A

PROJECT

REPORT ON

FABRICATION AND MECHANICAL PROPERTY INVESTIGATION OF AL-7075 REINFORCED WITH SIC AND GRAPHITE

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

BY

AVULA GANESH	**(19F21A0302)**
C. MANOHAR	**(20F25A0310)**
K. RAVEENDRA ACHARI	**(19F21A0319)**
K. SAI KUMAR	**(19F21A0321)**
S. PURUSHOTHAM YADAV	**(19F21A0315)**

Under the esteemed guidance of

Mr. S. CHANDRASEKHAR M. Tech
Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING

GATES INSTITUTE OF TECHNOLOGY

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CERTIFICATE

This is to certify that the project report entitled **'FABRICATION AND MECHANICAL PROPERTY INVESTIGATION OF AL-7075 REINFORCED WITH SIC AND GRAPHITE '**has been successfully presented by

AVULA GANESH	**(19F21A0302)**
C. MANOHAR	**(20F25A0310)**
K. RAVEENDRA ACHARI	**(19F21A0319)**
K. SAI KUMAR	**(19F21A0321)**
S. PURUSHOTHAM YADAV	**(19F21A0315)**

In partial fulfillment of the requirements for the award of degree of Bachelor of Technology in "MECHANICALENGINEERING" in GATES INSTITUTE OF TECHNOLOGY is a record of bonfire work carried out by them under my guidance and supervision.

PROJECT GUIDE:

Mr. S. CHANDRASEKHAR M. Tech
Assistant Professor,
Mechanical Engineering Department,
Gates Institute of Technology,
Gooty.

HEAD OF THE DEPARTMENT:

Dr. B. SIDDESWARA RAO M. Tech, PhD
Professor,
Mechanical Engineering Department,
Gates Institute of Technology,
Gooty.

EXAMINAR 1:

EXAMINAR 2:

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Project Associates:

AVULA GANESH	**(19F21A0302)**
C. MANOHAR	**(20F25A0310)**
K. RAVEENDRA ACHARI	**(19F21A0319)**
K. SAI KUMAR	**(19F21A0321)**
S. PURUSHOTHAM YADAV	**(19F21A0315)**

DECLARATION

We, the undersigned declare that the project entitled **"Fabrication and Mechanical Property Investigation of AL-7075 Reinforced with SIC and Graphite"** being submitted in partial fulfillment for the award of Bachelor of Mechanical Engineering Degree, affiliated to JNTUA, is the work carried out by

TEAM MEMBERS:

AVULA GANESH	**(19F21A0302)**
C. MANOHAR	**(20F25A0310)**
K. RAVEENDRA ACHARI	**(19F21A0319)**
K. SAI KUMAR	**(19F21A0321)**
S. PURUSHOTHAM YADAV	**(19F21A0315)**

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ABSTRACT

Composite material is defined as combination of two or more materials and to prepare and measure the characteristics of in detail about material. It can be classified into three types one is metal matrix composite, polymer matrix composite, ceramic matrix composite. The present work is on metal matrix composite "The present work deals with the preparation and mechanical characterization of Aluminium 7075 metal matrix reinforced with silicon carbide and graphite.Silicon carbide and graphite can be considered in different percentages like (2+3), (4+3) and (6+3). By using these materials to prepare and investigate the Mechanical characteristics like Ultimate tensile strength, Breaking strength, Rockwell hardness, Brinell hardness, Compressionstrength and toughness."

Aluminium Metal Matrix Composites (AMMC) have various properties which makes it to be applicableinto various places like automobile, military industries, aerospace, building constructions andothers due to light weight, thermal properties, stiffness, high mechanical strength corrosion resistance. During the analysis of the composite matrix of Aluminium, the properties / characteristic was investigated.

Key words: AMMC's, Stir casting, Mechanical properties of Aluminium 7075.

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CHAPTER – 1

INTRODUCTION

INTRODUCTION

1.COMPOSITE MATERIALS:

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are a reinforcement and a matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part.

1.1. Importance of composite materials:

1.1.1. Composites have a high strength-to-weight ratio.

Perhaps the biggest advantage of composites is their high strength-to-weight ratio. Carbon fibre weighs about 25% as much as steel and 70% as much as aluminium, and is much stronger and stiffer than both materials per weight. High-end auto engineers use composites to decrease vehicle weight by as much as 60% while improving crash safety; multilayer composite laminates absorb more energy than traditional single-layer steel. Harnessing the power of composites benefits manufacturers and consumers alike.

1.1.2. Composites are durable.

Composites never rust, regardless of their environment (though they are prone to corrosion when bonded to metal parts). Composites have less fracture toughness than metals but more than most polymers. Their high dimensional stability allows them to maintain their shape, whether hot or cold, wet or dry. This makes them a popular material for outdoor structures like wind turbine blades. Engineers choose composites over traditional materials to reduce maintenance costs and ensure long-term stability, major benefits for structures that are designed to last decades.

