EXPERIMENTAL INVESTIGATION ON IMPROVEMENTS IN MECHANICAL PROPERTIES OF AA2024/AL203/B4C HYBRID COMPOSITE

A project report submitted in partial fulfilment of the requirement for

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BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

BY

31812650152 PEDADA VENKATA SAI KIRAN
318126520139 GORLE DEVAKI
318126520171 VISHAL SUBHASH KHANDAGALE
318126520160 SANGANI BHASKARA VARMA
318126520145 KAKI NAVEEN

Under the esteemed guidance of

Mr. CH. MAHESWARA RAO, M.Tech, (Ph.D)

Assistant Professor

PRAGNANAM BRAHMA
ANITS

DEPARTMENT OF MECHANICAL ENGINEERING
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES

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Sangivalasa, Bheemunipatnam Mandal
Visakhapatnam (District) – 531162

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Sangivalasa, Bheemunipatnam Mandal
Visakhapatnam (District) – 531162

PRAGNANAM BRAHMA
ANITS

CERTIFICATE

This is to certify that the project Report entitled "**EXPERIMENTAL INVESTIGATION ON IMPROVEMENTS IN MECHANICAL PROPERTIES OF AA2024/AL_2O_3/B_4C HYBRID COMPOSITE**" being submitted by **PEDADA VENKATA SAI KIRAN (318126520152), VISHAL SUBHASH KHANDAGALE (318126520171), GORLE DEVAKI (318126520139), SANGANI BHASKARA VARMA (318126520160)** and **KAKI NAVEEN (31812652145)** in partial fulfilments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING.** It is the work of bonafide, carried out under the guidance and supervision of **Mr. CH. MAHESWARA RAO,** Assistant professor, **DEPARTMENT OF MECHANICAL ENGINEERING** during the academic year of 2018-2022.

Approved By:

PROJECT GUIDE	HEAD OF THE DEPARTMENT
(Mr. Ch. Maheswara Rao)	Dr. B. Naga raju
MTech, PhD, MBA, AMIE, ISTE	PhD
Assistant professor	Head of department
Mechanical Department	Mechanical Engineering
ANITS, visakhapatnam	ANITS, visakhapatnam

PROFESSOR & HEAD
Department of Mechanical Engineering
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES
Sangivalasa-531 162 VISAKHAPATNAM Dist A P

THIS PROJECT IS APPROVED BY THE FOLLOWING

BOARD OF EXAMINERS

1. **EXTERNAL EXAMINER**

2. **INTERNAL EXAMINER**

PROFESSOR & HEAD
Department of Mechanical Engineering
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES
Sangivalasa-531 162 VISAKHAPATNAM Dist A.P.

Abstract

The enhancement of manufacturing sector has somewhere advance to the increase in the use of Aluminium metal matrix composites (AMMCs). AMMCs are attracting considerable interest worldwide for automotive, architectural and aerospace sectors because of their superior mechanical and tribological properties. AMMCs possess high specific strength, greater strength to weight ratio at elevated temperature, greater wear resistance as compared to matrix phase. Numerous types of reinforcements in particulate like SiC, Al2O3, B4C, TiC and ZrSiO4 is used to improve the metallurgical as well as mechanical properties as compared to its base matrix. Various fabrication processes like solid state (Powder Metallurgy) and liquid state processes (Stir casting, Compo-casting, Squeeze Casting, in situ casting routes) were adopted by authors to fabricate AMMCs. Among these processes stir casting is cheapest and simple route for fabrication of AMMCs. This article elaborates detailed process to fabricate AL2024 as matrix material while B4C and SiC are reinforcements,using stir casting process.

Contents

List of Tables

List Of Figures

Chapter-1
Introduction

Introduction

1.1 Composites

In addition to metals, ceramics, and polymers, a fourth material category can be distinguished: composites. A composite material is a material system composed of two or more physically distinct phases whose combination produces aggregate properties that are different from those of its constituents. In certain respects, composites are the most interesting of the engineering materials because their structure is more complex than the other three types

The technological and commercial interest in composite materials derives from the fact that their properties are not just different from their components but are often far superior. Some of the possibilities include:

- Composites can be designed that are very strong and stiff, yet very light in weight, giving them strengthto-weight and stiffness-to-weight ratios several times greater than steel or aluminum. These properties are highly desirable in applications ranging from commercial aircraft to sports equipment.
- Fatigue properties are generally better than for the common engineering metals. Toughness is often greater, too.
- Composites can be designed that do not corrode like steel; this is important in automotive and other applications.
- With composite materials, it is possible to achieve combinations of properties not attainable with metals, ceramics, or polymers alone.
- Better appearance and control of surface smoothness are possible with certain composite materials.

1.2 CLASSIFICATION OF COMPOSITE MATERIALS

composite material consists of two or more distinct phases. The term phase indicates a homogeneous material, such as a metal or ceramic in which all of the grains have the same crystal structure, or a polymer with no fillers. By combining the phases, using methods yet to be described, a new material is created with aggregate performance exceeding that of its parts. The effect is synergistic.

composite materials can be classified in various ways. One possible classification distinguishes between

(1) traditional

(2) synthetic composites

1.2.1 **Traditional Composites:**Traditional Composites are those that occur in nature or have been produced by civilizations for many years. Wood is a naturally occurring composite material, while concrete and asphalt mixed with gravel are traditional composites used in construction.

1.2.2 Synthetic composites: Synthetic Composites are modern material systems normally associated with the manufacturing industries, in which the components are first produced separately and then combined in a controlled way to achieve the desired structure, properties, and part geometry

In the simplest manifestation of our definition, a composite material consists of two phases:

- primary phase
- secondary phase

The **primary phase** forms the matrix within which the secondary phase is imbedded. The imbedded phase is sometimes referred to as a reinforcing agent (or similar term), because it usually serves to strengthen the composite.

The **secondary phase** may also be one of the three basic materials, or it may be an element such as carbon or boron.

1.3 The classification system for composite materials based on the matrix phase:

1.3.1. Metal Matrix Composites (MMCs) include mixtures of ceramics and metals, such as cemented carbides and other cermets, as well as aluminum or magnesium reinforced by strong, high stiffness fibers.

1.3.2. Ceramic Matrix Composites (CMCs) are the least common category. Aluminum oxide and silicon carbide are materials that can be imbedded with fibers for improved properties, especially in high temperature applications.

1.3.3. Polymer Matrix Composites (PMCs) Thermosetting resins are the most widely used polymers in PMCs. Epoxy and polyester are commonly mixed with fiber reinforcement, and phenolic is mixed with powders. Thermoplastic molding compounds are often reinforced, usually with powders.

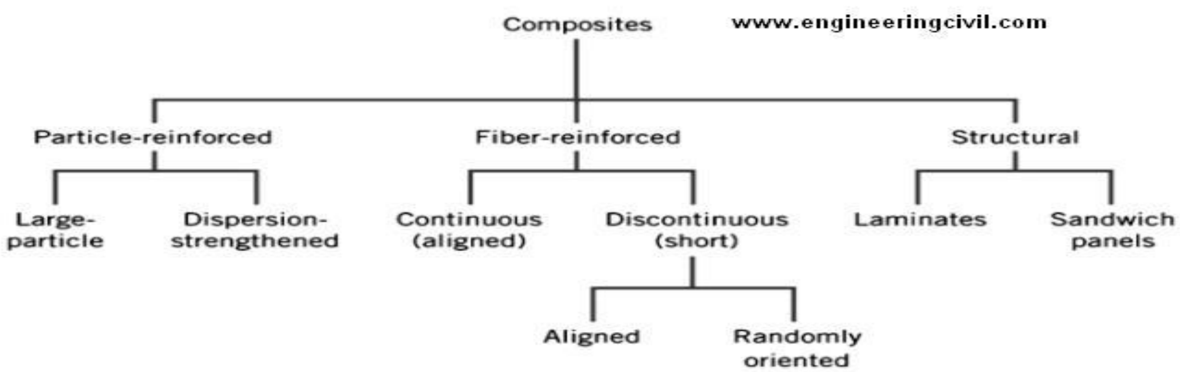


Figure 1.1.Classification Of Composites

1.4 Particle-Reinforced Composites:

Large-particle and dispersion-strengthened composites are the two sub classifications of particle-reinforced composites. The distinction between these is based on reinforcement or strengthening mechanism. For most of these composites, the particulate phase is harder and stiffer than the matrix. These reinforcing particles tend to restrain movement of the matrix phase in the vicinity of each particle. In essence, the matrix transfers some of the applied stress to the particles, which bear a fraction of the load. The degree of reinforcement or improvement of mechanical behavior depends on strong bonding at the matrix–particle interface. Matrix bears the major portion of an applied load, the small dispersed particles hinder or impede the motion of dislocations .plastic deformation is restricted such that yield and tensile strengths, as well as hardness.

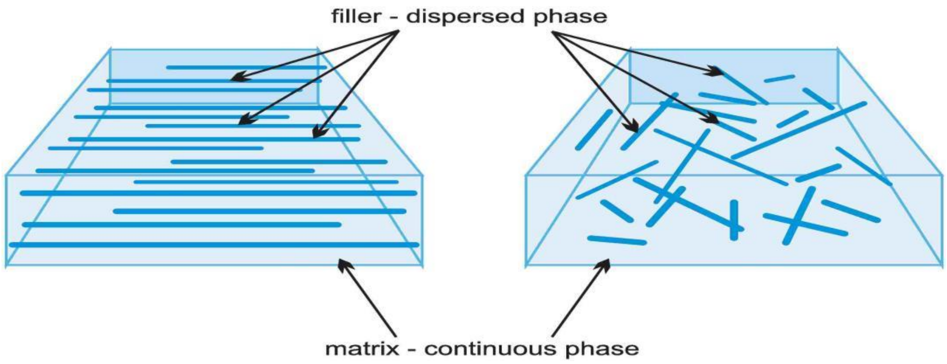


Figure 1.2 particle reinforced composite

1.5 LARGE-PARTICLE COMPOSITES

large-particle composite is concrete, which is composed of cement (the matrix) and sand and gravel (the particulates). Concrete is the discussion topic of a succeeding section.

1.5.1 Concrete

Concrete is a common large-particle composite in which both matrix and dispersed phases are ceramic materials. Because the terms concrete and cement are sometimes incorrectly interchanged, perhaps it is appropriate to make a distinction between them The two most familiar concretes are those made with portland and asphaltic cements, in which the aggregate is gravel and sand. Asphaltic concrete is widely used primarily as a paving material, whereas portland cement concrete is employed extensively as a structural building material.

1.5.2 Portland Cement Concrete

The ingredients for this concrete are portland cement, a fine aggregate (sand), a coarse aggregate (gravel), and water. The aggregate particles act as a filler material to reduce the overall cost of the concrete product because they are cheap, whereas cement is relatively expensive. To achieve the optimum strength and workability of a concrete mixture, the ingredients must be added in the correct proportions. The character of the aggregate particles is an important consideration. In particular, the size distribution of the aggregates influences the amount of cement–water paste required. Also, the surfaces should be clean and free from clay and silt, which prevent the formation of a sound bond at the particle surface.

Figure 1.3 portland cement

1.6 Dispersion-strengthened composites

Metals and metal alloys may be strengthened and hardened by the uniform dispersion of several volume percent of fine particles of a very hard and inert material. The dispersed phase may be metallic or non-metallic; oxide materials are often used. Again, the strengthening mechanism involves interactions between the particles and dislocations within the matrix, as with precipitation hardening. The dispersion strengthening effect is not as pronounced as with precipitation hardening; however, the strengthening is retained at elevated temperatures and for extended time periods because the dispersed particles are chosen to be unreactive with the matrix phase. For precipitation-hardened alloys, the increase in strength may disappear upon heat treatment as a consequence of precipitate growth or dissolution of the precipitate phase.

1.7 Fiber-Reinforced Composites

Technologically, the most important composites are those in which the dispersed phase is in the form of a fiber. Design goals of fiber-reinforced composites often include high strength and/or stiffness on a weight basis.These characteristics are expressed in terms of specific strength and specific modulus parameters, which correspond, respectively, to the ratios of tensile strength to specific gravity and modulus of elasticity to specific gravity. Fiber-reinforced composites with exceptionally high specific strengths and moduli have been produced that use low-density fiber and matrix materials.

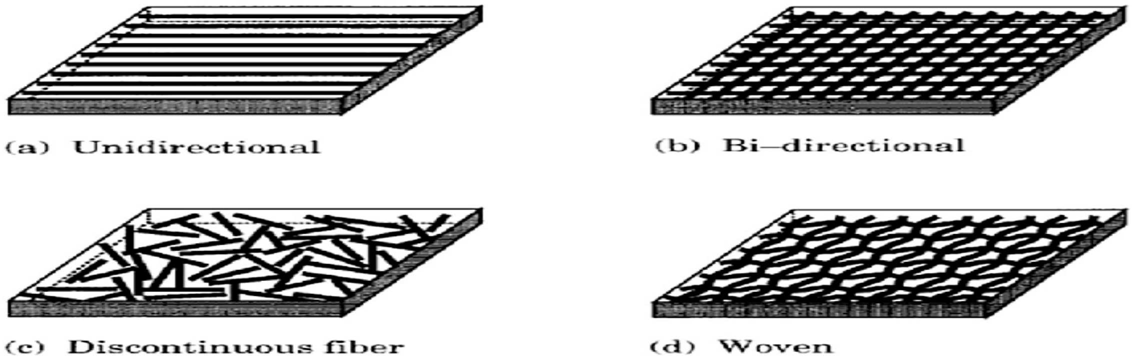


Figure 1.3 Fiber-Reinforced Composites

1.3.a. unidirectional 1.3.b. bi-directional

1.3.c.discontinuous 1.3.d.woven

1.8 Continuous Fibre Composites

The simplest method of producing continuous fibre composites is through the hand lay-up process. In a similar manner to the spray lay-up process a mould is used to which a gel coat is applied. The continuous fibres are then hand laid onto the mould in the form of cloth, mat, or fibre strands. The fibres stick to the gel coat and follow the contours of the mould surface. Further resin is then poured onto the fibres and impregnated using a roller. Successive layers of fibres are added until the desired thickness is achieved**.**

1.9 Fibre Reinforced Composites

Fibre reinforced composites are classed as either continuous (long fibres) or discontinuous (short fibres).When the fibres are aligned they provide maximum strength but only along the direction of alignment. The composite is considerably weaker along other directions and is therefore highly anisotropic.

1.9.1 Continuous aligned

This anisotropy can be overcome by randomly aligning fibres in all directions. This, however, is a less effective strengthening technique but has the advantage of increased formability and reduced cost.

1.9.2 Discontinuous random

Components that require strength in one particular direction will use aligned fibres while components that require strength in more than one direction will use randomly oriented fibres.

1.9.3 Discontinuous aligned

Composites that have fibres aligned in one principal direction are made using either continuous or discontinuous fibres. Composites with randomly oriented fibres are usually made with discontinuous fibres. Composites are essentially tailor made materials in that there are a number of parameters, other than the properties of the fibres and matrix, that can be changed to meet the design requirements of a given application

These MMCs are of interest because they combine the high tensile strength and modulus of elasticity of a fiber with metals of low density, thus achieving good strength-to-weight and modulus-to-weight ratios in the resulting composite material. Typical metals used as the low-density matrix are aluminum, magnesium, and titanium. Some of the important fiber materials used in the composite include Al2O3, boron, carbon, and SiC. Properties of fiber-reinforced MMCs are anisotropic, as expected. Maximum tensile strength in the preferred direction is obtained by using continuous fibers bonded strongly to the matrix metal. Elastic modulus and tensile strength of the composite material increase with increasing fiber volume. MMCs with fiber reinforcement have good high-temperature strength properties; and they are good electrical and thermal conductors. Applications have largely been components in aircraft and turbine machinery, where these properties can be exploited.

