. Dev.	s :	------	N/mm²	------	GPa	------
No of Readings	n :	1		1		1
Min. Reading	:	381.9	N/mm²	51.0	GPa	41.8
Max. Reading	:	381.9	N/mm²	51.0	GPa	41.8
Range	R :	------	N/mm²	------	GPa	------
Range/%	R/%:	0.00		0.00		0.00

HV=41.78

- Hardness for AMC with B_4C(Mesh Size-150)

		HM		EIT/ (1-vs^2)		HV
Mean value	x. :	725.34	N/mm²	178.04	GPa	75.77
Confid.interval	q :	------	N/mm²	------	GPa	------
Standard. Dev.	s :	------	N/mm²	------	GPa	------
No of Readings	n :	1		1		1
Min. Reading	:	725.3	N/mm²	178.0	GPa	75.8
Max. Reading	:	725.3	N/mm²	178.0	GPa	75.8
Range	R :	------	N/mm²	------	GPa	------
Range/%	R/%:	0.00		0.00		0.00

HV=75.77

- Hardness for AMC with B_4C(Mesh Size-200)

		HM		EIT/ (1-vs^2)		HV
Mean value	x. :	520.88	N/mm²	46.32	GPa	60.02
Confid.interval	q :	------	N/mm²	------	GPa	------
Standard. Dev.	s :	------	N/mm²	------	GPa	------
No of Readings	n :	1		1		1
Min. Reading	:	520.9	N/mm²	46.3	GPa	60.0
Max. Reading	:	520.9	N/mm²	46.3	GPa	60.0
Range	R :	------	N/mm²	------	GPa	------
Range/%	R/%:	0.00		0.00		0.00

HV=60.02

- Hardness for AMC with B_4C(Mesh Size-270)

		HM		EIT/ (1-vs^2)		HV
Mean value	x. :	413.65	N/mm²	76.54	GPa	44.91
Confid.interval	q :	------	N/mm²	------	GPa	------
Standard. Dev.	s :	------	N/mm²	------	GPa	------
No of Readings	n :	1		1		1
Min. Reading	:	413.7	N/mm²	76.5	GPa	44.9
Max. Reading	:	413.7	N/mm²	76.5	GPa	44.9
Range	R :	------	N/mm²	------	GPa	------
Range/%	R/%:	0.00		0.00		0.00