1.1.3. Composites open up new design options.

Composites offer design options that would be hard to achieve with traditional materials. Composites allow for part consolidation; a single composite part can replace a full assembly of metal parts. The surface texture can be altered to mimic any finish, from smooth to textured. Over 90% of recreational boat hulls are constructed from composites, in part because fiberglass can be moulded into a wide range of boat shapes. These benefits save production time and reduce maintenance costs in the long run.

1.1.4. Composites are now easier to produce.

In the past, engineers had to use a complex lay-up process to fabricate composites, which was time-consuming and restricted the design geometry. Digital composite manufacturing (DCM) has changed this. DCM is a patented manufacturing process that fabricates composite parts without manual labour. With DCM, composites can be tailored in three dimensions locally or globally, creating just the right strength, density, and flexibility for the project. DCM is enabling engineers to design for the flexibility of 3D printing, combined with the high performance of composites.

1.2 Advantages of composite materials

- Lower density (20 to 40%)
- Higher directional mechanical properties (specific tensile strength (ratio of material strength to density) 4 times greater than that of steel and aluminum.
- Higher Fatigue endurance.
- Higher toughness than ceramics and glasses.
- Versatility and tailoring by design.
- Easy to machine.
- Can combine other properties (damping, corrosion).
- Cost.

Disadvantages

- Not often environmentally friendly.
- Low recyclability.
- Cost can fluctuate.
- Can be damaged.
- Anisotropic properties.
- Matrix degrades.
- Low reusability.

1.3. Classifications of Composites.

Composites are usually classified by the type of material used for the matrix.

The four primary categories of composites are

1.Polymer matrix composites (PMCs),

2.Metal matrix composites (MMCs),

3.Ceramic matrix composites (CMCs)

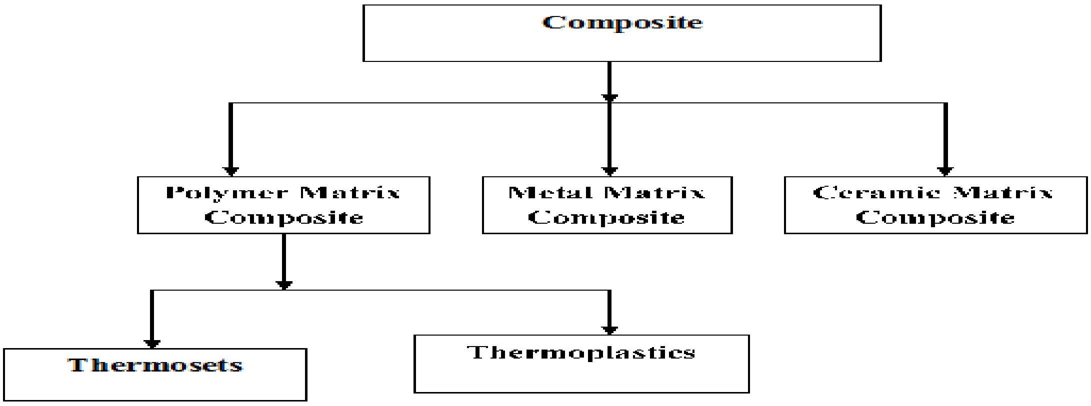


Fig 1: Classifications of Composites.

1.3.1. Polymer matrix composites (PMCs)

Polymer matrix composites (PMCs) are present in almost all aspects of modern life - from gadget components to a vast selection of automotive accessories. Derived from its name, meaning many repeating units, polymers are often made up of branches of carbon and hydrogen chemically linked together to make a chain.

Polymers that are often used as composites are either thermoplastic polymers, thermosetting polymers or elastomers. They are a source of a wide variety of low-priced, raw materials which offer many advantages like:

- Low specific weight
- High material stability against corrosion
- Good electrical and thermal insulation
- Ease of shaping and economic mass production
- Attractive optical properties

Polymer matrix composites are materials made up of fibres that are embedded in an organic polymer matrix. These fibres are introduced to enhance selected properties of the material. Polymer matrix composites are classified based on their level of strength and stiffness into two distinct types:

- **Reinforced plastics** - confers additional strength by adding embedded fibrous matter into plastics
- **Advanced Composites** - consists of fibre and matrix combinations that facilitate strength and superior stiffness. They mostly contain high-performance continuous fibres such as high-stiffness glass (S-glass), graphite, aramid, or other organic fibres

1.3.1.1. Properties of a PMC

The constituents of a PMC, which affect its overall properties are:

- **Matrix** - This is the polymer, which is a continuous phase and is classified as the weak link in a PMC structure.
- **Reinforcement** - This is a discontinuous phase and is a principal load-bearing component. It can either be glass, quartz, basalt, or carbon fibre.
- **Interphase** - The interphase between the reinforcement and matrix phases where load transmission takes place.