1.10 PROCESSING OF FIBER-REINFORCED COMPOSITES

To fabricate continuous fiber–reinforced plastics that meet design specifications, the fibers should be uniformly distributed within the plastic matrix and, in most instances, all oriented in virtually the same direction. In this section several techniques (pultrusion, filament winding, and prepreg production processes) by which useful products of these materials are manufactured will be discussed Pultrusion Pultrusion is used for the manufacture of components having continuous lengths and a constant cross-sectional shape (rods, tubes, beams, etc.).

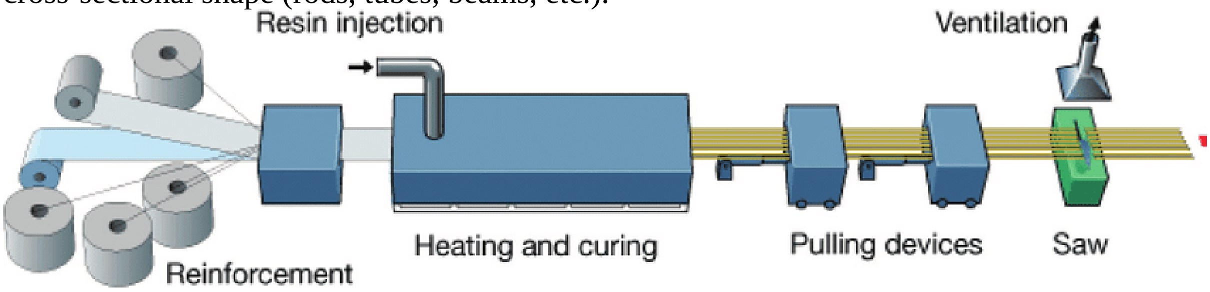


Figure 1.4 design of fiber–reinforced composite

With this technique illustrated schematically in continuous-fiber rovings, or tows,4 are first impregnated with a thermosetting resin; these are then pulled through a steel die that preforms to the desired shape and also establishes the resin/fiber ratio. The stock then passes through a curing die that is precision machined so as to impart the final shape; this die is also heated to initiate curing of the resin matrix. A pulling device draws the stock through the dies and also determines the production speed. Tubes and hollow sections are made possible by using center mandrels or inserted hollow cores. Principal reinforcements are glass, carbon, and aramid fibers, normally added in concentrations between 40 and 70 vol%. Commonly used matrix materials include polyesters, vinyl esters, and epoxy resins. Pultrusion is a continuous process that is easily automated; production rates are relatively high, making it very cost effective. Furthermore, a wide variety of shapes are possible, and there is really no practical limit to the length of stock that may be manufactured.

1.11 Prepreg Production Processes

Prepreg is the composite industry's term for continuous-fiber reinforcement preim pregnated with a polymer resin that is only partially cured. This material is delivered in tape form to the manufacturer, which then directly molds and fully cures the product without having to add any resin. It is probably the composite material form most widely used for structural applications.

At room temperature the thermoset matrix undergoes curing reactions; therefore, the prepreg is stored at 0 C (32 F) or lower. Also, the time in use at room temperature (or out-time) must be minimized. If properly handled, thermoset prepregs have a lifetime of at least six months and usually longer. Both thermoplastic and thermosetting resins are used; carbon, glass, and aramid fibers are the common reinforcements.

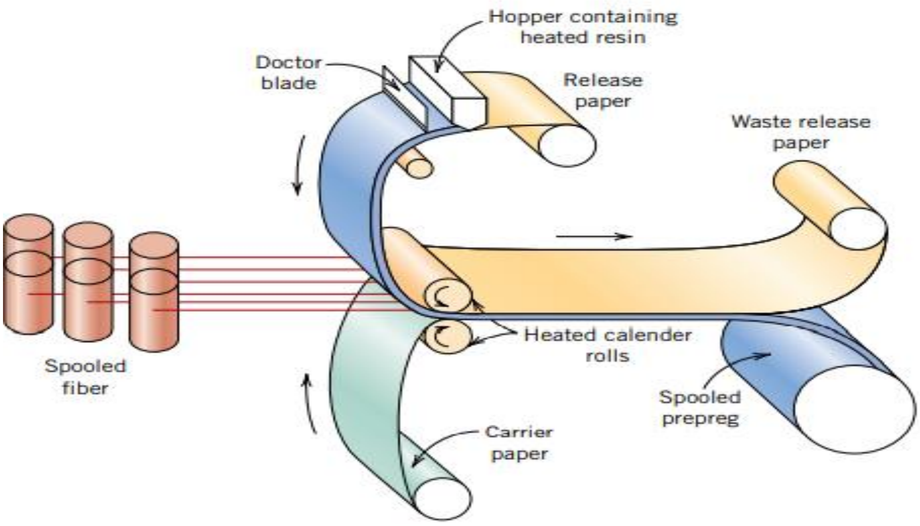


Figure 1.5

1.12 Filament Winding

Filament winding is a process by which continuous reinforcing fibers are accurately positioned in a predetermined pattern to form a hollow (usually cylindrical) shape. The fibers, either as individual strands or as tows, are first fed through a resin bath and then are continuously wound onto a mandrel, usually using automated winding equipment. After the appropriate number of layers have been applied, curing is carried out either in an oven or at room temperature, after which the mandrel is removed. As an alternative, narrow and thin prepregs (i.e., tow pregs) 10 mm or less in width may be filament wound.

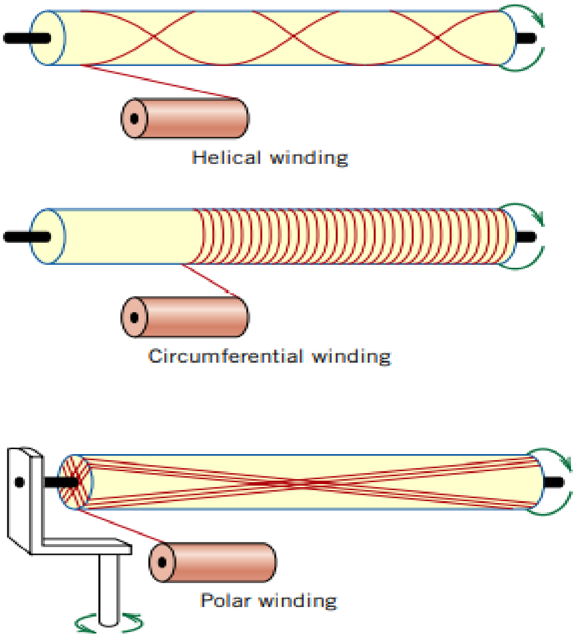


Figure 1.6 Filament winding

1.13 Structural Composites

A structural composite is normally composed of both homogeneous and composite materials, the properties of which depend not only on the properties of the constituent materials but also on the geometrical design of the various structural elements. Laminar composites and sandwich panels are two of the most common structural composites; only a relatively superficial examination is offered here for them.

1.14 LAMINAR COMPOSITES

A laminar composite is composed of two-dimensional sheets or panels that have a preferred high-strength direction, such as is found in wood and continuous and aligned fiber–reinforced plastics. The layers are stacked and subsequently cemented together such that the orientation of the high-strength direction varies with each successive layer. For example, adjacent wood sheets in plywood are aligned with the grain direction at right angles to each other. Laminations may also be constructed using fabric material such as cotton, paper, or woven glass fibers embedded in a plastic matrix. Thus a laminar composite has relatively high strength in a number of directions in the two-dimensional plane; however, the strength in any given direction is, of course, lower than it would be if all the fibers were oriented in that direction.

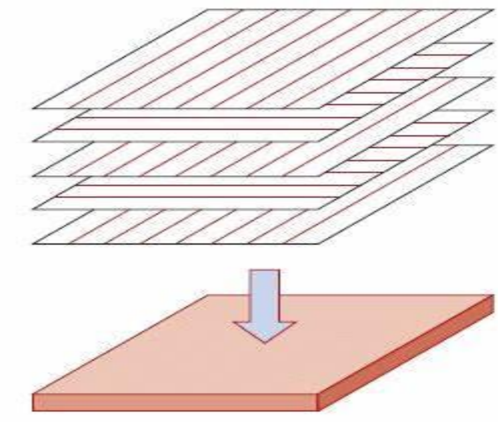


Figure 1.7 laminar composite

1.15 SANDWICH PANELS

Sandwich panels, considered to be a class of structural composites, are designed to be lightweight beams or panels having relatively high stiffnesses and strengths. A sandwich panel consists of two outer sheets, or faces, that are separated by and adhesively bonded to a thicker core .The outer sheets are made of a relatively stiff and strong material, typically aluminum alloys, fiber-reinforced plastics, titanium, steel, or plywood; they impart high stiffness and strength to the structure and must be thick enough to withstand tensile and compressive stresses that result from loading. The core material is lightweight and normally has a low modulus of elasticity. Core materials typically fall within three categories: rigid polymeric foams (i.e., phenolics, epoxy, polyurethanes), wood (i.e., balsa wood), and honeycombs (discussed shortly). Structurally, the core serves several functions. First of all, it provides continuous support for the faces. In addition, it must have sufficient shear strength to withstand transverse shear stresses and also be thick enough to provide high shear stiffness (to resist buckling of the panel). (Tensile and compressive stresses on the core are much lower than on the faces)

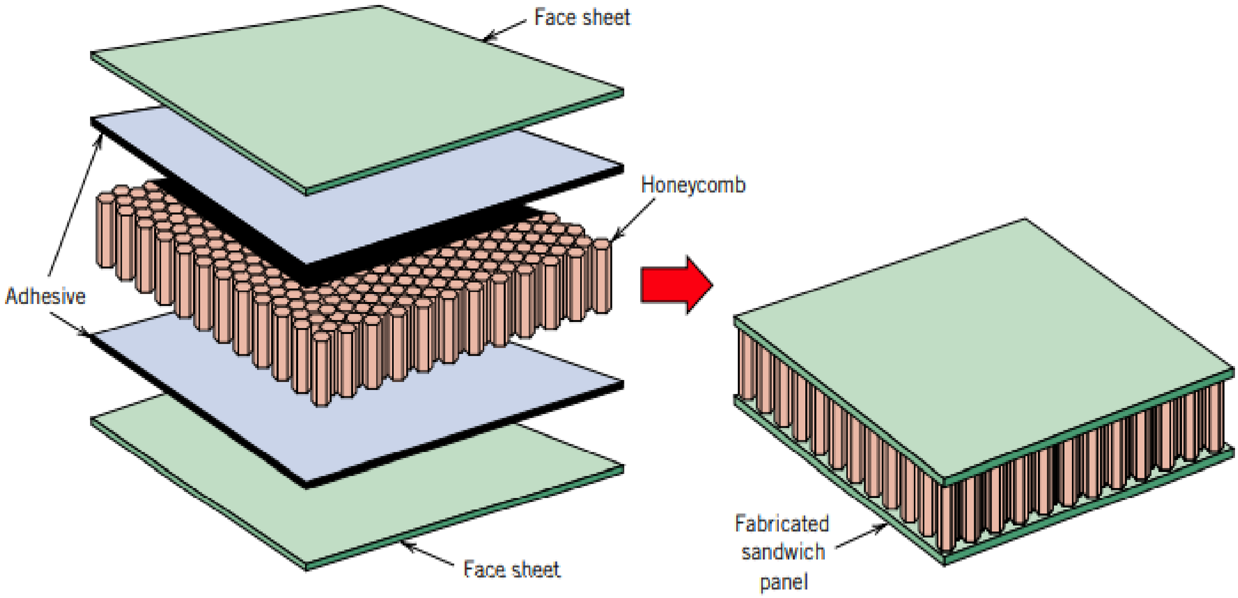


Figure 1.8 Sandwich panels

1.16 Classification of Matrix Materials

1.17 POLYMER-MATRIX COMPOSITES

Polymer-matrix composites (PMCs) consist of a polymer resin2 as the matrix, with fibers as the reinforcement medium. These materials are used in the greatest diversity of composite applications, as well as in the largest quantities, in light of their room-temperature properties, ease of fabrication, and cost. In this section the various classifications of PMCs are discussed according to reinforcement type (i.e., glass, carbon, and aramid), along with their applications and the various polymer resins that are employed.

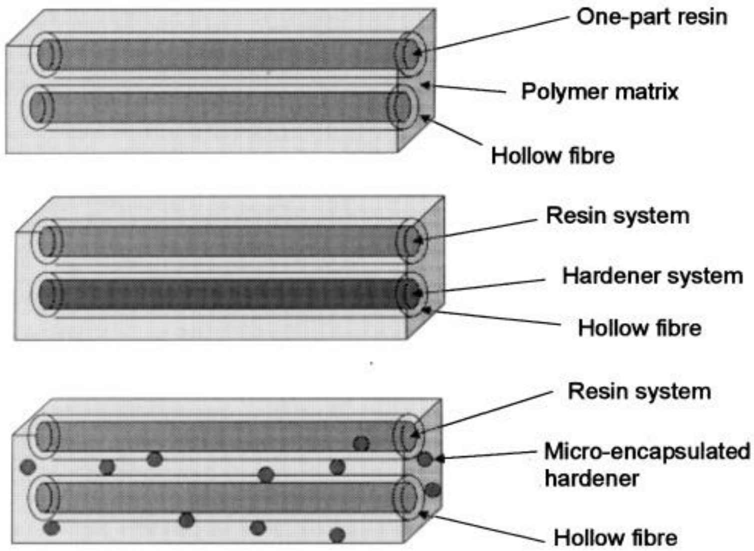


Figure 1.9 Polymer-matrix composites

1.18 Glass Fiber–Reinforced Polymer (GFRP) Composites

Fiberglass is simply a composite consisting of glass fibers, either continuous or discontinuous, contained within a polymer matrix; this type of composite is produced in the largest quantities. The composition of the glass that is most commonly drawn into fiber

There are several limitations to this group of materials. In spite of having high strengths, they are not very stiff and do not display the rigidity that is necessary for some applications (e.g., as structural members for airplanes and bridges). Most fiberglass materials are limited to service temperatures below 200 C (400 F); at higher temperatures, most polymers begin to flow or to deteriorate. Service temperatures may be extended to approximately 300 C (575 F) by using high-purity fused silica for the fibers and high-temperature polymers such as the polyimide resins

Many fiberglass applications are familiar: automotive and marine bodies, plastic pipes, storage containers, and industrial floorings. The transportation industries are using increasing amounts of glass fiber–reinforced plastics in an effort to decrease vehicle weight and boost fuel efficiencies. A host of new applications are being used or currently investigated by the automotive industry.

1.19 METAL-MATRIX COMPOSITES

As the name implies, for metal-matrix composites (MMCs) the matrix is a ductile metal. These materials may be used at higher service temperatures than their basemetal counterparts; furthermore, the reinforcement may improve specific stiffness specific strength, abrasion resistance, creep resistance, thermal conductivity, and dimensional stability. Some of the advantages of these materials over the polymermatrix composites include higher operating temperatures, non flammability, and greater resistance to degradation by organic fluids. Metal-matrix composites are much more expensive than PMCs, and, therefore, MMC use is somewhat restricted.