HV=44.91

Plotting a bar graph based on above reading,

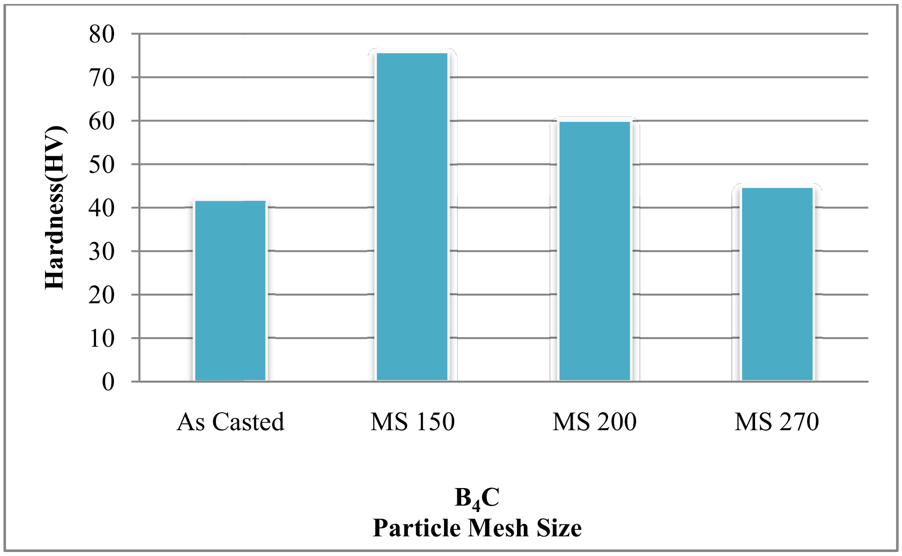


Figure 5-1Bar graph representing hardness value of base alloy and AMC's

From above graph, it is revealed that hardness of reinforced composite specimen is more than that of un reinforced base metal Al-6063.This can be explained on the fact that Boron Carbide is one of the hardest material known and presence of its particle on the surface of the prepared composite increases the resistance to the indentation or deformation .Therefore hardness of the composite increases. Within the AMC's, the hardness is maximum for the composite with B_4C mesh size-150 (HV=75.77) and then goes on decreasing for composite with B_4C mesh size 200 (HV=60.02) and 270(HV=44.91) accordingly. So it is concluded that as particle size of the reinforcement decreases, hardness of the composite decreases.

5.3 EVALUATION OF TENSILE STRENGTH

Following various stress-strain graphs shows the effect of reinforcement on the Ultimate Tensile Strength of various aluminum metal matrix composites. It is found that tensile strength of Base alloy Al-6063 is more than the fabricated composites. Among the composites, the one with B_4C mesh size-150 has higher tensile strength as compared to composite with B_4C of mesh size of

200 and 270.The decrease in the tensile strength is because B_4C induces less strength to the base alloy by reducing it capability to resist tensile strength. Among these composites, the hardness is found increased while tensile strength is found decreased on addition of reinforcement particle i.e. B_4C.