Aside from the types of matrices and reinforcement used, other factors affecting the properties of a PMC are the constituents' relative proportions, the reinforcement geometry and the nature of the interphase.

1.3.1.2. Production of polymer matrix composites

Polymers are reinforced with fibres which are 8 to 12 μ m in diameter either as continuous single or chopped multi-filaments that are woven into cloth and other types of preformed textiles. These fibres are then impregnated into the matrix polymer in liquid form by injection, extrusion, pressing or stamping and then cured to produce the final composite.

During the fabrication and shaping of polymer matrix composites into finished products, often the formation of the material itself is incorporated in the fabrication process. These processes include:

- Hand lay-up
- Vacuum moulding
- Spray lay-up
- Pultrusion
- Resin transfer moulding (RTM)
- Filament winding

1.3.1.3. Advantages of polymer matrix composites:

1.High tensile strength

2.High stiffness

3.High Fracture Toughness

4.Good abrasion resistance

5.Good puncture resistance

6.Good corrosion resistance

Disadvantage of polymer matrix composites:

1.Low thermal resistance

2.High coefficient of thermal expansion

1.3.1.4. Applications of polymer matrix composites:

Transportation vehicles: Polymer matrix composites find many uses in automotive, aerospace, and marine applications. Some examples of these uses are provided below.

- **Automotive vehicles:** Examples of polymer matrix composite use include tires and various belts and hoses as well as polymer matrix composite components in automotive bodies. Some very expensive sports cars, such as Bugatti, use carbon fiber reinforced polymer matrix composite as the main material of construction of the body of the car. It is interesting to note also that the first polymer matrix nanocomposite ever used in a commercial product was a timing belt cover launched in 1993 for the Toyota Camry. This breakthrough was followed over the decades with other applications, such as bumpers, body panels, engine parts, fuel tanks, and mirror housings. The technology has, by now, expanded to reduce the rolling resistance of tires, as well as provide ultra-hard protective coatings for paintwork, windscreen glass, and headlamps.
- **Aerospace vehicles:** Polymer matrix composites are also used in aircraft tires and interiors. Of even greater value, however, is the ability of polymer matrix composites to help satisfy the relentless drive in the aerospace industry to enhance performance while reducing weight. Most importantly, fiber-reinforced polymer matrix composites can be optimized to combine high strength, stiffness, and toughness, and low density, and thus to obtain exceptional strength-to-density and stiffness-to-density ratios along with superior physical properties, so that they are often the structural materials of choice for use in aircraft components.
- **Marine vehicles:** Polymer matrix composites find many uses in marine vehicles. Fiberglass boats are among the most familiar examples since fiberglass is a composite where a matrix polymer is reinforced by glass fibers which may be arranged randomly, or as a chopped strand mat, or as a woven fabric. The growing use of lighter, stiffer, and stronger carbon fibers instead of glass fibers is an emerging trend in boatbuilding.

Medical devices: Polymers and composites are essential components of many medical devices and applications. Some examples of these uses are provided below.

- Polymer matrix composites are used as components in a wide range of medical devices; such as MRI scanners, C scanners, X-ray couches, mammography plates, tables, surgical target tools, wheelchairs, and prosthetics.
- Polymer matrix nanocomposites containing carbon nanotubes or TiO_2 nanotubes reduce the healing time of broken bones by acting as a "scaffold" which guides the growth of replacement bone.
- The potential uses of nanocomposites in diagnostics and therapy are being explored. For example, the combination of magnetic nanoparticles and fluorescent nanoparticles in nanocomposite particles that are both magnetic and fluorescent appears to make a tumor easier to see during MRI tests performed prior to surgery and may also help the surgeon to see the tumor better during surgery.

Personal protective equipment: Polymer matrix composites are used in protective equipment for use in harsh environments (as in extreme heat or cold), when exposed to fire (as firefighters often are), when facing deadly weapons (as soldiers and law enforcement personnel often face), and in many other hazardous situations. Protection against temperature extremes, moisture, rain, chemical exposure, fire, clothing puncture, projectiles, abrasion, biohazards, radiation, explosions, high voltage, static electricity, and more can be achieved through the use of composites.

Footwear: The performance and comfort of footwear, as well as the durability of shoe interiors and exteriors, can be improved with the help of polymer matrix composites. In addition, biologically resistant or reactive composites may be used to counteract the typical drawbacks of conventional shoe textiles, such as odour, bacteria, and fungi. Synthetic (artificial) leather prepared from polyurethane formulations and often used as an alternative to natural (most often cow) leather in performance footwear is also often a composite made of two layers, including a backing layer that is most often made of woven or nonwoven polyester fibers. The optimum use of polymer matrix composites is essential for manufacturing footwear that can be used for prolonged periods in harsh environments.

Sporting goods: Polymer matrix composites find many uses in sporting goods. The following are some examples.