Some matrix–reinforcement combinations are highly reactive at elevated temperatures. Consequently, composite degradation may be caused by high-temperature processing or by subjecting the MMC to elevated temperatures during service. This problem is commonly resolved either by applying a protective surface coating to the reinforcement or by modifying the matrix alloy composition.

Normally the processing of MMCs involves at least two steps: consolidation or synthesis (i.e., introduction of reinforcement into the matrix), followed by a shaping operation. A host of consolidation techniques are available, some of which are relatively sophisticated; discontinuous fiber MMCs are amenable to shaping by standard metal-forming operations (e.g., forging, extrusion, rolling).

Automobile manufacturers have recently begun to use MMCs in their products. For example, some engine components have been introduced consisting of an aluminum-alloy matrix that is reinforced with aluminum oxide and carbon fibers; this MMC is light in weight and resists wear and thermal distortion. Metal-matrix composites are also employed in driveshafts (that have higher rotational speeds and reduced vibrational noise levels), extruded stabilizer bars, and forged suspension and transmission components. The aerospace industry also uses MMCs. Structural applications include advanced aluminum-alloy metal-matrix composites; boron fibers are used as the reinforcement for the space shuttle orbiter, and continuous graphite fibers for the Hubble Space Telescope.

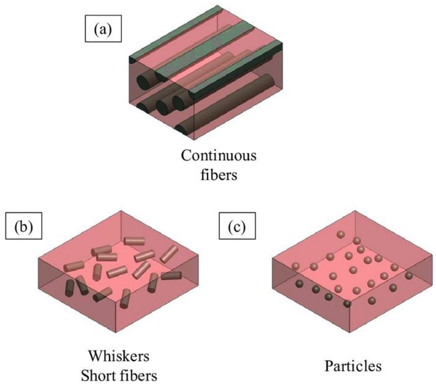


Figure 1.10 metal-matrix composites

Fig 1.10.a. continuous fibers 1.10.b.whiskers short fibers

1.10.c. particles

1.20 Composition

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

1.21 Matrix

The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such as aluminum, magnesium, or titanium, and provides a compliant support for the reinforcement. In high-temperature applications, cobalt and cobalt–nickel alloy matrices are common.

1.22 Reinforcement

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

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

1.23 Types of metal matrix

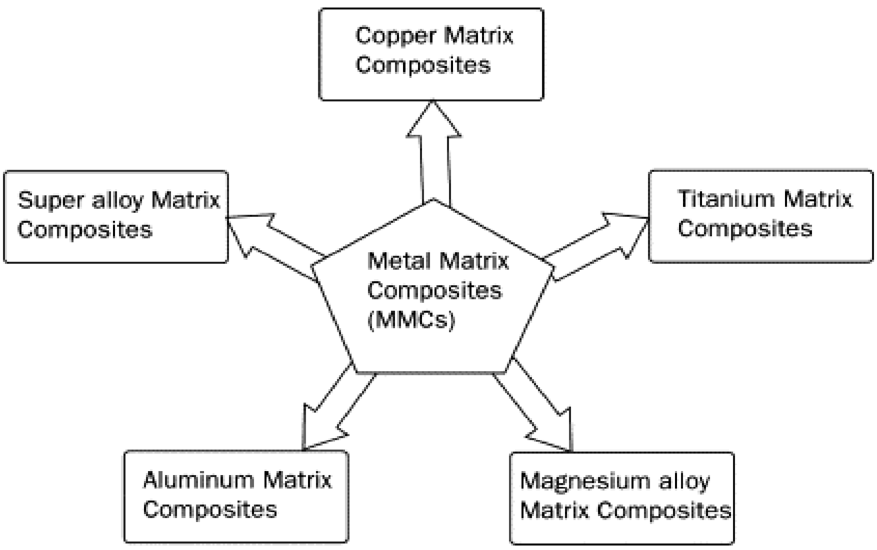


Figure 1.11 types of metal matrix

1.24 Metal-matrix composites (MMCs) are a class of materials with potential for a wide variety of structural and thermal management applications. They are non-flammable, do not outgas in a vacuum, and suffer minimal attack by organic fluids, such as fuels and solvents. This article presents an overview of the status of MMCs, and provides information on physical and mechanical properties, processing methods, distinctive features, and various types of continuously and discontinuously reinforced aluminum, magnesium, titanium, copper, superalloy, and intermetallic-matrix composites. It further discusses the property prediction and processing methods for MMCs.

1.25 Superalloys

Superalloys are commonly used for turbine engine hardware and, therefore, superalloy-matrix composites were among the first candidate materials considered for upgrading turbine performance by raising component operating temperatures. Superalloy MMCs were developed to their present state over a period of years, starting from the early 1960s. High-temperature strength in superalloy MMCs has been achieved only through the use of refractory metal reinforcements (tungsten, molybdenum, tantalum, and niobium fibers with compositions specially modified for this purpose). The strongest fiber developed, a tungsten alloy, exhibited a strength of more than 2070 MPa (300 ksi) at 1095 °C (2000 °F), or more than six times the strength of the superalloy now used in the Space Shuttle main engine. Much of the early work on superalloy MMCs consisted of fiber-matrix compatibility studies, which ultimately led to the use of matrix alloys that exhibit limited reaction with the fibers. Tungsten fibers, for example, are least reactive in iron-base matrices, and they can endure short exposures at

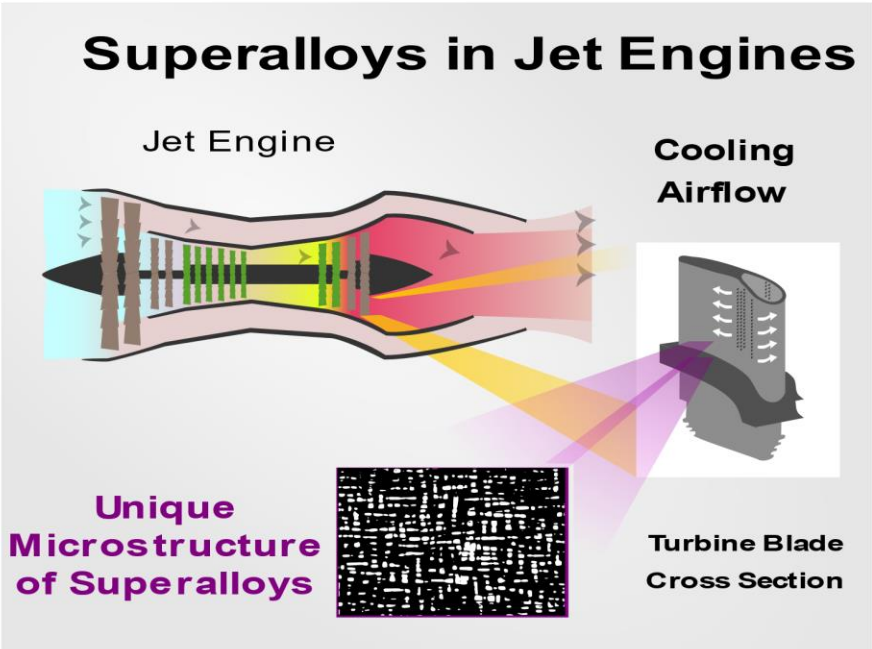


Figure 1.12 super alloys in jet engines

1.26 Fabrication of superalloy MMCs is accomplished via solid-phase, liquid-phase, or deposition processing. The methods include investment casting, the use of matrix metals in thin sheet form, the use of matrix metals in powder sheet form made by rolling powders with an organic binder, powder metallurgy techniques, slip casting of metal alloy powders, and arc spraying. Iron-, nickel-, and cobalt-base MMCs have been made, and a wide range of properties have been achieved with these MMCs, including elevated-temperature tensile strength, stressrupture strength, creep resistance, low- and high-cycle fatigue strength, impact strength, oxidation resistance, and thermal conductivity.

1.27 Titanium matrix composites (TMCs) offer high specific strength and stiffness compared with steel and nickel-base materials. High-temperature TMCs can offer up to 50% weight reduction relative to monolithic superalloys while maintaining equivalent strength and stiffness in jet engine propulsion systems. Regardless of the reinforcements are continuous fibres or discontinuous particulates, the unique properties of TMCs have thrust them to the forefront of extensive research and development programmes around the world. Even though TMCs are one of the most studied and sought-after material systems, useful information about their properties, fabrication methods and design is scattered in the literature. This review covers important research work that has led to the advances in TMCs material systems. It also provides comprehensive details about common reinforcements, manufacturing processes, and reviews static and dynamic properties of some common TMCs. The review also presents common industrial applications of TMCs and highlights the promising outlook of TMCs.

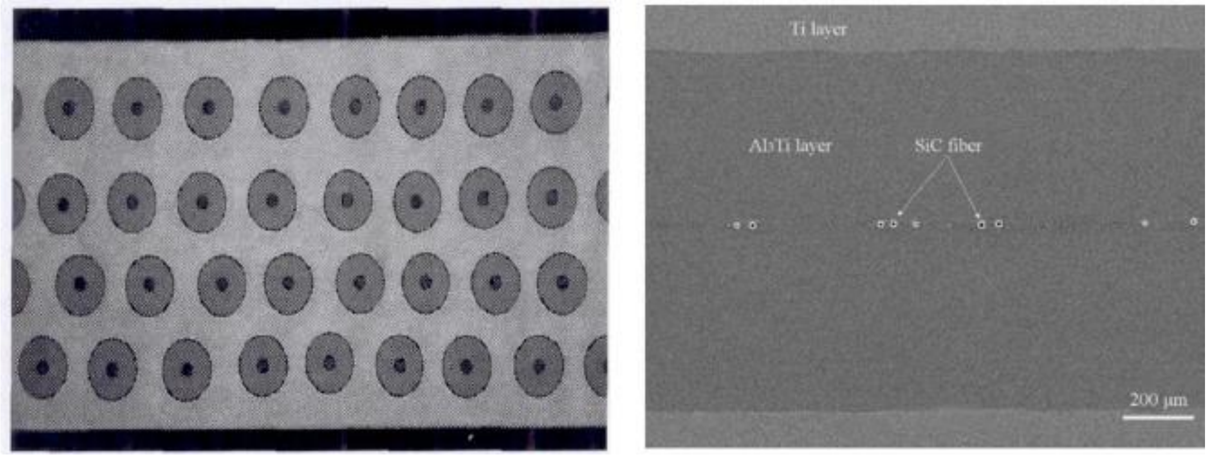


Figure 1.13 titanium matrix composites

1.28 Magnesium composites are new class metal matrix composites widely used in aerospace and automobile industries due to their low density, good mechanical properties, better corrosion and wear resistance, low thermal coefficient of expansion as compared to conventional metals and alloys. The performance of composites depends upon the right combination and composition of reinforcement material with the matrix material. This paper presents few of the available literature review the combination of reinforcement material with magnesium matrix metal. Magnesium metal matrix composites with reinforcement(s) and filler materials are finding increased applications because of improved mechanical and tribological properties. Addition of reinforcing materials such as Al_2O_3, SiC, B_4C, metallic glass, etc., is one of the ways to enhance various mechanical and tribological properties of Mg based MMCs. When graphite is added composites decrease in tensile and hardness was observed whereas with graphite addition specific wear rate decreases. Waste materials may used as reinforcement such as fly ash, rice husk ash, etc. for low cost reinforcement which may results in better mechanical and wear properties.

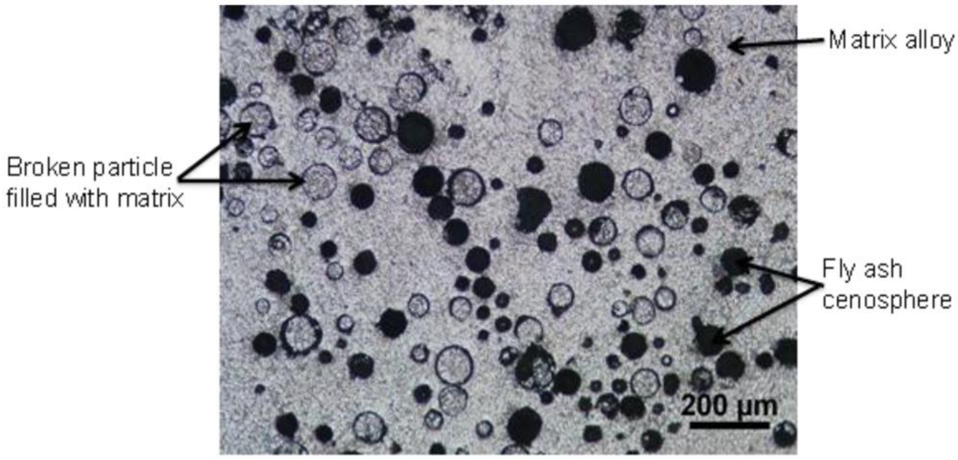


Figure 1.14 magnesium composites

1.29 Copper Metal Matrix

In the last few decades, man has become more innovative in discovering new materials to make his life more sustainable. Copper metal matrix composite is the most promising material for many engineering applications where the higher temperature resistance and good microstructural stability is required. The sustainable development of copper metal matrix composite is based on the use of ceramics as reinforcements. The choice of reinforcement material is highly influenced by their mechanical properties such as hardness, wear resistance, cost advantage, availability in market and refractory nature. In the current scenario, copper and its alloy are gaining popularity due to their high sustainability, high conductivity and good corrosion resistance. However, the relatively low wear resistance and high temperature strength restrict the use of copper in many applications. Recent developments in metal matrix composites have provided new means to produce high sustainable copper metal matrix composite materials with high wear resistance and high strength materials. It has been found that the wear resistance and strength of materials can be improved by adding hard ceramic particles such as Al_2O_3, SiC, TiC and ZrO_2 into the metal matrix. The aim of the present study is to summarise the research work carried out in the field of sustainable copper metal matrix composites. It also reports the various manufacturing routes along with the structural, mechanical, electrical and corrosion properties. It is found that copper metal matrix composites are preferred over the conventional composites. Sustainability issues around the globe has forced the industries to adopt the eco-friendly materials with their fabrication and machining routes, which results in less carbon emission and also has less affect to the environment. Fabrication of eco-friendly composites is an emerging research area, which has made several research scopes in production of sustainable composites. It is expected that this study can be beneficial for the researcher to decide their research direction in the field of sustainable material production.

Among any of the other commonly used metals, copper is the one characterized by the best thermal conductivity, which explains why it is commonly chosen in the first instance for a matrix material. On the other hand, having very low mechanical properties, it has to be strengthened by ceramic particles, for example, which is one of the most reliable methods of reinforcement.The carbides (e.g., SiC, TiC, NbC, WC, TaC, B_4C), oxides (e.g., Al_2O_3, Y_2O_3, SiO_2, Cr_2O_3, TiO_2), and borides (e.g., TiB_2, ZrB_2) are widely used as reinforcement additives; volcanic tuff, diamond particles, intermetallic phases, shavings of steel processing, and carbon tubes or fibers are also starting to play a significant role in this domain. Among those modern reinforcing materials, TiN-based nitrides play a pronounced role, since they are characterized by high hardness, excellent electrical conductivity, good thermal and chemical stability, excellent stability at high temperatures, and good corrosion resistance . Moreover, titanium nitride is susceptible to oxidation (whose products are TiO_xN_y and TiO_2 – potentially useful as protective coating materials) The mechanical alloying (MA) process allows us to obtain a material with a variety of chemical, physical, and mechanical properties that combine the features of copper with those of titanium nitrides. Thus, this fabrication method seems to be aconvenient one in order to produce materials with great electrical conductivity and durability at a relatively low cost of production.