- **As Casted Al-6063**

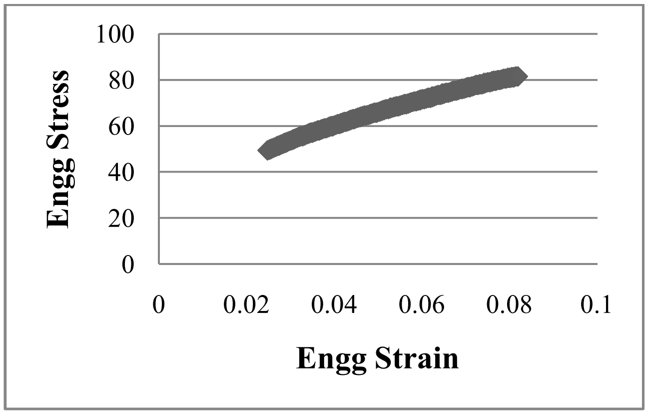


Figure 5-2 Graph between Engg Stress and Engg Strain

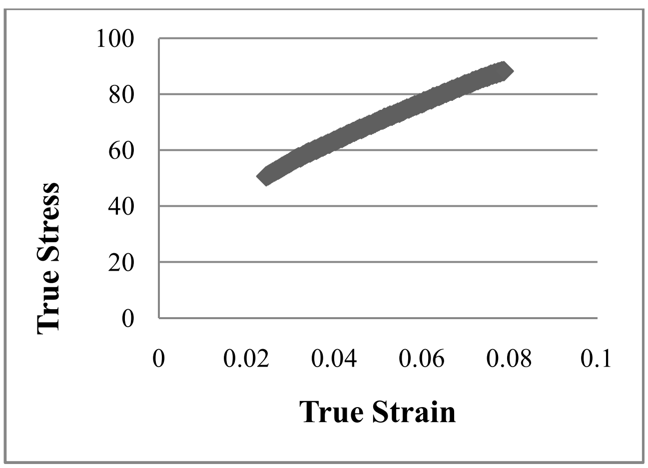


Figure 5-3 Graph between True Stress and True Strain

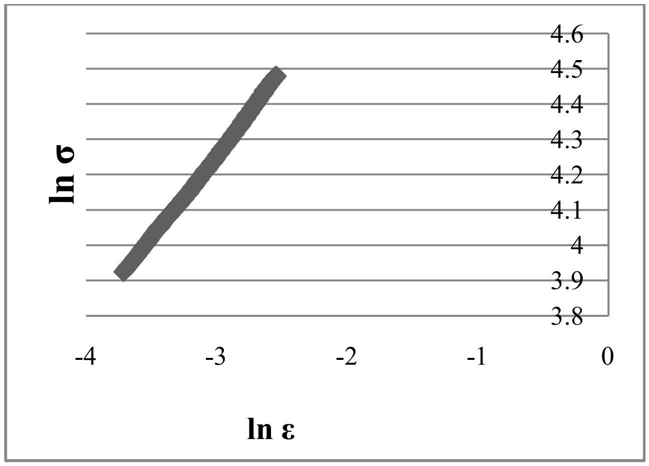


Figure 5-4 Graph between ln σ and ln ε

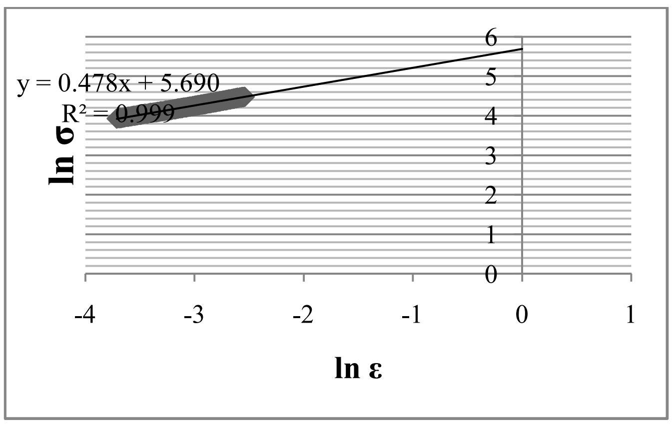


Figure 5-5 Regression graph between ln σ and ln ε

- **AMC with B_4C MS-150**

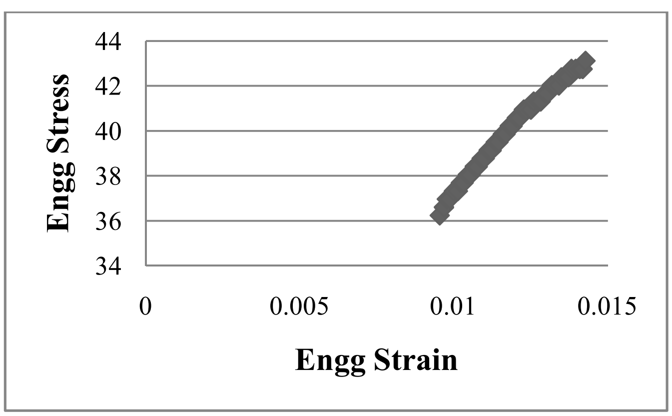


Figure 5-6 Graph between Engg Stress and Engg Strain

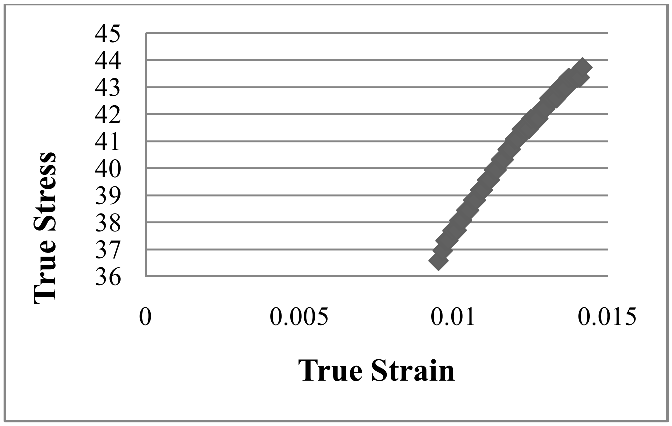


Figure 5-7 Graph between True Stress and True Strain

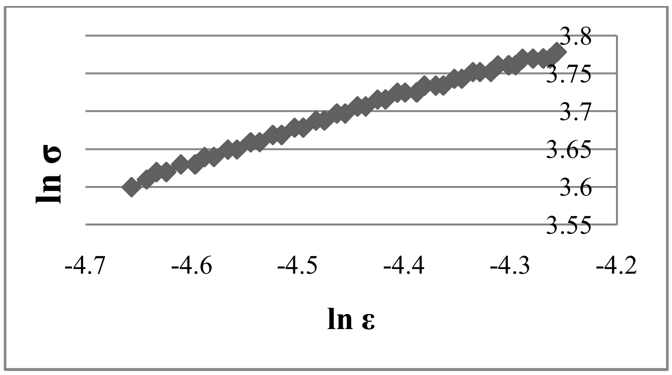


Figure 5-8 Graph between ln σ and ln ε