- Polymer matrix composites are used in performance footwear.
- Some versions of synthetic leather, a polyurethane-based material which is often used as an alternative to natural leather in performance footwear, are composite made of two layers, including a backing layer that is most often made of woven or nonwoven polyester fibers.
- Biologically resistant or reactive composites can provide protection against the hazards posed by sports equipment use, primarily excessive moisture, which promotes the growth of bacteria and fungi.
- Fiber-reinforced polymer matrix composites are used as materials of construction in high-performance sports gear because of their light weight, high strength, many degrees of freedom of design, and easy processing and forming characteristics. Examples of sports gear where such composites are used include skis, baseball bats, golf clubs, tennis rackets, and bicycle frames.

Industrial equipment: Polymer matrix composites are used in a vast range of industrial equipment. They are used as the main material of construction, or as components of equipment, or in some instances both as the main material of construction and as components. The uses of equipment in which polymer matrix composites are incorporated span almost all industries.

Packaging: Polymer matrix composites are used in many packaging applications. The following are some examples.

- Polymer matrix nanocomposite films where exfoliated clay nanoplatelets are dispersed with a high degree of orientation parallel to the plane of the film offer excellent barrier to oxygen and other gases. Hence such nanocomposites are useful as packaging materials for foods and other products that need protection against exposure to gases.
- It is also possible to design versions of such protective packaging films which provide high resistance to water vapor transmission.
- Work is in progress to develop biodegradable versions of such barrier packaging films. Such versions must remain stable and able to protect the packaged food but undergo biodegradation after being discarded.
- Work is in progress to develop “active” nanocomposite food packaging materials incorporating nanofiller particles with antimicrobial and/or antioxidant activity so that

the package inhibits and retards food spoilage even more effectively than would be expected from its gas barrier performance by itself.

- Work is in progress to develop “intelligent” food packaging materials incorporating reactive nanoparticles that can serve as nano sensors and manifest visible changes that warn the consumer of spoilage of the packaged food.

Building, construction, and civil engineering: Examples of polymer matrix composite use include the replacement, repair, retrofitting, or reinforcement of a structural component manufactured from a traditional structural material with fiber-reinforced polymers, as well as the emerging technology of composite panels used for the modular construction of buildings.

Impellers, blades, housings, and covers:

- Windmill blades are among the many types of products where the high strength-to-weight ratio achievable by using polymer matrix composites is essential for providing the necessary end use performance. Examples include blades manufactured from carbon nanotubes or graphene nanoplatelets in an epoxy thermoset matrix polymer.
- Such nanocomposites conduct electricity. Their electrical conductivity depends on the distance between the nanofiller components. This distance changes when strong wind gusts cause the blades to bend. Hence these structural components also serve as stress sensors which warn the windmill operator when the windmill should be shut down to protect it from serious damage.
- Polymer matrix nanocomposites are also used as the materials of construction of impellers for many applications, including vacuum cleaners.
- Polymer matrix nanocomposites are also used as the materials of construction of many housings and covers; such as power tool housings, lawn mower hoods, and covers for portable electronic equipment such as mobile phones and pagers.

Energy storage devices: Polymer matrix composites are used in many energy storage devices. The following are some examples.

- Anodes manufactured from a nanocomposite of silicon nanospheres and carbon nanoparticles provided lithium-ion batteries with greater power output. After this initial work, other nanocomposite formulations were also evaluated with favorable results. It should be noted that, although they are mentioned here because of their importance, these particular nanocomposites do not possess a polymeric matrix.

- Carbon nanotubes can be incorporated into paper to manufacture a conductive paper which can then be soaked in an electrolyte to obtain flexible batteries. Since cellulose (a polymer) is the main component of paper, the conductive paper is a polymer matrix nanocomposite. This work is a significant step forward in the emerging field of flexible (bendable) electronics.
- Polymer matrix nanocomposites are used in thin film capacitors for computer chips.

  Oil and gas exploration, production, transport, and storage: Polymer matrix composites are used in many oil and gas industry applications. The following are some examples.
- Fiber-reinforced polymer matrix composites are used as materials of construction in structures, such as offshore oil platforms and components on such platforms, used for oil and gas exploration and production. Much lighter weight and greater corrosion resistance are among the major advantages of polymer matrix composites over metals for such applications.
- The use of fiber-reinforced thermoset polymer matrix composites for repairing oil and gas transport and storage media ranging from high-pressure equipment and piping to oil storage tanks has been growing rapidly over the last two decades. Such composite repair systems are being used as alternatives to replacing damaged steel pipeline components or repairing them by installing heavy metal sleeves.
- The use of thermoset nanocomposite beads as nearly neutrally buoyant proppants, gravel pack materials, and solid lubricants during oil and gas drilling and completion operations is growing rapidly.