1.30 Aluminium metal matrix

The term "composite" broadly refers to a material system which is composed of a discrete constituent (the reinforcement) distributed in a continuous phase (the matrix), and which derives its distinguishing characteristics from the properties of its constituents, from the geometry and architecture of the constituents, and from the properties of the boundaries (interfaces) between different constituents. Composite materials are usually classified on the basis of the physical or chemical nature of the matrix phase, e.g., polymer matrix, metal-matrix and ceramic composites. In addition there are some reports to indicate the emergence of Inter metallic-matrix and carbon-matrix composites. This review is concerned with metal matrix composites and more specifically on the aluminium matrix composites (AMCs). In AMCs one of the constituent is aluminium/aluminium alloy, which forms percolating network and is termed as matrix phase. The other constituent is embedded in this aluminium/aluminium alloy matrix and serves as reinforcement, which is usually non-metallic and commonly ceramic such as Sic and Al2O3. Properties of AMCs can be tailored by varying the nature of constituents and their volume fraction. The major advantages of AMCs compared to unreinforced materials are as follows:

- Greater strength

- Improved stiffness
- Reduced density(weight)
- Improved high temperature properties
- Controlled thermal expansion coefficient
- Thermal/heat management
- Enhanced and tailored electrical performance
- Improved abrasion and wear resistance
- Control of mass (especially in reciprocating applications) • Improved damping capabilities.

AMC material systems offer superior combination of properties (profile of properties) in such a manner that today no existing monolithic material can rival. Over the years, AMCs have been tried and used in numerous structural, non-structural and functional applications in different engineering sectors. Driving force for the utilisation of AMCs in these sectors include performance, economic and environmental benefits. The key benefits of AMCs in transportation sector are lower fuel consumption, less noise and lower airborne emissions. With increasing stringent environmental regulations and emphasis on improved fuel economy, use of AMCs in transport sector will be inevitable and desirable in the coming years

1.31 BORON CARBIDE REINFORCED AMC. investigated the trimodal aluminium metal matrix composites and the factors affecting its strength. The test result shows that the attributes like nano-scale dispersoids ofAl_2O_3, crystalline and amorphous AlN and Al_4C_3, high dislocation densities in both NC-Al and CG-Al domains, interfaces between different constituents, and nitrogen con- centration and distribution leads to increase in strength. Vogt et al. studied the cryomilled alu- minium alloy and boron carbide nano-composite plates made in three methods, hot isostatic pressing (HIP) followed by high strain rate forging (HSRF), HIP followed by two-step quasi-isostatic forging (QIF), and three-step QIF. The test results showed that the HIP/HSRF plate exhibited higher strength with less ductility than the QIF plates, which had similar mechanical properties. The in- creased strength and reduced ductility of the HIP/ HSRF plate is attributed to the inhibition of dynamic recrystallization during the high strain rate forging procedure. Mahesh Babu et al. [investigated the characteristics of surface quality on machining hy- brid aluminium-B4C-SiC metal matrix composites using taguchi method. It was found that feed rate was the most important parameter followed by the cutting speed. Moreover it was concluded that the feed rate does not have a significant effect on surface quality.

1.32 CERAMIC-MATRIX COMPOSITES

Ceramic matrix composites (CMC) are generally made from ceramic fibres or whiskers embedded in a ceramic matrix. These ceramics cover a varied range of inorganic materials that are usually non-metallic and commonly used at high temperatures. Ceramics can be classified into two classes:

- Traditional or conventional ceramics – which usually are in monolithic form. They include tiles, bricks, pottery, and a wide range of art materials.
- Advanced or high-performance ceramics – which often undergo chemical processing to be derived. These include nitrides, oxides, and carbides of aluminium, silicon, zirconium, and titanium.

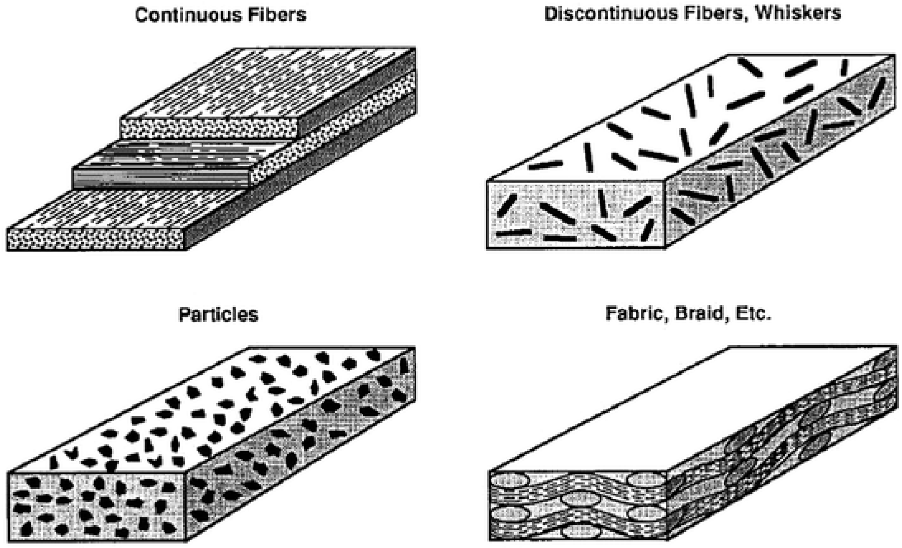


Figure 1.15 Ceramic matrix composites

1.33 Properties of ceramic matrix composites

Conventional ceramics have limited thermal shock resistance and low fracture toughness. These drawbacks are addressed by the use of fibre-reinforcement in ceramic matrix composites.

Common properties of ceramic matrix composites are

- High thermal shock and creep resistance
- High temperature resistance
- Excellent resistance to corrosion and wear
- Inertness to aggressive chemicals
- High tensile and compressive strength, thus no sudden failure as compared to conventional ceramics
- Increased fracture toughness due to reinforcement
- Lightweight due to reduced density
- High strength retention at elevated temperatures

1.34 CARBON–CARBON COMPOSITES

One of the most advanced and promising engineering materials is the carbon fiber–reinforced carbon-matrix composite, often termed a carbon–carbon composite; as the name implies, both reinforcement and matrix are carbon. These materials are relatively new and expensive and, therefore, are not currently being used extensively. Their desirable properties include high-tensile moduli and tensile strengths that are retained to temperatures in excess of 2000 C (3630 F), resistance to creep, and relatively large fracture toughness values. Furthermore, carbon–carbon composites have low coefficients of thermal expansion and relatively high thermal conductivities;

these characteristics, coupled with high strengths, give rise to a relatively low susceptibility to thermal shock. Their major drawback is a propensity to hightemperature oxidation.

The primary reason that these composite materials are so expensive is the relatively complex processing techniques that are employed. Preliminary procedures are similar to those used for carbon-fiber, polymer-matrix composites. That is, the continuous carbon fibers are laid down having the desired two- or three-dimensional pattern; these fibers are then impregnated with a liquid polymer resin, often a phenolic; the workpiece is next formed into the final shape, and the resin is allowed to cure. At this time the matrix resin is pyrolyzed, that is, converted into carbon by heating in an inert atmosphere; during pyrolysis, molecular components consisting of oxygen, hydrogen, and nitrogen are driven off, leaving behind large carbon-chain molecules. Subsequent heat treatments at higher temperatures will cause this carbon matrix to densify and increase in strength. The resulting composite, then, consists of the original carbon fibers that remained essentially unaltered, which are contained in this pyrolyzed carbon matrix

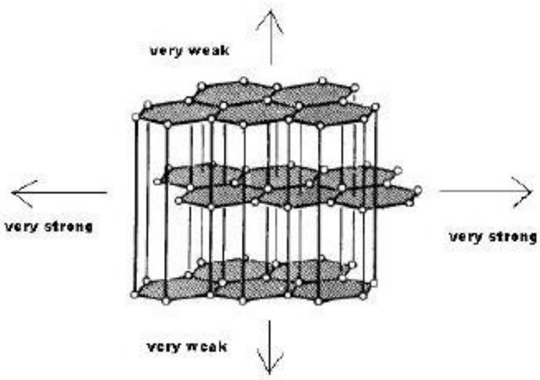


Figure 1.16 carbon-carbon composites

CHAPTER-2
LITERATURE SURVEY

AUTHORS: j Babu Rao, D Venkata Rao, I Narasimha Murthy

Composites are most promising materials of recent interest. Metal matrix composites (MMCs) possess significantly improved properties compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Hence, composites with fly ash as reinforcement are likely to over come thecost barrier for wide spread applications in automotive and small engine applications. In the present investigation, AA 2024 alloy – 2 to 10 wt% fly ash composites were made by stir casting route. Phase identification and structural characterization was carried out on fly ash by X-ray diffraction studies. Scanning electron microscopy and optical microscopy was used for microstructure analysis. The hardness, compression and pitting corrosion tests were carried out on all these alloy and composites. The SEM studies reveal that there was a uniform distribution of fly ash particles in the matrix phase and also very good bonding is exist between the matrix and reinforcement. With increasing the amount of fly ash the density of the composites was decreased and the hardness was increased. The increase in compression strength was observed with increase in amount of fly ash. Fly ash particles lead to an enhanced pitting corrosion of the aluminium–fly ash (ALFA) composites in comparison with unreinforced matrix (AA 2024 alloy). The enhanced pitting corrosion of ALFA composites is associated with the introduction of nobler second phase of fly ash particles.

Referencelink:
https://journals.sagepub.com/doi/abs/10.1177/0021998311419876

Authors: Muna Khethier Abbass, Sabah Khamass Hussein & Ahmed Adnan Khudhair

In this work, friction stir spot welding (FSSW) was performed for dissimilar aluminum alloys (AA2024-T3) sheets of 2 mm thick at different tool rotational speeds (800, 1000 and 1250 rpm), plunging times (30, 60 and 90 s) and tool pin profile or geometry. Process parameters were optimized by using Taguchi technique and depending on design of experiment (DOE), and data analysis based on the Taguchi method is performed by utilizing the Minitab 17 to estimate the significant factors of the FSSW and main effects using few experimental tests only. It was found that maximum shear force was (2860 N) obtained at best welding process parameters: 800 rpm of rotation speed, 60 s of plunging time and taper cylindrical pin which are obtained from the DOE. Pareto chart of the standardized effects of tensile shear results showed that the pin profile was the most effective parameter than other welding parameters. Also it was found that the contribution percentage was 61.5% for pin profile followed by tool rotation speed 20.1% and plunging time 18.4%.

Referencelink:https://link.springer.com/article/10.1007/s13369-016-2172-9

Authors: Pierpaolo Carlone , Gaetano S. Palazzo

Material stirring and heat generation in friction stir welding processes induce significant microstructure and material properties alterations. Previous studies highlighted the relationship among microstructure, grain size, microhardness, and performance of the joint. In this context, an opportune definition of process parameters, in particular rotating and welding speed, is crucial to improve joint reliability. In this article, results provided by a numerical and experimental investigation on the influence of rotating and welding speed on microstructure, mechanical properties, and joint quality in AA2024-T3 friction stir welded butt joints are reported. Experimental data are presented and discussed considering numerically computed temperature and strain rate distributions, providing useful information for parameters setting. Processing window, i.e., parameters resulting in a successful material deposition, is also individuated.

Reference Link : https://link.springer.com/article/10.1007/s13632-013-0078-4

Authors: Balasubramanian Kaliyaperumal,V. Balusamy

The hot cracking is a major problem in welding of high strength aluminum alloys. Many methods are available to control hot cracking tendency. In the present investigation, an effort was made to control the hot cracking tendency in high strength aluminum alloy using vibration. Here, vibration was generated and applied to the specimen while welding takes place. The material used for this investigation is

AA2024 alloy. The welding technique used for this work is Gas Tungsten Arc Welding (GTAW). Test specimens were prepared with and without application of vibration. The welded joints prepared in the presence and absences of vibration were compared by means of hot cracking test and some characterization tests, viz, X-ray diffraction techniques, cooling rate measurements and hardness measurements. Experiments conclude that the welded joints prepared with vibration have improved properties of the material and reasonable resistance to hot cracking.

Reference link:
https://www.researchgate.net/publication/325882214_Behavior_of_h ot_cracking_tendency_in_AA2024_alumi num_alloy_joint_with_vibration_and_its_influence_on_properties_of _the_materials

Authors: S. F. Tian, L.T. Jiang, Q. Guo and G.H. Wu

55 vol.% TiB2/2024Al composites were fabricated by pressure infiltration method. The effect of surface roughness of GCr15 steel disc (Ra 0.606, 0.372, 0.023, 0.005 mu m) on the tribological properties of composites was investigated. Results showed that with the change of surface roughness, there is an optimal value (Ra 0.023 mu m) under which the friction coefficient and wear rate is the lowest. The optimal surface roughness is in the same order of mixture of TiO2 and B2O3, observed on the surface of TiB2 particles after pre-heating process. During sliding, the filling of this oxidation layer into the asperity gap of GCr15 and greatly reduces adhesion between aluminium and GCr15, furthermore, decreases the friction coefficient and wear rate.

ReferenceLink:
https://www.researchgate.net/publication/271882746_WITHDRAW N_Effect_of_surface_roughness_on_tribolog ical_pr operties_of_TiB2Al_composites

Authors: H.H.SUN, H.RONG and H.WANG

Al2O3-Al composite coatings were fabricated on AZ91D magnesium alloy by plasma spraring with Al2O3 and Al mixed powders. Microstructure, microhardness and wear resistance of the coatings were examined and the effect of Al2O3 contents on the microstructure and tribological properties of the coatings was investigated. The results showed that in these composite coatings Al2O3 distributed in the compacted Al matrix. The microstructure of the coatings is banded structure and consisted of many tiny lamella with some pores. The hardness of Al is about 62 HV and that of Al2O3 is up to 1380 HV. The wear test results show that Al2O3-Al composite coatings have lower friction coefficient and less mass loss and improved the wear resistance of AZ91D magnesium alloy greatly. When the volume fraction of Al2O3 is lower than that of Al, wear resistance of the coatings increases with increasing Al2O3. When the volume fraction of Al2O3 is higher than that of Al, wear resistance of the coatings decreases.

ReferenceLink:https://www.researchgate.net/publication/282187785_Effect_of_Al2O3_contents_on_microstructure_and_tribological_properties_of_Al2O3Al_composite_coatings

Authors: Chenxu Liu, Ruo-Nan Ji, Jin Zhang and Shu-Guang Zhang

Al2O3/polytetrafluoroethylene (PTFE) composite coating was prepared on titanium alloy by cathode plasma electrolytic deposition (CPED) and impregnation method, to improve the hydrophobicity and tribological properties. Scanning electron microscopy (SEM) and energy-dispersive spectroscopy (EDS) analysis of the coating indicate that PTFE penetrates into the interior of the coating and is well bonded to titanium alloy substrate by cross-linking with Al2O3 ceramic coating. The contact angles were measured by contact angle measurement and the tribological properties of the composite coating were evaluated by sliding wear test. The surface of the composite coating is found to possess good hydrophobicity with a water contact angle of 140°. The results also indicate an improved tribological properties of Al2O3/PTFE composite coating at room temperature with a steady friction coefficient as low as 0.05. The selflubricating anti-wear composite coating is expected to solve fouling problems and poor wear resistance of titanium alloys.