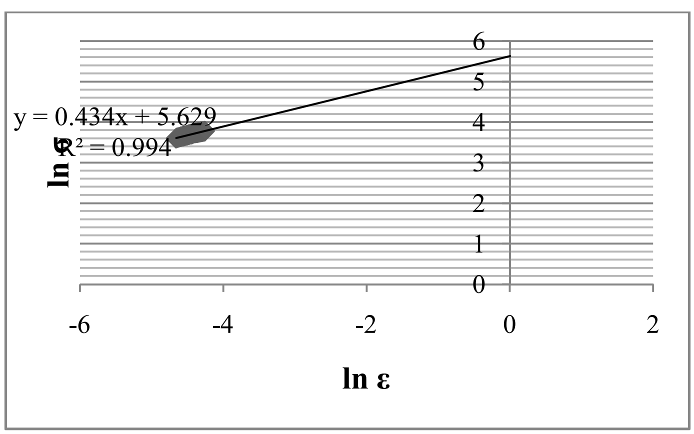


Figure 5-9 Regression graph between ln σ and ln ε

- **AMC with B_4C MS-200**

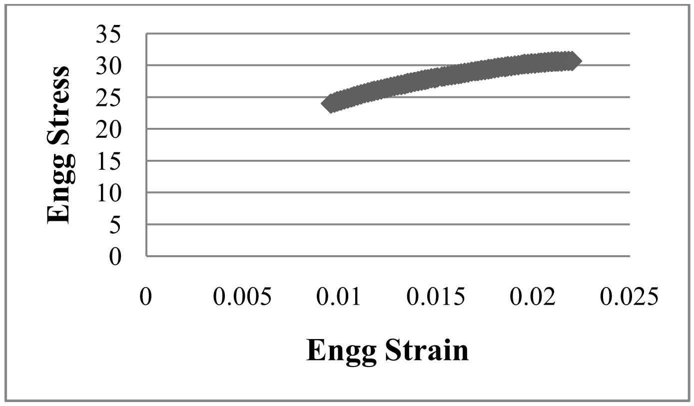


Figure 5-10 Graph between Engg Stress and Engg Strain

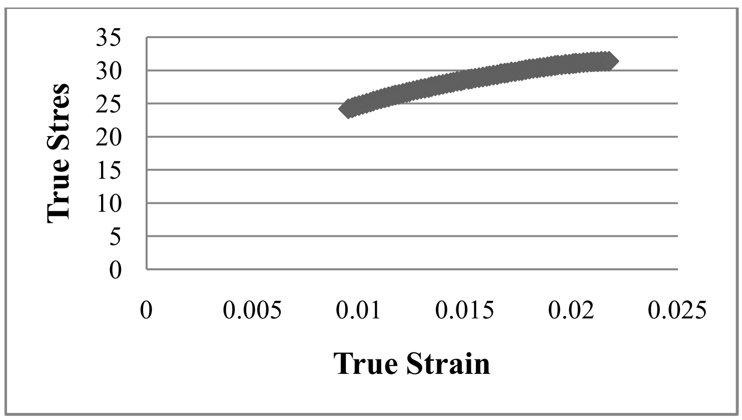


Figure 5-11 Graph between True Stress and True Strain

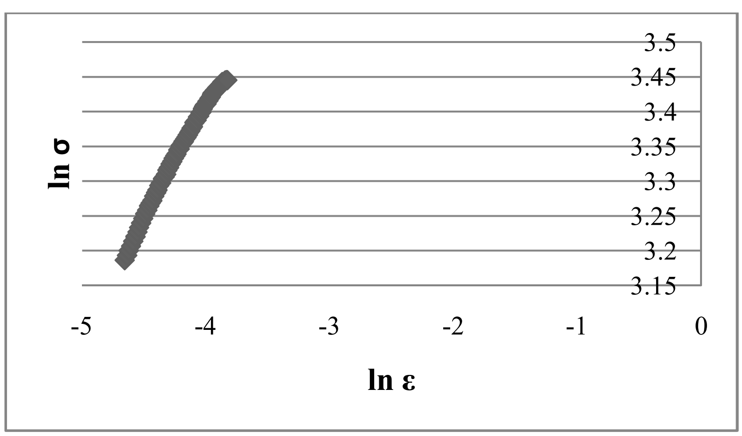


Figure 5-12Graph between ln σ and ln ε

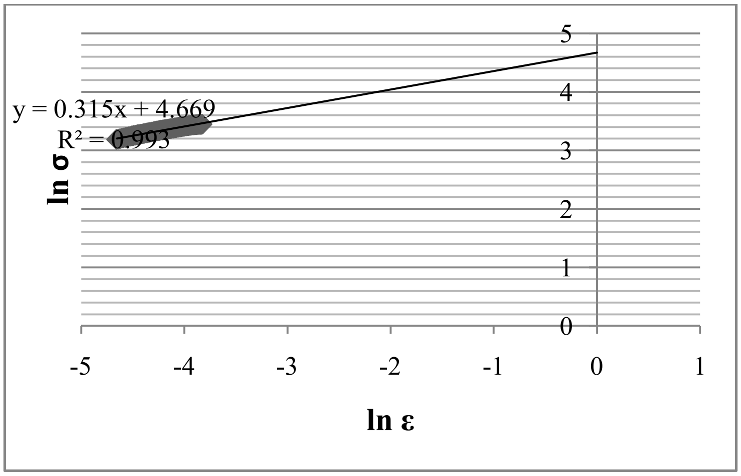


Figure 5-13Regression graph between ln σ and ln ε

- **AMC with B_4C MS 270-**

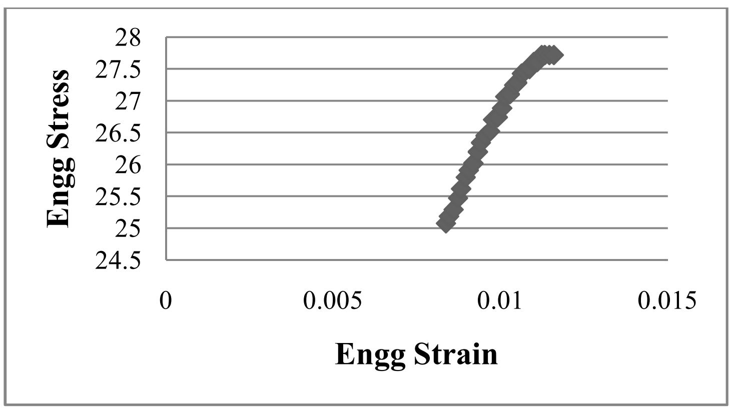


Figure 5-14Graph between Engg Stress and Engg Strain

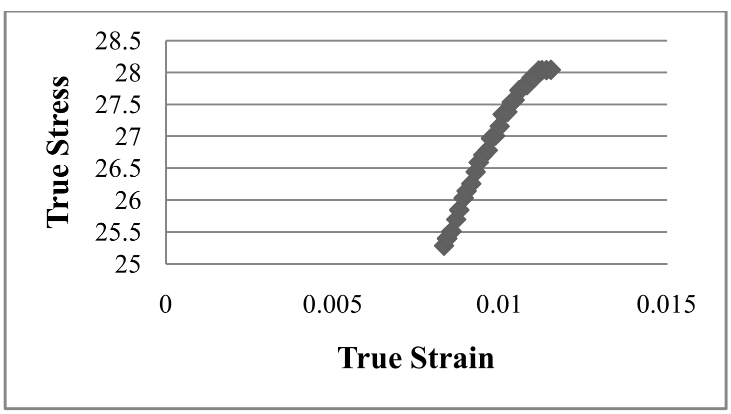