1.3.2. Metal matrix composites (MMCs):

Metal matrix composites (MMCs) comprise a relatively wide range of materials defined by the metal matrix, reinforcement type, and reinforcement geometry. In the area of the matrix, most metallic systems have been explored for use in metal matrix composites, including Al, Be, Mg, Ti, Fe, Ni, Co, and Ag. By far the largest usage is in aluminum matrix composites. From a reinforcement perspective, the materials used are typically ceramics since they provide a very desirable combination of stiffness, strength, and relatively low density. Candidate reinforcement materials include SiC, Al2O3, B4C, TiC, TiB2, graphite, and a number of other ceramics. In addition, there has been work on metallic materials as reinforcements, notably W and steel fibers. The morphology of the reinforcement material is another variable of importance in metal matrix composites. The three major classes of reinforcement morphology are continuous fiber, chopped fiber or whisker, and particulate. Typically, selection of the reinforcement morphology is determined by the desired property/cost combination. Generally, continuous fiber reinforced MMCs provide the highest properties in the direction of the fiber orientation but are the most expensive. Chopped fiber and whisker reinforced materials can produce significant property improvements in the plane or direction of their orientation, at somewhat lower cost. Particulates provide a comparatively more moderate but isotropic increase in properties and are typically available at the lowest cost. By adding to the three variables of metallic matrix, reinforcement material, and reinforcement morphology, the further options of reinforcement volume fraction, orientation, and matrix alloy composition and heat treatment, it is apparent that there is a very wide range of available material combinations and resultant properties. The specifics of the MMC systems, their manufacturing processes, and properties have been covered in Volume 3 of this series. This chapter will focus on how MMCs have been applied in specific application areas.

1.3.2.1. Properties in Metal Matrix Composites:

Metal matrix composite materials are defined as materials whose microstructures compromise a continuous metallic matrix phase into which a second phase, or phases, have been artificially introduced. This is contrast to conventional alloys whose microstructures are produced during processing by naturally occurring phase transformations. Metal matrix composites are distinguished from the more extensively developed resin matrix composites by virtue of their metallic nature in terms of physical and mechanical properties and by their ability to lend themselves to conventional metallurgical processing operations. Electrical conductivity, thermal conductivity and non-inflammability, matrix shear strength, ductility and abrasion resistance, ability to be coated, joined, formed and heat treated are some of the properties that differentiate metal matrix composites from resin matrix composites. They are a class of advanced materials, which have been developed for weight-critical applications in the aerospace industry. reinforced composites can be made with properties that are isotropic in three dimensions or in a plane.

1.3.2.2. Advantages of MMC:

- High strength
- High modulus
- High toughness and impact properties
- Low sensitivity to changes in temperature or thermal shock
- High surface durability and low sensitivity to surface flaws

- High electrical conductivity
- Excellent reproducibility of properties
- Excellent technological background with respect to
    - Design
    - Manufacture
    - Shaping and forming
    - Joining and finishing
    - Service durability information

Disadvantages of MMC:

- Some fabrication processes are complex and expensive
- Higher cost of some reinforcing fibers
- Relatively immature technology
- Machining difficult
- Complex fabrication methods
- Reinforcing material may reduce ductility and fracture toughness
- Fiber-matrix interactions at high temperature degrade fibers

1.3.2.3. APPLICATIONS of MMC:

- High performance tungsten carbide cutting tools are made from a tough cobalt matrix cementing the hard tungsten carbide particles; lower performance tools can use other metals such as bronze as the matrix.
- Some tank armors may be made from metal matrix composites, probably steel reinforced with boron nitride, which is a good reinforcement for steel because it is very stiff and it does not dissolve in molten steel.
- Some switched back to cast iron. Modern high performance sport cars, such as those built by automotive disc brakes use MMCs. Early Lotus Elise models used aluminum MMC rotors, but they have less than optimal heat properties, and Lotus has since Porsche, use rotors made of carbon fiber within a silicon carbide matrix because of its high specific heat and thermal conductivity. 3M developed a preformed aluminum matrix insert for strengthening cast aluminum disc brake calipers, reducing weight by half compared to cast iron while retaining similar stiffness. 3M has also used alumina preforms for AMC pushrods.
- Ford offers a Metal Matrix Composite (MMC) driveshaft upgrade. The MMC driveshaft is made of an aluminum matrix reinforced with boron carbide, allowing the

critical speed of the driveshaft to be raised by reducing inertia. The MMC driveshaft has become a common modification for racers, allowing the top speed to be increased far beyond the safe operating speeds of a standard aluminum driveshaft.