Reference Link:
https://www.researchgate.net/publication/328859934_Hydrophobicity_and_tribological_properties_of_A l2O3PTFE_composite_coating

Authors: V. V. Narulkar, Shalvin Prakash and Kamlesh Chandra

The Al2O3- TiO2 coating for turbine blades is being used since long. During the last decades, a large number of papers have been published, but work on property assessment of Al2O3-TiO2 coating on rotating component from tribological point of view is very less. This paper assesses the wear behaviour of Al 2O3 -TiO2 coating on inconel 601. The Al2O3 -TiO2 coating on inconel 601 is deposited by plasma spray process. The SEM results show that above 300 °C the friction coefficient decreases due to softening of coating material. The wear rate increases with increase in temperature. The coating showed brittle fracture at higher temperature. Other test results have shown the drastic changes in property due to load and temperature.

Reference Link:
https://www.researchgate.net/publication/287461639_Effects_of_Temperature_on_Tribological_
Properties_of_Al2O3TiO2_Coating

Chapter-3
Material selection

3.1 What is Aluminum Oxide ?

Al_2O_3 is an inorganic chemical reagent with chemical name Aluminum oxide. It is also called as Alpha-Alumina, alumina, alundum or aloxide.

It is found naturally as corundum, Ruby's, sapphires, and emeralds. It is an amphoteric substance, which reacts with both acids and bases. It occurs as solid and appears white. It is odourless and insoluble in water. The most common occurrence of this compound is in crystalline form, called α-aluminium oxide or corundum. Due to its hardness, is widely used and suitable to use as an abrasive and in cutting tools.

3.2 Aluminium oxide Structure

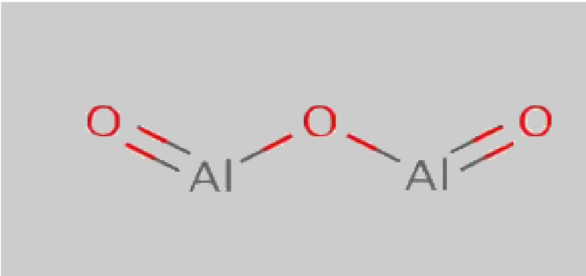


Figure 3.1 aluminum oxide structure

3.3 Properties of Aluminum oxide – Al_2O_3

Al_2O_3	Aluminium oxide
Molecular Weight/ Molar Mass	101.96 g/mol
Density	3.95 g/cm³
Boiling Point	2,977 °C
Melting Point	2,072 °C

Figure 3.2 properties of aluminum oxide

3.4 Aluminium oxide (Al_2O_3) Uses

- Aluminium oxide is one of the common ingredients in sunscreen and also present in cosmetics such as nail polish, blush, and lipstick.
- It is used in formulations of glass.
- It is used as a catalyst.
- It is used in the purification of water to remove water from the gas streams.
- It is used in sandpaper as an abrasive.
- Aluminium oxide is an electrical insulator used as a substrate for integrated circuits.

- Used in sodium vapour lamps.

3.5 Applications of Aluminium Oxide

Most of the aluminium oxide produced is used to form aluminum metal. Oxygen typically catalyses corrosion in reaction with the metal aluminium. However, when bonded with oxygen to form aluminium oxide, a protective coating forms and prevents further oxidation. This adds strength and makes the material less vulnerable to deterioration.
Industries that use aluminium oxide include:

3.5.1 Medical industry

Due to aluminium oxide's hardness, bio-inertness and chemical properties, it is a preferred material for bearings in hip replacements, as prostheses, bionic implants, prosthetic eye substitutes, tissue reinforcements, dental crowns, abutments, bridges, and other dental implants. It is also used in lab equipment and tools like crucibles, furnaces and other labware.

3.5.2 Military and protective equipment

Aluminium oxide's strength and lightweight qualities contribute to enhancing body armours, like breastplates, as well as vehicle and aircraft armour, which is its biggest market. Aluminium oxide is also used in synthetic-sapphire bulletproof windows and ballistics.

3.5.3 Electrical and electronics industry

Its high melting and boiling points, in addition to its excellent thermal resistive properties, make aluminium oxide desirable in the manufacture of high-temperature furnace insulations and electrical insulators. Alumina films are also vital components in the microchip industry. Some of its other uses include spark plug insulators, micro-electric substrates and insulating heatsinks.

3.5.4 Gem industry

Aluminium oxide is a valuable element in the formation of rubies and sapphires. Its crystalline form, corundum, is the base element for these precious gems. Rubies owe their deep red colour to chromium impurities while sapphires get their variant colours from traces of iron and titanium.

3.5.5 Industrial applications

Since alumina is chemically inert, it is utilised as a filler in plastics, bricks, and other heavy clayware, like kilns. Due to its extreme strength and hardness, it is often used as an abrasive for sandpaper. It is also an economical substitute for industrial diamonds.

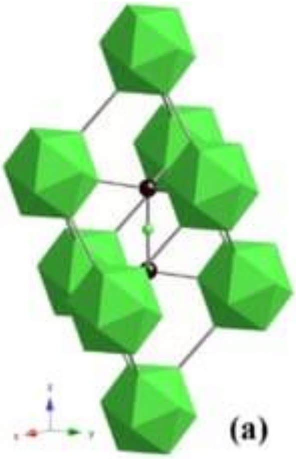
Aluminium oxides are used, as well, for the production of piping components such as elbows, tees, straight pipes, hydro cyclones, reducers, nozzles, and valves. Other applications include the production of various machining tools, cutting tools, thermocouple sheaths, wear-resistant pump impellers, and baffle plates.

3.6 What is Boron Carbide?

Boron carbide (chemical formula B_4C) is a boron–carbon ceramic and covalent substance that is used in tank armour, bulletproof vests, engine sabotage powders, and a variety of other industrial applications. It is one of the hardest known materials.

discovered in mid 19th century as a by-product in the production of metal borides, boron carbide was only studied in detail since 1930.

3.7 Boron Carbide Crystal Structure



Unit cell of B4C. The green sphere and icosahedra consist of boron atoms, and black spheres are carbon atoms.

Figure 3.1 Boron carbide structure

Boron carbide has a complex crystal structure that is characteristic of borides centred on icosahedrons. B_{12} icosahedra forms a rhombohedral lattice unit around a C-B-C chain in the unit cell's middle, and all carbon atoms bridge the neighbouring three icosahedra. The B_{12} icosahedra and bridging carbons form a network plane that runs parallel to the c-plane and stacks along the c-axis, forming a layered structure. The B_{12} icosahedron and the B6 octahedron are the two fundamental structural units of the lattice. The B_6 octahedra are too small to bind due to their small size. Instead, they bind to the B_{12} icosahedra in the neighbouring layer, which weakens the c-plane bonding.

The chemical formula of "ideal" boron carbide is sometimes written as $B_{12}C_3$, and the carbon deficiency of boron carbide is defined in terms of a combination of the $B_{12}C_3$ and $B_{12}C$ units, due to the B12structural unit. Some research suggests that one or more carbon atoms can be incorporated into the boron icosahedra, resulting in formulas like $B_{11}CCBC$ = B_4C at the carbon-heavy end of the stoichiometry, but formulas like $B_{12}(CBB)$ = $B_{14}C$ at the boron-rich end. "Boron carbide" is therefore a family of compounds of varying compositions, rather than a single compound. $B_{12}(CBC)$ = $B_{6.5}C$ is a common intermediate that approximates a frequently found element ratio. The crystal symmetry of the B_4C composition and the nonmetallic electrical character of the $B_{13}C_2$ compositions are both determined by configurational disorder between boron and carbon atoms at different positions in the crystal,according to quantum mechanical calculations.

3.8 Physical properties of boron carbide

Density (g.cm-3)	2.52
Melting Point (°C)	2445
Hardness (Knoop 100 g) (kg.mm-2)	2900 - 3580
Fracture Toughness (MPa.m-½)	2.9 - 3.7
Young's Modulus (GPa)	450 – 470
Electrical Conductivity (at 25 °C)	140S
Thermal Conductivity (at 25 °C) (W/m.K)	30 – 42
Thermal Expansion Co-eff. x10-6 (°C)	5
Thermal neutron capture cross section (barn)	600

3.9 Chemical properties of boron carbide

Boron carbide, after diamond and cubic boron nitride, is the third hardest material identified as of 2015.

Boron carbide is a tough substance with high toughness (roughly 9.5 to 9.75 on the Mohs hardness scale), a large cross-section for neutron absorption (i.e. strong neutron shielding properties), and resistance to ionising radiation and most chemicals.

Boron carbide was first synthesised in 1899 by Henri Moissan in an electric arc furnace by reducing boron trioxide with carbon or magnesium in the presence of carbon. In the case of carbon, the reaction takes place at temperatures above B_4C melting point and results in the release of a significant amount of carbon monoxide. If magnesium is used, the reaction can be performed in a graphite crucible, with the magnesium by products being extracted by acid treatment.

$2B_2C_3 + 7C \rightarrow B_4C + 6CO$

Boron with a purity of 95% can be made from the oxide by combining it with powdered magnesium:

$B_2O_3 + 3Mg \rightarrow 2B + 3MgO$

By passing a mixture of BCl_3 or BBr_3 and hydrogen over a heated tantalum filament, high-purity boron (>99.9%) can be obtained:

$2BBr_3(g) + 3H_2(g) \rightarrow 2B(s) + 6HBr(g)$

3.10 Uses of boron carbide

- Grit blasting nozzles
- Because of its high wear and abrasion resistance, boron carbide is used as slurry pumping nozzles, grit blasting nozzles, and water jet cutters.
- High-pressure water jet cutter nozzles
- Scratch and wear-resistant coatings
- Cutting tools and dying.
- Boron carbide abrasive is a powder used in polishing and lapping applications, as well as a loose abrasive in cutting applications such as water jet cutting, due to its high hardness. It's also useful for polishing diamond tools.
- Neutron absorber in nuclear reactors: The material's ability to absorb neutrons without producing long-lived radionuclides makes it appealing as a neutron absorbent in nuclear power plants. Boron carbide is used in nuclear applications such as insulation, control rods, and shut down pellets.
- Metal matrix composites
- High energy fuel for solid fuel ramjets
- In brake linings of vehicles

3.11 8 Series Of Aluminum And Aluminum Alloy: To Be An Aluminum Expert

The specific gravity of aluminum is lighter, and the rebound in forming is smaller; the strength is relatively high, close to or more than high-quality steel; the plasticity is good, and when the product forming is more complicated, it is easier to control than stainless steel, and has excellent electrical conductivity, thermal conductivity and corrosion resistance.

At present, the surface treatment process of aluminum anodic oxidation, brushing, sandblasting, etc. has been very mature, and the use of aluminum in cell phones is also very much.

According to the processing method, aluminum alloy can be divided into deformed aluminum alloy and cast aluminum alloy, and the serial number of aluminum and aluminum alloy is mainly divided into eight series.

Table of Contents

3.12 Representation of alloy grades

International brand (using four Arabic numerals, now commonly used):

- 1XXX indicates that it ispure aluminum series with more than 99% such as 1050 and 1100.
- 2XXX indicates that it is an aluminum-copper alloy series such as 2014.
- 3XXX indicates that it is an aluminum-manganese alloy series such as 3003.
- 4XXX indicates that it is an aluminum-silicon alloy series such as 4032.
- 5XXX indicates that it is an aluminum-magnesium alloy series such as 5052.

- 6XXX indicates that it is an aluminum-magnesium-silicon alloy series such as 6061, 6063.
- 7XXX indicates that it is an aluminum-zinc alloy series such as 7001.
- 8XXX indicates that it is an alloy system other than that mentioned above.

3.13 8 Series Of Aluminum And Aluminum Alloy

3.13.1 1XXX Series

Among all series, 1000 series is the one with the most aluminum content, and the purity can reach more than 99.00%.

1000 series aluminum plate determines the minimum aluminum content of this series according to the last two Arabic numerals.

For example, the last two Arabic numerals of 1050 series are 50. According to the international brand naming principle, the aluminum content must reach 99.5% and the above is the qualified product.

The primary aluminum has good formability and surface treatment, and its corrosion resistance is the best among aluminum alloys. The lower its strength, the higher its purity, the lower its strength.

Alloy system	Alloy number		Summary of material properties
	JIS	A.A	
1000 series	1060	1060	As a conductive material, IACS guarantees 61%, and 6061 is used when strength is required
	1085 1080 1070 1050 1N30	1085 1080 1070 1050	It has good formability and surface treatment. Among aluminum alloys, its corrosion resistance is the best because it is pure aluminum with low strength. The higher the purity, the lower the strength.
	1100 1200	1100 1200	General purpose aluminum with Al purity of more than 99.0% is slightly white after anodizing, which is the same as the above.
	1N00		The strength is slightly higher than 1100, the formability is good, and its chemical properties are the same as 1100.

The ones commonly used on mobile phones are 1050, 1070, 1080, 1085, 1100, do simple extrusion molding (without bending), of which 1050 and 1100 can do chemical sand, glossy, fog, normal effect, with obvious material lines and good coloring effect; 1080 and 1085 specular aluminum are often used to do bright word, fog effect, no obvious material lines.

The first series of aluminum are relatively soft and are mainly used for decoration or interior decoration.

3.13.2 2XXX Series

It is characterized by high hardness but poor corrosion resistance, among which the content of copper is the highest.

2000 series aluminum alloy represents 2024, 2A16, 2A02.

The copper content of 2000 series aluminum sheet is about 3% to 5%.

2000 series aluminum bars belong to aviation aluminum materials, which are used as structural materials, but are not often used in conventional industries at present.

Alloy system	Alloy number		Summary of material properties
	JIS	A.A	
2000 series	2011	2011	Fast cutting alloy, good machinability and high strength. But the corrosion resistance is poor. When corrosion resistance is required, 6062 series alloy shall be used
	2014 2017 2024	2014 2017 2024	Containing a large amount of Cu, the corrosion resistance is poor, but the strength is high, so it can be used as,. Used for construction materials. Forged products can also be used.
	2117	2117	After solid solution heat treatment, it is used as hinge nail material, which is an alloy to delay the aging rate at room temperature.
	2018 2218	2018 2218	Alloy for forging. Good forging property and high temperature strength, so Used for forgings requiring heat resistance. Poor corrosion resistance.
	2618	2618	Alloy for forging. High temperature strength is superior, but corrosion resistance is poor.
	2219	2219	High strength, good low and high temperature characteristics, excellent solubility, but poor corrosion resistance.
	2025	2025	Alloy for forging. Good forging property and high strength, but poor corrosion resistance.
	2N01	–	Alloy for forging. It has heat resistance and high strength, but the corrosion resistance is not good

3.13.3 3XXX Series

3000 series aluminum bars are mainly composed of manganese.

3000 series aluminum alloy representatives are 3003, 3105, 3A21-based.

The manganese content is between 1.0% and 1.5%, which is a series with good anti-rust function.

It is often used as grooves and tanks for liquid products, building workpieces, construction tools, all kinds of lamp parts, and various pressure vessels and pipes for sheet processing.

Good formability, solubility and corrosion resistance.

Alloy system	Alloy number		Summary of material properties
	JIS	A.A	
3000 Series	3003 3203	3003 3203	The strength is about 10% higher than 1100, and the formability, solubility and corrosion resistance are good.
	3004 3104	3004 3104	Higher strength than 3003, superior formability and good corrosion resistance.
	3005	3005	The strength is about 20% higher than that of 3003, and the corrosion resistance is also better.
	3105	3105	The strength is slightly higher than 3003, and other characteristics are similar to 3003.

3.13.4 4XXX Series

Usually the silicon content is between 4.5% and 6.0%, the higher the silicon content is, the higher the strength is. The 4000 series aluminum bars represent 4A01, and the 4000 series aluminum plates belong to the series with high silicon content.