Figure 5-15Graph between True Stress and True Strain

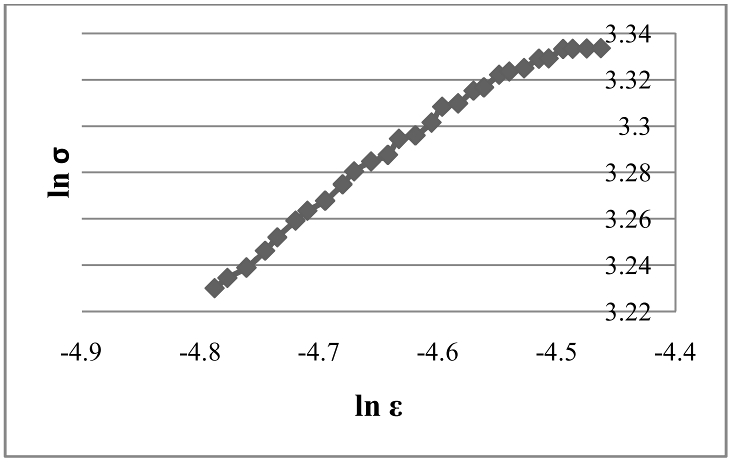


Figure 5-16 Graph between ln σ and ln ε

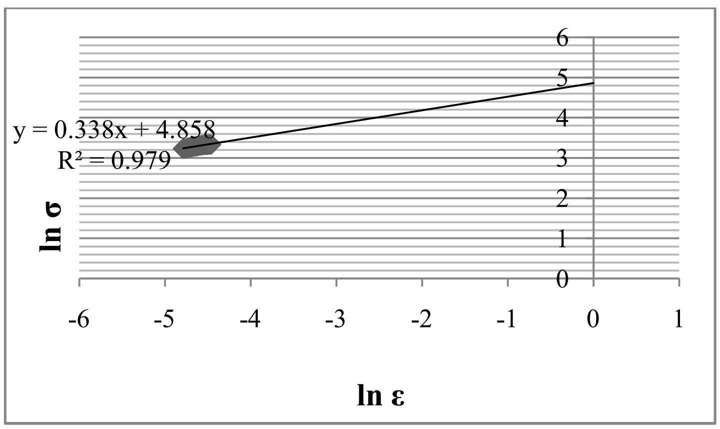


Figure 5-17Regression graph between ln σ and ln ε

CONCLUSIONS

From the experiment, following significant conclusions has been derived-

1) Aluminum Metal Matrix composite using Al 6063 T6 as base matrix and Boron Carbide powder with different mesh sizes (viz 150,200,270) by stir casting technique was prepared successfully.

2) Optical microscopy study reveals a uniform distribution of B_4C powder at maximum region of aluminum melt along with cluster formation at some minimal regions.

3) The hardness of the reinforced composite was found more than that of un-reinforced base alloy. Maximum hardness was found for the composite with B_4C mesh size 150 (104µ) and shows a decreasing trend as size decreases from 200 (74µ) to 270 (53µ).

4) Ultimate tensile strength of Base alloy Al 6063 has been found more than the prepared AMC's. Among AMC's, the composite with B_4C mesh size 150 has maximum tensile strength as compared to one with mesh size of 200 and 270 respectively.

.

FUTURE SCOPE

Every study has a further improvement. Following are the areas which can still be explored in the context of the present research:

(1) Other fabrication technique can be used to develop the desired composite.