- Honda has used aluminum metal matrix composite cylinder liners in some of their engines, including the B21A1, H22A and H23A, F20C and F22C, and the C32B used in the NSX.
- Toyota has since used metal matrix composites in the Yamaha-designed 2ZZ-GE engine which is used in the later Lotus Lotus Elise S2 versions as well as Toyota car models, including the eponymous Toyota Matrix. Porsche also uses MMCs to reinforce the engine's cylinder sleeves in the Boxster and 911.
- The F-16 Fighting Falcon uses monofilament silicon carbide fibers in a titanium matrix for a structural component of the jet's landing gear.
- Specialized Bicycles has used aluminum MMC compounds for its top of the range bicycle frames for several years. Griffin Bicycles also made boron carbide aluminum MMC bike frames, and Invega briefly did so as well.
- Some equipment in particle accelerators such as Radio Frequency Quadrupoles (RFQs) or electron targets use copper MMC compounds such as Glidcop to retain the material properties of copper at high temperatures and radiation levels.
- Copper-silver alloy matrix containing 55% by volume diamond particles, known as Dymally, is used as a substrate for high-power, high-density multi-chip modules in electronics for its very high thermal conductivity.
- Aluminium-Graphite composites are used in power electronic modules because of their high thermal conductivity, the adjustable coefficient of thermal expansion and the low density.

1.3.3. Ceramic Matrix Composites (CMC):

Composite materials are materials in which a homogenous matrix is reinforced by a stronger and stiffer constituent that is usually fibrous but may have a particulate or other shape (web.mit.edu). They are produced when two or more materials or phases are used together to give a combination of properties that cannot be attained otherwise. For example, steel reinforced concrete, plywood and fibre glass.

Ceramic matrix composites are a type of composite with ceramics as both the reinforcement and the matrix material. The reinforcement provides its special properties while the matrix material holds everything together. These composites were developed for applications with demanding thermal and mechanical requirements, such as in aerospace vehicles, nuclear industries, ground transportation, space structures and chemical industries.

1.3.3.1. Properties of ceramic matrix composites are:

Thermal resistance: while technical ceramics are proven thermal insulators, CMC is adding dimensional components (namely fibers, matrix and pores) that enhance the resistance to thermal shocks.

Lightweight: compared with the previous composite technologies used in extreme environment, a CMC part is much lighter. For example, it is 1/3 the weight of nickel superalloys for a similar part.

Fracture toughness: CMC material is less brittle than a conventional technical ceramic, since fibers contribute to bridge the cracks

Electrical insulation: oxide CMCs show dielectric transparency, unlike other types of CMCs.

Chemical stability: High Purity Alumina matrix shows excellent corrosion resistance against most chemicals

- 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

1.3.3.2. Advantages of CMC:

- Excellent wear and corrosion resistance in a wide range of environments and temperature
- Higher strength to weight ratio
- Higher strength retention at elevated temperature
- Higher chemical stability
- Non-catastrophic failure
- High hardness

Disadvantage of CMC:

- Processing routes for CMCs involve high temperatures - can only be employed with high temperature reinforcements.
- CMCs are designed to improve toughness of monolithic ceramics, the main disadvantage of which is brittleness.
- High processing temperature results in complexity in manufacturing and hence expensive processing.
- Difference in the coefficients of thermal expansion between the matrix and the reinforcement lead to thermal stresses on cooling from the processing temperatures.

1.3.3.3. Applications of ceramic matrix composites:

- **Heat exchangers and burner components**
- **Gas turbine components** – these include turbine blades, combustion chambers, stator vanes and turbine engines, where coated silicon carbide fibres are embedded in a ceramic matrix to impart temperature resistance, toughness, and low density.
- **Aerospace industry** – including body flaps, shrouds and space shuttle shielding, where coated ceramic tiles provide protection from extreme heat.
- **Engine exhaust systems** – including ceramic exhaust nozzles for commercial aircraft to increase component life and reduce weight and engine noise.
- **Hypersonic vehicles** – these utilise structural materials such as ultra-high-temperature ceramics, which make good candidates for high heat flux areas.

Nuclear power industry – including internal reactor structures made from MAX phase composites that can withstand high temperatures and have high mechanical damage tolerance and good chemical compatibility with coolants such as sodium and molten lead.

CHAPTER - 2

LITERATURE SURVEY

2.1. Literature Review

Zhao et.al. studied the microstructures and mechanical properties of equal-channel angular pressing (ECAP) processed and naturally aged ultrafine grained (UFG) and coarse grained (CG) Al7075 alloys and their evolutions during heat treatment. Their studies established that after the tests, natural aging, tensile yield strength, ultimate strength and micro hardness of UFG samples were higher by 103%, 35% and 48% respectively than those of the CG samples. Their studies show that severe plastic deformation has the potential to significantly improve the mechanical properties of age-hardening Al alloys.

Mr. S. Chandrasekhar deals with the preparation and mechanical characterization of aluminium 6063metal matrix reinforced with silicon carbide and graphite. Silicon carbide and graphite can be considered in different percentages like (1+2), (3+2), (5+2). By using these materials to prepare and investigate the mechanical characteristics like ultimate tensile strength, breaking strength, Rockwell hardness, Brinell hardness, compression strength and toughness. Aluminium metal composites have various properties which makes it to be applicable into various places like automobile, military industries, aerospace, building constructions and others due to light weight, thermal properties, stiffness, high mechanical strength, corrosion resistance. During the analysis of the composite matrix of aluminium the properties / characteristic were investigated

Karthikeyan et.al. Al7075 alloy composites containing different volume fraction of short basalt fiber are developed using the stir casting process. The experimental strength values of the composites are compared with the theoretical values in this paper. The results suggested that the experimental values best suited the theoretical values owing to the random distribution of basalt fibers in the Al7075 matrix.