Less solidification shrinkage, belonging to building materials, mechanical parts, forging materials, welding materials; low melting point, good corrosion resistance, heat resistance and wear resistance.

Alloy system	Alloy number		Summary of material properties
	JIS	A.A	
4000 series	4032	4032	Good heat resistance, abrasion resistance and low coefficient of thermal expansion.
	4043	4043	Less solidification shrinkage, treated with sulfuric acid anodizing, showing a natural gray color.

3.13.5 5XXX Series

5000 series aluminum bar belongs to the more commonly used alloy aluminum plate series, the main element is magnesium, the magnesium content is between 3-5%.

5000 series aluminum alloy represents 5052, 5005, 5083, 5A05 series.

It can also be called aluminum-magnesium alloy.

The main characteristics are low density, high tensile strength and high elongation.

Under the same area, the weight of Al-mg alloy is lower than that of other series, so it is widely used in conventional industry.

Alloy system	Alloy number		Summary of material properties
	JIS	A.A	
5000 Series	5005	5005 5050	The strength is the same as that of 3003, with good processability, solubility and corrosion resistance. The modification processing after anodizing is good, which is commensurate with the color of 6063 shape material.
	5052	5052	It is the most representative alloy with medium strength, with good corrosion resistance, solubility and formability, especially high fatigue strength and good seawater resistance.
	5652	5652	The alloy that limits the impure elements of 5052 and inhibits the separation of hydrogen peroxide. Other properties are the same as those of 5052
	5154	5154	The strength is about 20% higher than 5052, and other characteristics are the same as 5052
	5254	5254	The alloy that limits the impure elements of 5154 and inhibits the decomposition of hydrogen peroxide has the same other properties as 5154.
	5454	5454	The strength is about 20% higher than that of 5052, and its characteristics are roughly the same as those of 5154, but its corrosion resistance in vicious environment is better than that of 5154.
	5056	5056	Excellent corrosion resistance, cutting and working surface modification, good anodizing and dyeing.
	5082	5082	The strength is similar to 5083, and the formability and corrosion resistance are good.
	5182	5182	The strength is about 5% higher than 5082, and other characteristics are the same as 5082.
	5083	5083	Alloy for fusion construction. It is the highest strength corrosion-resistant alloy in practical non heat treated alloys and is suitable for solution bonding structures. Good seawater resistance and low temperature characteristics
	5086	5086	The strength is higher than that of 5154. It is a non heat treatment fusion structure alloy with good seawater resistance.
	5N01	–	The strength is the same as that of 3003, and the anodizing treatment after brilliant treatment can have high brilliance. Good formability and corrosion resistance.
	5N02		Alloy for hinge nail, good seawater resistance

The most commonly used on mobile phones is 5052, which is the most representative alloy with medium strength, with good corrosion resistance, solubility and formability, especially high fatigue strength, good sea water resistance, and is often used to do products with high strength, but its coloring effect is not ideal, so it is suitable for sandblasting process, not suitable for chemical sand blasting, fog surface, etc., mainly using casting molding, not suitable for extrusion molding.

3.13.6 6XXX Series

6000 series aluminum alloy represents 6061, which mainly contains magnesium and silicon, so it integrates the advantages of 4000 series and 5000 series.

6061 is a cold-treated aluminum forging product, which is suitable for applications requiring high corrosion resistance and oxidation resistance. Good usability, easy coating and good processability.

Alloy system	Alloy number		Summary of material properties
	JIS	A.A	
6000 Series	6061	6061	Heat treated corrosion resistant alloy. T6 treatment can have a very high endurance value, but the strength of the fusion interface is low, so it is used for screws and hinge screws
	6N01		The medium strength extrusion alloy has the middle strength of 6061 and 6063. It has good extrusion, stamping and quenching properties. It can be used as large thin meat shape materials with complex shapes. It has good corrosion resistance and fusion joint.
	6063	6063	The representative extrusion alloy has lower strength than 6061 and good extrudability. It can be used as shape material with complex section shape, with good corrosion resistance and surface treatment
	6101	6101	High strength conductive material. 55% ACS guarantee
	6151	6151	It has excellent forging processability, corrosion resistance and surface treatment. It is suitable for complex forging products.
		6262	Corrosion resistance fast cutting alloy has better corrosion resistance and surface treatment than 2011, and its strength is the same as 6061.

6061 and 6063 are mostly used on mobile phones. The strength of 6061 is higher than that of 6063. Casting molding can cast more complex structures and can be used as snap parts, such as battery cover, etc.

3.13.7 7XXX Series

It mainly contains zinc, and 7000 series aluminum alloy represents 7075. It also belongs to Aviation series. It is aluminum magnesium zinc copper alloy, heat treatable alloy, superhard aluminum alloy and has good wear resistance.

Alloy system	Alloy number		Summary of material properties
	JIS	A.A	
7000 series	7072	7072	The electrode potential is low. It is mainly used for anti-corrosion covering leather materials. It is also suitable for heat sink of heat exchanger.
	7075	7075	One of the aluminum alloys with the highest strength, but the corrosion resistance is poor. The coating material with 7072 can improve its corrosion resistance, but the cost is increased.
	7050	7050	The alloy with improved quenching property of 7075 has good stress corrosion cracking resistance. It is suitable for thick plates and forged products
	7N01		The alloy for welding structure has high strength, and the strength of the welding part can be returned to the strength close to the base metal when placed at room temperature. Corrosion resistance is also very good.
	7003	7003	The extrusion alloy for fusion structure has slightly lower strength than 7N01, but has good extrudability. It can be used as a large shape material with thin meat. Other characteristics are roughly the same as 7N01.

3.13.8 8XXX Series

8011 is commonly used in 8000 Series aluminum alloy, which belongs to other series. Most applications are aluminum foil, which is not commonly used in the production of aluminum rods.

CHAPTER 4

EXPERIMENTAL DETAILS

4.1 SELECTION OF MATERIAL

The matrix material utilized in the current study is Al2024. The distinctive alloying parts are magnesium, copper, manganese, element, and atomic number 30. It belongs to a gaggle of hypo mixture Al-Si alloys and includes a wide field of application within the automotive and aeronautics industries. Besides this, the Al 2024 alloy is employed as a matrix for getting composites that have Associate in Nursing increased wear resistance, favourable mechanical properties at temperature, and increased mechanical properties at elevated temperatures. Al 2024 alloys naturally have Associate in nursing modulus of elasticity of regarding 70GPa. In general, stiffer and lighter styles are achieved with Al 2024 alloys than is feasible with steels.

4.2 Applications of Al2024: It is typically used in

- Truck frames
- Rail coaches
- Military and commercial bridges
- Ship building operations
- Towers and pylons
- Rivets
- Aerospace applications (i.e., helicopter rotor skins)
- Transport operations.

4.3 Chemical Composition

Elements	Cu	Mg	Si	Fe	Mn	Cr	Zn
Wt %	0.4	1.2	0.8	0.7	0.15	0.45	0.25

figure 4.1 Al2024 Chemical Composition

4.4Mechanical Properties

Base Material	Al 2024
Density value	2.7 g/cm^3
Young's modulus value	68.9Gpa
Tensile strength value	124-290Mpa
Elongation at break value	12-25%
Poisson's ratio value	0.33
Melting temperature value	585°c
Thermal conductivity value	151-202 W/(m-k)
Linear thermal expansion coefficient value	2.32X10
Specific heat capacity value	897 J/(kg-k)

Figure 4.2 Al 2024 Mechanical Properties

4.5 REINFORCEMENTS

4.5.1 Boron Carbide

Boron carbide, (B_4C), crystalline compound of boron and carbon. It is an extremely hard, synthetically produced material that is used in abrasive and wear-resistant products, in lightweight composite materials, and in control rods for nuclear power generation.

With a Mohs hardness between 9 and 10, boron carbide is one of the hardest synthetic substances known, being exceeded only by cubic boron nitride and diamond. As an abrasive, it is used in powdered form in the lapping (fine abrading) of metal and ceramic products, though its low oxidation temperature of 400–500° C (750–930° F) makes it unable to withstand the heat of grinding hardened tool steels. Because of its hardness, together with its very low density, it has found application as a reinforcing agent for aluminum in military armour and high-performance bicycles, and its wear resistance has caused it to be employed in sandblasting nozzles and pump seals. A neutron absorber, boron carbide is used in powdered or solidified form to control the rate of fission in nuclear reactors.

Element	B	C	Ca	Fe	Si	F	Cl
%	80.0	18.1	0.3	1.0	0.5	0.025	0.075

Figure 4.3 Chemical Composition of B_4C

Fig. 4.4 B_4C Powder

4.5.2 Composition of Al_2O_3: Aluminium oxide, normally remarked as aluminium oxide, possesses robust ionic put down atomic bonding giving rise to its fascinating material characteristics. It will exist in many crystalline parts that all revert to the foremost stable polygon alpha phase at elevated temperatures.

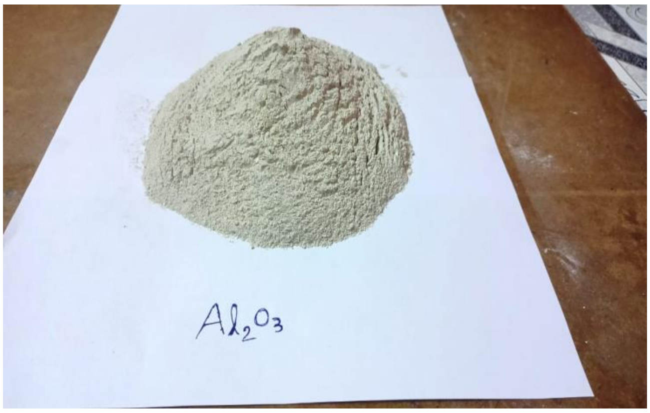


Fig. 4.5 Al_2O_3 Powder

4.5.3 Properties:

1. Density - 3.428 g/cm^3
2. Tensile strength - 665MPa
3. Young's modulus - 215GPa

4.5.4 Key properties of Al_2O_3

- High strength and high stiffness
- Hard and wear-resistant
- Good size and shape capability
- Good thermal conductivity
- High temperature applications.

4.6 MUFFLE-FURNACE

A furnace is one of the most elements of your HVAC system. Once you set your thermostat, you activate the chamber to start heating air. a disciple switches on and circulates this heated air through your home. However, the warmth is transferred to the air depends on the kind of furnace.

A **muffle furnace** or **muffle oven** (sometimes **retort furnace** in historical usage could be a chamber inside which the theme material is segregated from the fuel and all of the product of burning, just as gases and flying debris. at the point when the occasion of high-temperature warming parts and boundless charge in created nations, new mute heaters immediately delighted to electrical styles.

Fig: 4.6 Muffle Furnace

One will set the desired temperature by pressing red colour push by finger, hold a similar in pressing position and temporary worker by rotating coarse, fine knobs and unharness the finer from the push. When emotional push, junction rectifier show of controller indicates an actual temperature of furnace**.** There are four main styles of furnaces: gas, oil, electric, and fuel. Electrical furnaces will heat the air by exposing heated parts, whereas alternative styles of furnaces generally need a device or chamber that warms the encompassing air.

4.7 ELECTRIC ARC FURNACE

An Electric arc furna**ce** (**EAF**) is a furnace that heat charged material by means that of an electrical arc. Mechanical circular segment heaters place size from small units of around one-ton ability (utilized in foundries for assembling fashioned iron items) as much as 400 ton units utilized for optional steelmaking. Circular segment heaters used in investigation research centres and by dental specialists may have a capacity of exclusively around dozen grams. Modern flash chamber temperatures will reach one,800 °C (3,272 °F), while research centre units will surpass three,000 °C (5,432 °F). Circular segment heaters differ from enlistment heaters, in this, the charged material is straightforwardly presented to an electrical bend, and furthermore the flow inside the chamber terminals goes through the charged material.

Fig: 4.7 Electric Arc Furnace

4.8 FABRICATION and METHADOLOGY

4.8.1 PRE-HEATING:

Preheating of Reinforcement ought to be exhausted to get rid of agglomeration, wetness, and gases conferred in it. Assault and Al_2O_3 are preheated in a Muffle chamber at a temperature of 3500c for one day. A six-finger die is preheated for one hour at 400^{o}c in Arc chamber such, the liquefied metal doesn’t get solid quick.

Fig: 4.8 Muffle Furnace **Fig.4.8 Electric Arc Furnace**

4.8.2 STIR CASTING

Stir casting could be a liquid state technique for the manufacture of composite materials, within which a dispersed particle is combined with a liquefied metal matrix by means that of mechanical stirring. Stir Casting is that the simple technique of liquid state fabrication

It is one of all the foremost appropriate techniques for manufacturing metal matrix composites for various combinations of ceramic and metals.

It could be a sort of easy operation, lower price of production and production capabilities created this system versatile.

In recent past composites as well as steel and titanium-based alloys have additionally been rumoured. The hybrid composites are a brand new age of metal framework composites to achieve desired properties at a nearer approximation of real desires. These might have the potential of satisfying the recent demands of advanced engineering applications.

Fig: 4.9. Stir Casting Furnace

The Aluminium 2024 is placed within the vessel nearly 800gm-1000gm as per our demand of dying as shown in fig. shut the lid on the vessel and wait until the bottom material turns into liquid and add the reinforcements I Chronicles,2% consistent with the load of the Al-2024 within the chamber.

4.8.3. CRUCIBLE

Crucible is that the instrumentality within which the metal is molten then poured into a mould to perform casting. The fabric of mould ought to have a more freezing point, more strength {and ought to |and will| and may} be a sensible conductor of warmth so that heat loss should be low. They are many materials on the market for this purpose like B_4C, solid steel, and atomic number 6. For our necessities, the B_4C vessel is good for suited, but the price is incredibly high therefore can't be afforded. We have got taken here an atomic number 6 vessel that serves our functions as its melting temperature is 2700°C that is way on top of operating temperature. The vessel is formed in an exceedingly form of a cylinder with decrease diameter so that the high portion remains a cylinder but the lowest half takes the form of a hemisphere. A handle is connected to the aspect of the vessel to carry it whereas putting it within the chamber and whereas gushing hot metal into the mould cavity. It will face up to terribly high temperatures and is employed for metal, glass, and for pigment production additionally as a variety of newly laboratory processes.

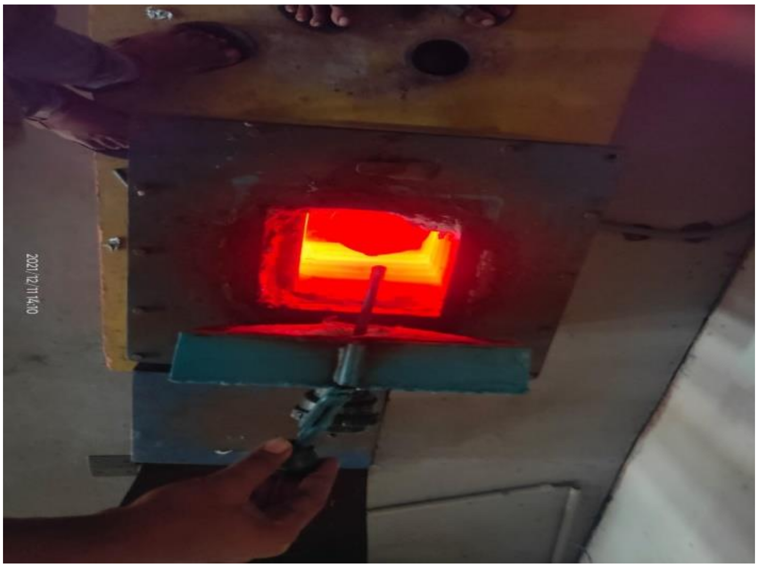


Fig: 4.10 Al 2024 in Crucible

4.8.4. STIRRER

The strategy used in the manufacture of MMC needs the scattered particles that are the ceramic particles (B_4C) to be blended in a strong state inside the fluid metal. Consequently for the uniform blend of the ceramic particles inside the fluid metal, it's necessary that the combination be mixed well. Thus, a stirrer is required which might withstand the warm temperature and doesn't affect the virtue of the composite. The stirrer is made of a chrome steel pole whose face is associated with a nuclear number 6 fan. It's driven by a ½ H.P. AC engine and pivots at a disturbing 400 rates. The stirrer is embedded upward into the vessel concerning 33% of its tallness once adding the fired particles. Here we've given approaches to mixing through outside mediums that might be associated with the chamber at any reason through the most elevated.