(2) Variation in size level of reinforcement like nano or a hybrid of nano and micro can be used to get more enhancements in the properties of the composites.

(3) Other tests like tribological study can be made by performing wear test on pin on disk tribometer

REFERENCES

[1] U B Krishna Gopal, K V Rao Sreenivas and B Vasudeva," Effect of percentage reinforcement of B4C on the tensile property of Aluminum matrix composite," International journal of mechanical engineering and robotics research, Vol. 1, No. 3, 2012, ----- .

[2] Ye Tenge,Xu Yuxin and Ren Jie, "Effect Of Sic Particle Size On Mechanical Properties Of SiC Particle Reinforced Aluminum Metal Matrix Composite, "Journal Of Material Science And Engineering, 753,146-155,2019.

[3] Mohanavel.V, Rajan K, Kumar Suresh.S and Udishkumar.S.Jayasekar,"Effect of silicon carbide reinforcement on mechanical and physical properties ol aluminum matrix composite," ICAMA, 2938-2944,2018.

[4] Raja Sridhar K.S ,Raja Bupesh V.K," Effect of boron carbide particle in wear characteristic of cast aluminium A356 composite," IOSR Journal Of Mechanical And Civil Engineering ,2278-1684,pp 73-77,2014.

[5] S.P Saikeerthi, B Vijayaramnath and Elanchezhian,"Experimental Evaluation Of The Mechanical Properties Of Aluminium 6061- B_4C-sic Composite," International Journal Of Engineering Research,2319-6890 ,vol no.3,pp: 70-73 ,2014.

[6] Subramani N, Vijayaraghavan,Arunsankar.V and Sudha,"Analysis and investigation on A2024 metal matrix composites with B_4C and graphite," International Journal Of Innovative Research In Science, Engineering And Technology ,vol. 2, issue 9, 2013.

[7] Rao Rama.S, Padmanabhan.G," Fabrication and mechanical properties of aluminium-boron carbide composites," International Journal Of Materials And Biomaterials Applications, 2249–9679,2012.

[8] Rebba Bhargavi , Ramanaiah.N,"Studies on mechanical properties of 2024 Al – B_4C composites," Advanced Materials Manufacturing & Characterization,vol 4,issue 1,2014.

[9] Baradeswaran .A, Perumal Elaya.A," Influence of B_4C on the tribological and mechanical properties of Al 7075–B_4C composites," ELSEVIER ,146–152,2013.

[10] Harichandran.R, Selvakumar. N,"Effect of nano/micro B_4C particles on the mechanical properties of AMCs fabricated by ultrasonic cavitations-assisted solidification process,"ELSEVIER,147 – 158,2014.

[11] Raviteja.T, Radhika.N and Raghu.R,"Fabrication and mechanical properties of stir cast al-Si12cu/B_4Ccomposites,"International Journal Of Research In Engineering And Technology ,2319-1163,2014.

[12] Senthilkumar.N, Tamizharasan.T and Anbarasan,"Mechanical Characterization and Tribological Behaviour of Al-Gr-B_4C Metal Matrix Composite prepared by Stir Casting Technique," Journal of Advanced Engineering Research,2393-8447,vol 1,pp.48-59,2014.

[13] U.B Gopal Krishna,Mohanty RM, Balasubramanian K and Seshadri SK,"Boron carbide-reinforced aluminium 6061 matrix composites: fabrication and properties,"Material Science Eng,498:42–52,2018.

[14] Nieto Andy, Yang Hanry, Jiang Lin And Schoenung M Julie," Reinforcement size effects on the abrasive wear of boron carbide reinforced aluminum composite," ELSEVIER,228-235,2017.

[15] K.T Akhil., Varghese Jerry, Raphel Arun, K Vinoj, Francis Frenosh K ,"To study the cooling rate and influence of boron carbide on mechanical properties of aluminum LM 13 matrix b_4c reinforced composites" ICAAMM, 7202-7207,2017.