Pradeep R et.al observed the study of mechanical properties of Al- Red Mud and Silicon Carbide Metal Matrix Composite (MMC) of Aluminum alloy of grade 7075 with addition of varying weight percentage composition such as SiC8%+Al7075, SiC6%+Red mud2%+ Al7075, SiC4%+Red mud 4%+Al7075, SiC2%+Red mud 6%+Al7075, Red mud 8%+Al7075ed mud and Silicon Carbide particles by stir casting technique. The experimental result reveals that the combination of a matrix material with reinforcement such as Sic and Red mud particles, improves mechanical properties.

Ravichandran M et.al carried out the research work by fabricating aluminum metal matrix composites through liquid powder metallurgy route. The aluminum matrix composite containing TiO_2 reinforcement particle was produced to study the mechanical properties such as tensile strength and hardness.

Yadean et.al. Have investigated the fabrication and precipitation hardening characterization of nanostructure Al7075 alloy. In their experiment, the Al7075 alloy is milled up to 15 h and then hot pressed. The milled and hot-pressed samples are characterized by XRD, TEM, SEM and DTA. Their results indicated that after 15 h of milling, the alloying elements are dissolved in the Al matrix and a supersaturated solid solution with average crystallite size of 30±5 nm is obtained. Hot pressing the powder samples at 500oC under 400 MPa resulted in a fully dense bulk nanostructure Al7075 alloy. The hardness value of the consolidated sample increased from 165 HV to 240 HV after appropriate hardening.

Keshava Murthy R et.al studied about Al7075-TiB_2 in-situ composite, processed by stir casting technique using commercially available Al-10%Ti and Al- 3%Br master alloys. Both matrix alloy and composite were subjected to microstructure analysis, micro hardness test, grain size studies and tensile test. Microstructure shows fairly uniform distribution of TiB_2 particles in matrix alloy. Average grain size of the composite was lower than unreinforced alloy. Micro hardness, yield strength and ultimate tensile strength of Al7075-TiB_2 composite, were considerably higher when compared with unreinforced alloy.

Anand Kumar et.al research work carried out by Addition of reinforcement such as Tic, Sic, Al_2O3, TiO2, Tin, etc. to Aluminum matrix for enhancing the mechanical properties has been a well– established fact. In-situ method of reinforcement of the Aluminum matrix with ceramic phase like Titanium Carbide (Tic) is well preferred over the Ex–situ method. In the present investigation, Al- Cu alloy (series of 2014 Aluminum alloy) was used as matrix and reinforced with Tic using In-situ process. The Metal Matrix Composite (MMC) material, Al-.5%Cu/10%TiC developed exhibits higher yield strength, ultimate strength and hardness as compared to Al-4.5%Cu alloy. Percentage increase in yield and ultimate tensile strengths were reported.

CHAPTER – 3

MATERIALS AND METHODOLOGY

3.1 METAL MATRIX COMPOSITES:

A composite material (also called a composition material or shortened to composite) is a material made from two or more constituent materials with significantly different physical or chemical properties that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger lighter, or less expensive when compared to traditional materials. More recently, researchers have also begun to actively include sensing, actuation, computation and communication into composites, which are known as Robotic Materials. Composite materials are generally used for buildings, bridges, and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite and marble sinks and countertop.

3.1.1 Materials of A Metal Matrix Composites:

Metal matrix composites (MMCs) are a group of materials (such as metals, alloys or intermetallic compounds) incorporated with various reinforcing phases, such as particulates, whiskers or continuous fibres.

- Graphene
- Al_2O_3
- Microstructure
- Magnesium
- Nanotubes
- Matrix Composite

3.1.2 Properties of Metal Matrix Composites:

Metal matrix composites (MMCs), by virtue of their low density, high strength-to-weight ratio, high temperature strength retention, and excellent creep, fatigue, and wear resistances, have the potential for replacing cast iron and other materials in engines and brakes.

And also MMC’s have

- Higher strength-to-density ratios
- Higher stiffness-to-density ratios
- Better fatigue resistance rate

- Better elevated temperature properties. -- Higher strength. -- Lower creep
- Lower coefficients of thermal expansion
- Better wear resistance

3.1.3 Applications of Metal Matrix Composites:

- Pushrods for racing engines
- Carbide drills
- Tank amors
- Automotive industry - disc brakes, driveshaft, engines
- Aircraft components - structural component of the jet's landing gear
- Bicycle frames
- Space systems

3.1.4. Materials Used

3.1.4.1. AL--7075

Aluminium 7075 is a heat -treatable aluminium alloy with zinc as the primary alloying element. It has moderated formability when in the fully soft, annealed temper and can heat-treated to strength levels that are comparable to many steel alloys.