Fig: 4.11 Adding of Reinforcement according to their Percentages

4.8.5. CASTING ON MOLTEN ALUMINIUM

Subsequent to preparing the form, the liquefied metallic component was filled the shape pass on from the vessel and was left to set. When the projecting is finished, it had been isolated from the shape as displayed in the figure 4.11

Fig: 4.11. Pouring the Molten Liquid into the 6 Finger Die

CHAPTER 5

TESTING TOOLS AND MACHINES

5.1. CAST IN THE MOULD

The 6 finger die was opened after the mould poured in the die gets solidify and then we get the shape of the die with cast of aluminium with mixture of the reinforcements as shown in figure 5.1.

Fig: 5.1 After Casting

5.1.1. MACHINING

Machining is any of different cycles where a piece of crude material is cut into an ideal last shape and size by a controlled material-expulsion measure. The cycles that have this normal topic, controlled material evacuation, are today all in all known as subtractive assembling, in qualification from cycles of controlled material expansion, which are known as added substance fabricating. Precisely what the "controlled" a piece of the definition infers can shift, however it quite often suggests the utilization of machine instruments (notwithstanding power apparatuses and hand devices). Machining is a piece of the assembling of many metal items, however it can likewise be utilized on materials like wood, plastic, artistic, and composites. An individual who has some expertise in machining is known as a mechanical engineer. A room, building, or organization where machining is done is known as a machine shop. Quite a bit of present day machining is completed by PC mathematical control (CNC), in which PCs are utilized to control the development and activity of the plants, machines, and other cutting machines.

In turning, a cutting instrument with a solitary forefront is utilized to eliminate material from a pivoting work piece to create a round and hollow shape. The essential movement is given by turning the work piece, and the feed movement is accomplished by moving the cutting instrument gradually toward a path corresponding to the hub of revolution of the work piece.

Fig: 5.2 During Machining

A cutting device has at least one sharp front lines and is made of a material that is more enthusiastically than the work material. The state of the art serves to isolate chip from the parent work material. Associated with the forefront are the two surfaces of the apparatus:

- The rake face; and
- The flank.

The rake face which coordinates the progression of recently shaped chip, is arranged at a specific point is known as the rake point "α". It is estimated comparative with the plane opposite to the work surface. The rake point can be positive or negative. The flank of the instrument gives a leeway between the device and the recently shaped work surface, hence shielding the surface from scraped area, which would debase the completion. This point between the work surface and the flank surface is known as the help point. There are two essential kinds of cutting instruments:

- Single point device; and
- Multiple-state of the art device

A solitary point device makes them cut edge and is utilized for turning, exhausting and arranging. During machining, the place of the device infiltrates underneath the first work surface of the work part. The fact is in some cases adjusted to a specific range, called the nose sweep.

Different state of the art devices have more than one forefront and typically accomplish their movement comparative with the work part by turning. Penetrating and processing use pivoting numerous state of the art apparatuses. Albeit the states of these instruments are unique in relation to a solitary point device, numerous components of hardware math are comparative.

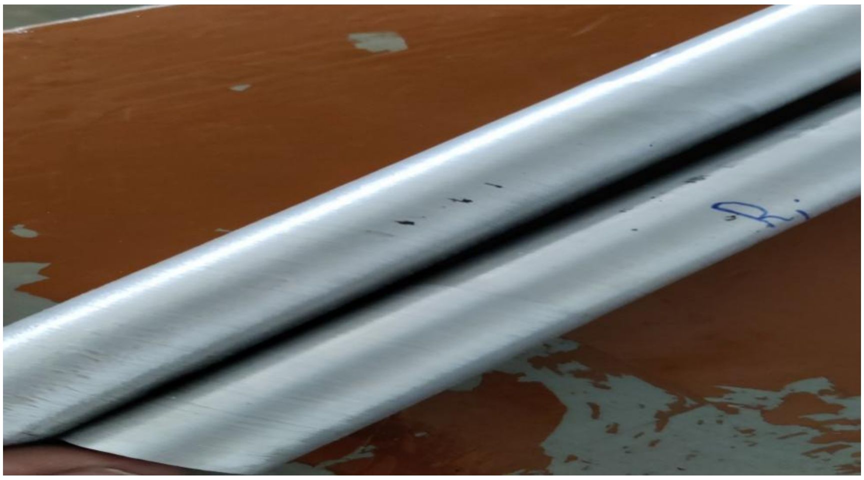


Fig: 5.3. After Machining

5.2. Tests Conducted

- Density
- Tensile
- Compression
- Hardness

5.2.1. DENSITY

The density of the composites was gotten by the Archimedean strategy for gauging little pieces cut from the composite chamber first in air and afterward in water, while the hypothetical density was determined utilizing the blend rule as per the weight part of the molecule.

Fig 5.4 Density Measurement Apparatus

Fig 5.5 Density Measurement Tested Specimens

5.2.2. TENSILE TEST

One material property that is broadly utilized and perceived is the strength of a material. In any case, what does "strength" mean? "Strength" can have numerous implications, so let us investigate what is implied by the strength of a material. We will take a gander at an exceptionally simple test that gives heaps of data about the strength or the mechanical conduct of a material, called the malleable test.

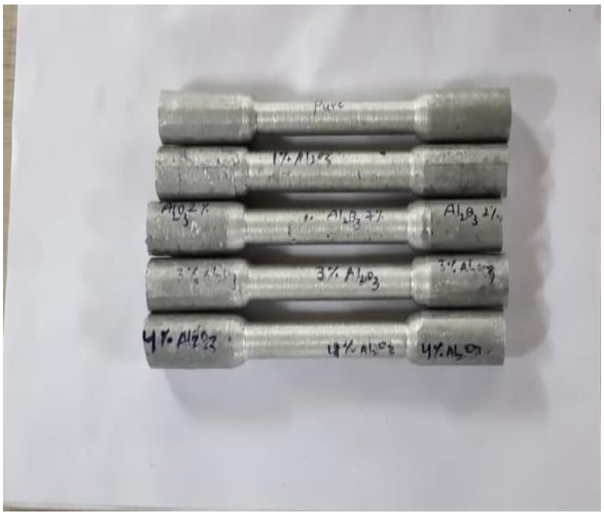


Fig 5.6 Tensile Pieces after Machining

The fundamental thought of a pliable test is to put an example of a material between two installations called "grasps" which clasp the material. The material has known measurements, similar to length and cross-sectional region. We then, at that point start to apply weight to the material held toward one side while the opposite end is fixed. We continue to expand the weight (frequently called the heap or power) while simultaneously estimating the adjustment of length of the example.

Fig. 5.7 Universal Testing Machine (UTM)

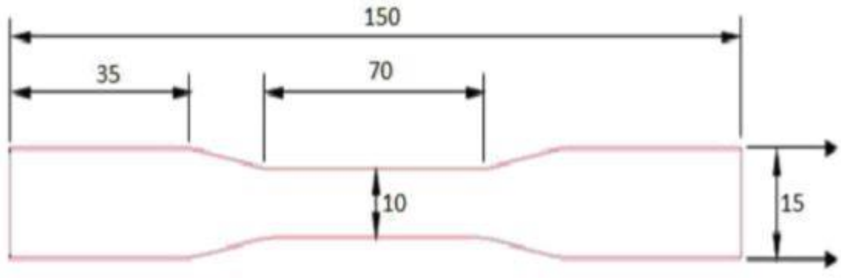


Fig 5.8 Tensile Test Specimen (ASTM-E08Standard)

Fig 5.9 Tensile Test Specimen after testing (ASTM-E08Standard)

5.2.3. COMPRESSION TEST

A compression test is any test wherein a material encounters contradicting powers that push internal upon the example from inverse sides or is generally packed, "crushed", squashed, or smoothed.

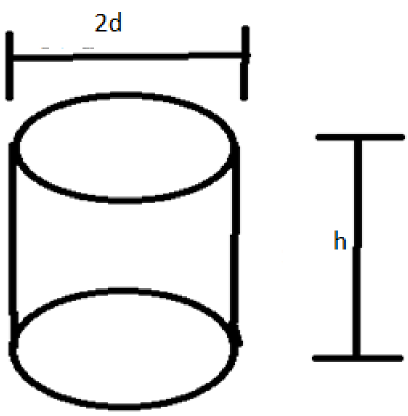


Fig 5.10 Compression test Specimen

The test is for the most part positioned in the middle of two plates that disseminate the applied burden across the whole surface space of two inverse countenances of the test and afterward the plates are moved together by a widespread test machine making the example level. A compacted test is typically abbreviated toward the applied powers and extends toward the path opposite to the power. A pressure test is basically something contrary to the more normal strain test.

Fig 5.11 Compression Pieces after Machining

Fig 5.12 Compression Pieces after testing

5.2.4. VICKERS HARDNESS TEST

`The hardness of a material can be determined by Brinell Rockwell and Vickers hardness test. In Vickers hardness test, diamond indentation is used to determine the hardness. Vickers test decides the hardness by the estimation of the profundity of infiltration of an indenter under load more than contrasted with the entrance made by a preload. There are various scales, meant by a solitary letter, that utilization various burdens or indenters.

Fig 5.13 Vickers Hardness Testing Machine

The hardness of the Al2024 alloy and composites was determined with Vickers Micro Hardness Tester (LECOAT700 Micro hardness Tester). The dimension of each specimen for hardness testing was 20x10mmand each specimen was grinded and polished to obtain a flat smooth surface. During the testing, a load of 100gm. was applied for 10s on the specimen through square based diamond indenter and the hardness readings taken in a standard manner.

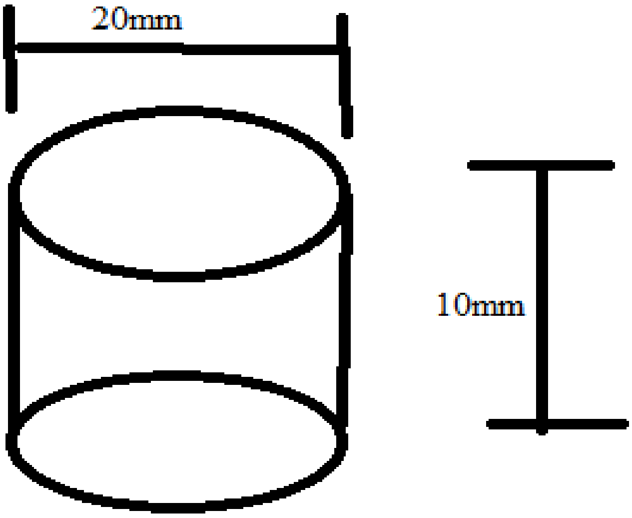


Fig 5.14 Hardness test Specimen dimensions

Fig 5.15 Hardness test Specimens after testing

5.2.5 IMPACT TEST

It is to determine the impact strength of the material.

It is the resistance of a material to fracture by a blow or the sudden load

It is expressed in terms of the amount of energy absorbed before fracture

There are two types of impact testing equipment namely Charpy and Izod. We performed the test on the Charpy equipment in this stud

Fig 5.16 : Specimens before Impact test

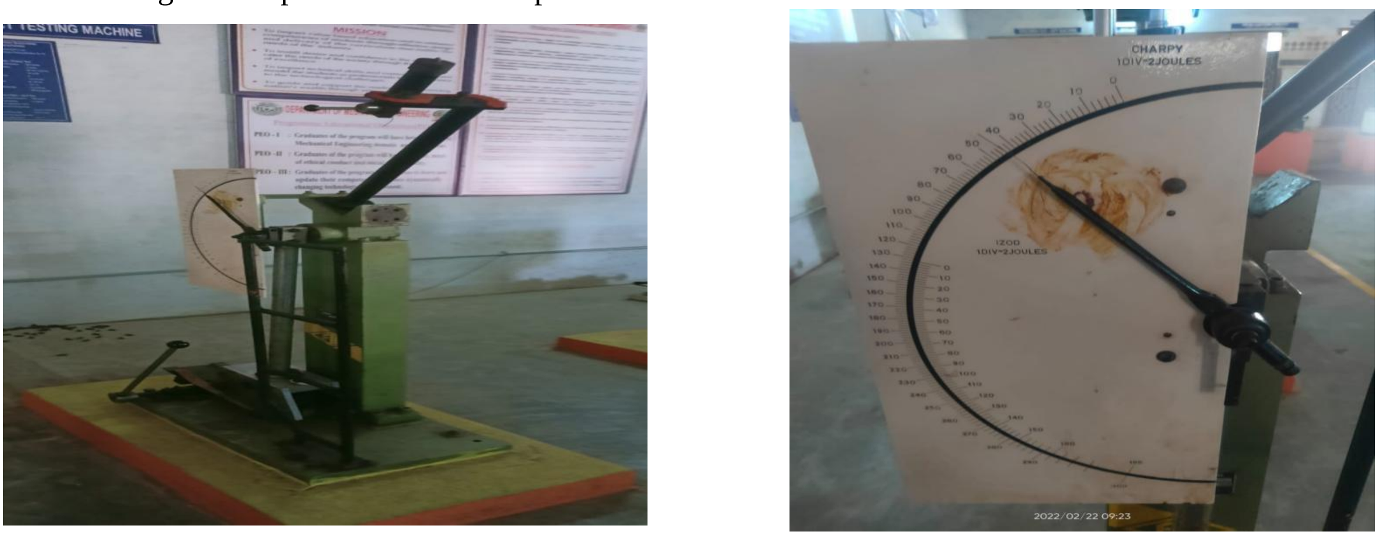


Fig 5.17 : Charpy Impact Testing Equipment

CHAPTER 6

RESULTS AND DISCUSSION

6.1 Density Test

The test performed on the specimens with B_4C and Al_2O_3 (mixture of both B_4C and $Al_2O_3$with equal %) reinforcement.