[16] K Shirvanimoghaddam., H Khayyam., H Abdizadah., Akbari Karbalaei.M, Pakseresht A.H., Ghasali E and Naebe M,"Boron carbide reinforced aluminum composite: physical, mechanical characterization and mathematical modelling," Material Science And Engineering A 658,135-149,2016.

[17] Yuvaraj Narayana, Sivanandam Aravindan , Vipin,"Fabricationof Al5083/B_4C surface composite by friction stir processing and its tribological characterization," Journal Of Material Research and Technology,398–41,2015.

[18] Subramaniam Prabagaran, Govindarajulu Chandramohan and Palanisamy Shanmughasundaram,"Influence of graphite on the hardness and wear behaviour of AA6061–B_4C," Composite Materials And Technology,2014

Figure 0-1hh**[19] Thomas A Tony, R Parameshwaran.,.A Muthukrishnan and Kumaran.M Arvind,“Development Of Feeding and Stirring Mechanisms For Stir Casting Aluminium Matrix Composites,” ELSEVIER,1182-1191,2014.**

[20] S Gopalakrishnan. ,.N Murugan,”Production and wear characterisation of AA 6061 matrix titanium carbide particulate reinforced composite by enhanced stir casting method,”ELSEVIER,302–308,2012.

[21] Swamy A. R. K , Ramesha A, Kumar G.B. Veeresh,Prakash J. N,”Effect Of Particulate Reinforcements On The Mechanical Properties Of Al6061-WC And Al6061-Gr MMCs,”Journal of Minerals & Materials Characterization & Engineering,vol. 10, no.12, pp.1141-1152, 2011

[22] YC Feng, L Geng, PQ Zheng, ZZ Zheng, GS Wang,”Fabrication and characteristic of Al-based hybrid composite reinforced with tungsten oxide particle and aluminum borate whisker by squeeze casting,”Materials & Design,2008.

[23] F Toptan, A Kilicarslan, M Cigdem and Kerti, “Processing and micro structural characterization of A1070 and AA6063 matrix B_4C reinforced composites,”Material Design,87-91,2010.

[24] Kouzeli Marianna, Marchi Christopher San and Mortensen Andreas,”Effect of reaction on the tensile behavior of infiltrated boron carbide aluminum composites,” Materials Science and Engineering,264-273,2002.

[25] Hashim J., Looney L., and Hashmi M.S.J,” Metal Matrix Composites: Production by the Stir Casting Method,” Journal of Material Processing and Technology, 92, pp.17,1999.

[26] Mohanty RM, Balasubramanian K and Seshadri SK,”Boron carbide-reinforced alumnium 1100 matrix composites: fabrication and properties,”Material Science Eng, 498:42–52,2008.

[27] Lashgari HR, ZangenehSh, Shahmir H, Saghafi M and Emamy M.,”Heat treatment effect on the microstructure, tensile properties and dry sliding wear behavior of A356–10% B_4C cast composites,”Material Design,4414–22,2010.

[28] E. Mohammad Sharifi, F. Karimzadeh and M.H. Enayati,”Fabrication and evaluation of mechanical and tribological properties of boron carbide reinforced aluminum matrix nano composites,” Materials and Design,3263–3271,2011.

[29] M. Yandouzi a, A.J. Böttger, R.W.A. Hendrikx, M. Brochu, P. Richer, A.Charest and B. Jodoin,”Microstructure and mechanical properties of B_4C reinforced Al-based matrix composite

coatings deposited by CGDS and PGDS processes, Surface & Coatings Technology, 2234–2246,2010.

[30] Marianna Kouzeli, Christopher San Marchi, Andreas Mortensen,"Effect of reaction on the tensile behavior of infiltrated boron carbide aluminum composites,"Materials Science and Engineering,264-273,2002

[31] Baradeswaran, A and A. Elaya Perumal, "Influence of B4C on the tribological and mechanical properties of Al 7075–B_4C composites", Composites Part B Engineering, 54, 146,2013.