Table 6.1 Density Varying with B_4C & Al_2O_3

S.No	Sample	Measured in g/cm^3
1	Al2024	2.547
2	Al2024+ 1% Al_2O_3+0.5%B_4C	2.593
3	Al2024 + 2% Al_2O_3+0.5%B_4C	2.633
4	Al2024 + 3% Al_2O_3+0.5%B_4C	2.762
5	Al2024 + 4% Al_2O_3+0.5%B_4C	2.793

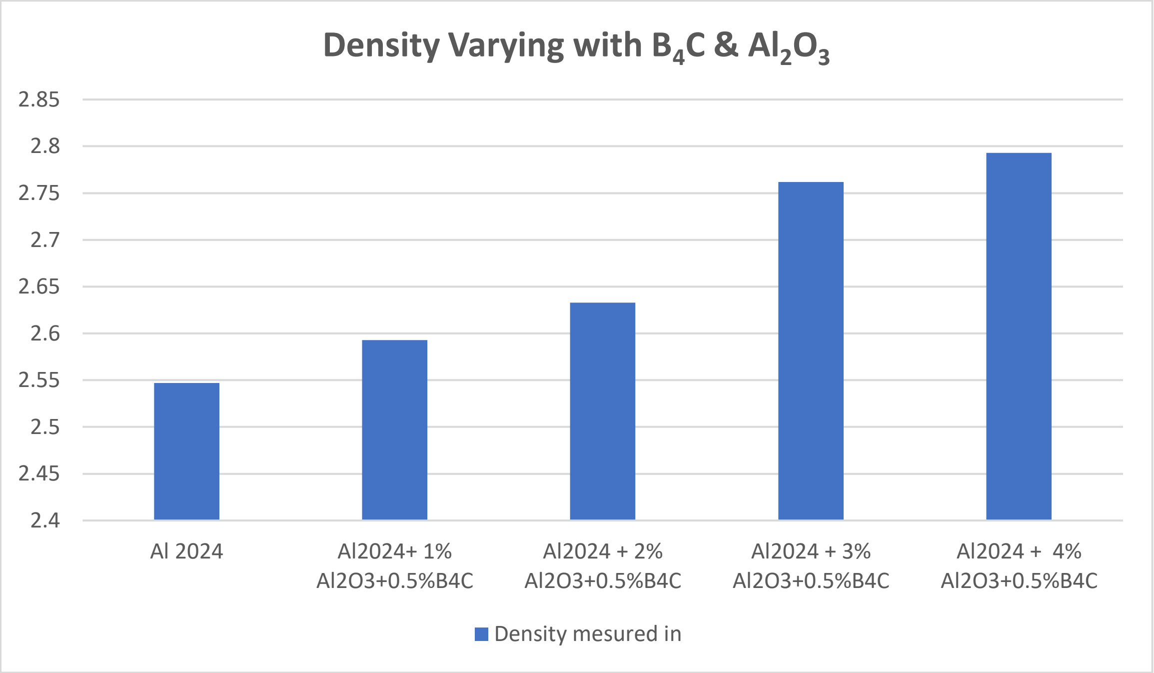


Fig: 6.1 Density v/s % of Reinforcement

6.2 Tensile Test

The test performed on the specimens with B_4C and Al_2O_3 (mixture of both B_4C and Al_2O_3 with equal %) reinforcement.

Table 6.2 Tensile Strength

S.No	% of reinforcement	Ultimate Tensile strength (MPa) of Al_2O_3+ B_4C
1	0	419.18
2	1	433.15
3	2	453.78
4	3	458.49
5	4	464.85

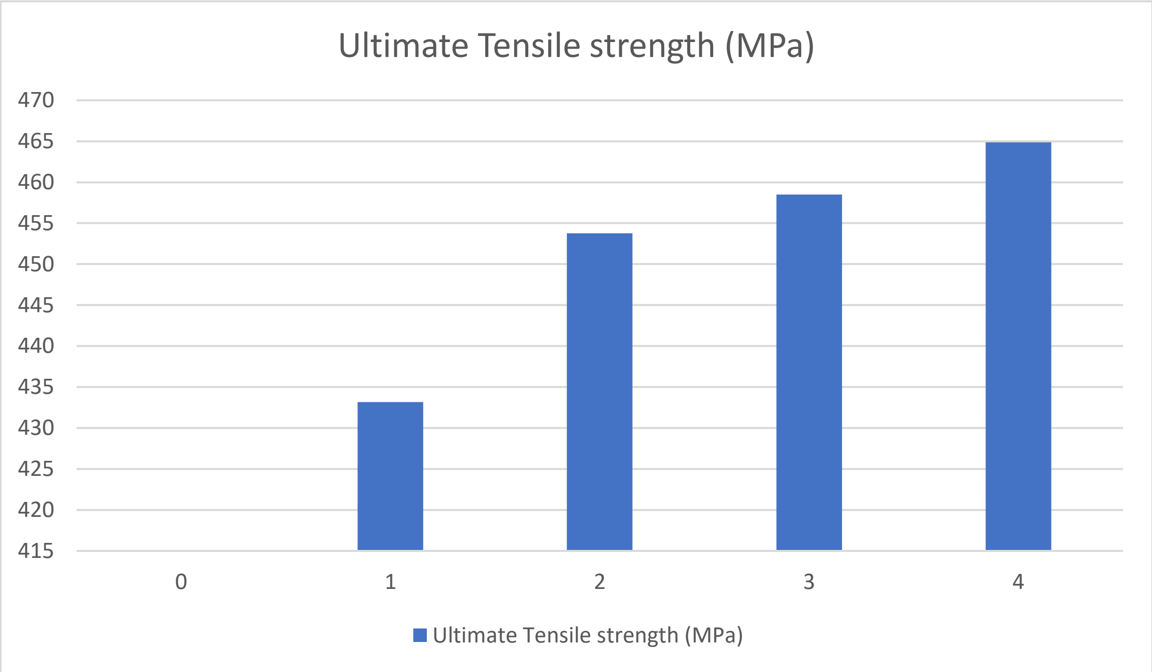


Fig 6.2 Tensile Strength v/s% of Reinforcement

6.3 Compression Test

The test performed on the specimens with B_4C and Al_2O_3 (mixture of both B_4C and Al_2O_3 with equal %) reinforcement.

Table 6.3 Compressive Strength

S.No	% of reinforcement	Avg . Compressive strength (Mpa) of Al_2O_3+ B_4C
1	0	

2	Al2024+ 1% Al_2O_3+0.5%B_4C	309
3	Al2024 + 2% Al_2O_3+0.5%B_4C	316.02
4	Al2024 + 3% Al_2O_3+0.5%B_4C	320.95
5	Al2024 + 4% Al_2O_3+0.5%B_4C	324.88

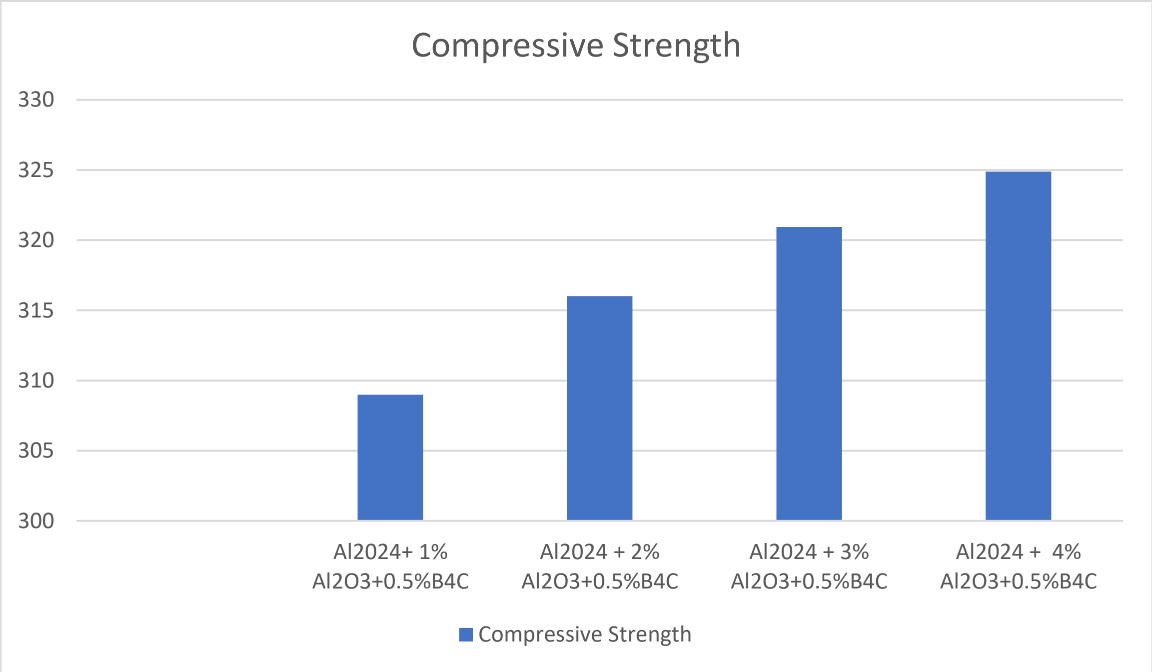


Fig: 6.3 Compression Strength v/s % of Reinforcement

6.4 Impact strength test

The test performed on the specimens with B_4C and Al_2O_3 (mixture of both B_4C and Al_2O_3 with equal %) reinforcement

Table 6.4 Impact Strength

S.No	**Sample**	**Impact strength (joules)**
1	Al2024+ 1% Al_2O_3+0.5%B_4C	11
2	Al2024+ 1% Al_2O_3+0.5%B_4C	12.8
3	Al2024 + 3% Al_2O_3+0.5%B_4C	14.4
4	Al2024 + 4% Al_2O_3+0.5%B_4C	16.2

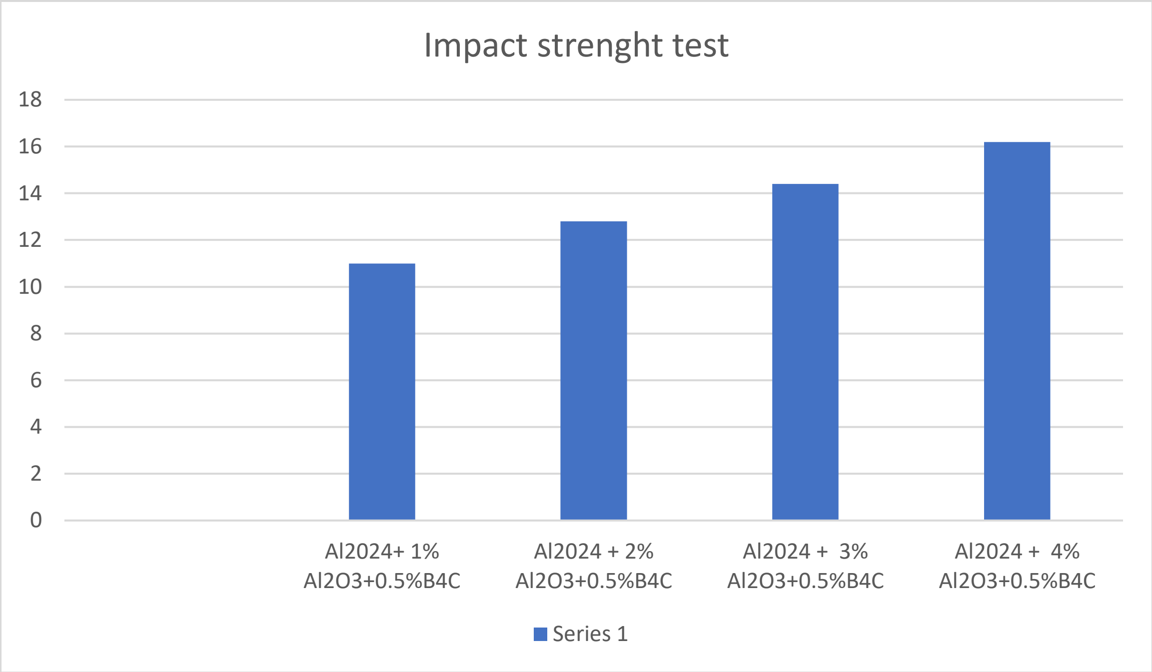


Fig: 6.4 Impact Strength v/s % of Reinforcement

6.5 Hardness Test

The hardness test performed on the specimens with B_4C and Al_2O_3 (mixture of both B_4C and Al_2O_3 with equal %) reinforcement

Table 6.5 Vicker's Hardness

S.No	%of reinforcement	Avg . VHN of Al_2O_3+ B_4C
1	0	
2	Al2024+ 1% Al_2O_3+0.5%B_4C	121.01
3	Al2024 + 2% Al_2O_3+0.5%B_4C	124.01
4	Al2024 + 3% Al_2O_3+0.5%B_4C	126.7
5	Al2024 + 4% Al_2O_3+0.5%B_4C	128.16

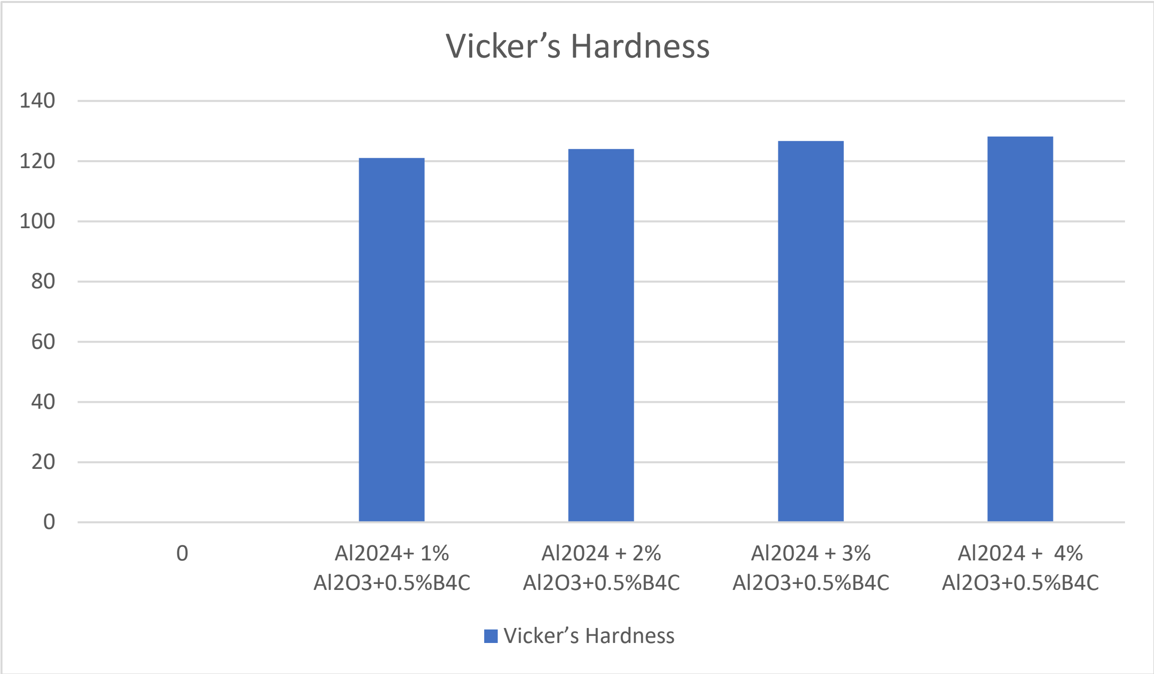


Fig 6.4 Hardness v/s % of Reinforcement

CHAPTER 7

CONCLUSIONS

Aluminium Metal matrix hybrid composites reinforced with Al_2O_3 and B_4C are fabricated by stir casting technique. Composites are made at three different weight fractions of reinforcements for density, micro structure, tensile test, and compression test and hardness measurement. The micro structural studies revealed that there is a fairly uniform distribution of B_4C particles and somewhat non uniform distribution Al_2O_3 in the Al2024 Metal matrix composites.

- The tensile strength has improved with increase in B_4C and Al_2O_3 reinforcements.
- The compression strength also increases by increasing B_4C and Al_2O_3 reinforcements
- The Density of the material increased with increasing the B_4C and Al_2O_3 reinforcements.
- Hardness of the pure Aluminium is up to 80 HB but our composite having more Hardness number.