Chemical Analysis:

Grade	%Zn	%Mg	%Cu	%Cr	%Si	%Mn	%Ai
AA7075	6.10	2.65	1.55	0.0028	0.01	0.001	BAL

Table 1. Chemical Analysis of AL-7075

Density (ρ)	2.81g/cm
Melting temperature (T_m)	477^0C(891^0F)
Thermal conductivity(k)	130-150W/m*K

Table 2. Properties of AL7075

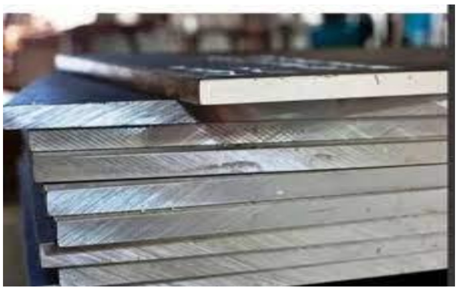


Fig 2. Aluminium 7075

3.1.4.2. Graphite:

It is a crystalline form of the element carbon. It consists of stacked layers of graphene. Graphite occurs naturally and is the most stable form of carbon under standard conditions.

Properties of graphite:

- Graphite occurs in the free state but can also be prepared artificially
- It is greyish black opaque substance
- Lighter than diamond, smooth and slippery to touch
- It is good conductor of heat and electricity
- It is crystalline solid
- It melts about 1800K

Fig 3. Graphite

Physical Properties of Graphite:

APS	Purity	Molecular weight	Form	Density	Solubility	Melting point	Colour
80-90µm	99%	12.011g/mol	Powder	20.26g/cm^3	Insoluble in water	3650^{0}C	Black

Table 3. Physical Properties of Graphite

3.1.4.3. Silicon carbide(sic):

It is a hard chemical compound containing silicon and carbon. A semiconductor, it occurs in nature as the extremely rare mineral grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance such as car bikes etc...

Properties of Sic:

- Low density and High strength
- Good high temperature strength
- Oxidation resistance

Physical properties of sic:

APS	Purity	Molecular weight	Form	Density	Solubility	Melting point	Colour
80-100nm	99%	40.096g/mol	Powder	3.16g/cm^3	Insoluble in water	2730^{0}c	Black

Table 4. Physical properties of SIC

Fig 4. Silicon carbide

Specimen Composition

S. No	Specimen Name	AL7075(g)	SIC(g)	GRAPHITE(g)
1	A	950	20	30
2	B	930	40	30
3	C	910	60	30

Table 5. Specimen Composition

3.1.5 Fabrication Techniques of Metal matrix composites:

- Stir Casting
- Squeeze Casting
- Spray Forming

3.1.6 Stir Casting:

Stir casting is currently the most popular commercial method of producing aluminium-based composites Stir casting of MMCs was initiated in 1968, when S. Ray introduced alumina particles into aluminium melt by stirring molten aluminium alloys containing the ceramic powders; allows for the use of conventional metal processing methods with the addition of an appropriate stirring system such as mechanical stirring; ultrasonic or electromagnetic stirring; or centrifugal force stirring. to achieve proper mixing of reinforcement into melt which depends on material properties and process parameters such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification. The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added and finally the liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies.

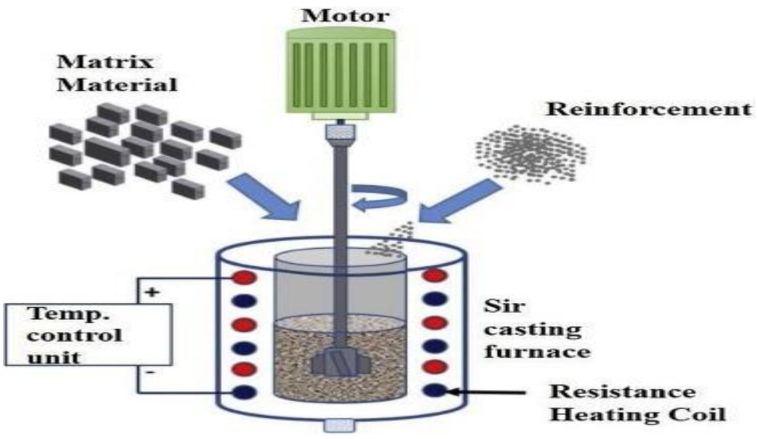


Fig 5. Stir Casting process

3.1.7 Squeeze Casting:

The concept of squeeze casting dates back to the 1800s. The idea was suggested by Chernov in 1878 to apply steam pressure to molten metal while being solidified. Squeeze casting experiment was not conducted until 1931. Squeeze casting technique is a liquid phase fabrication method of AMCs in which metal solidifies under pressure within closed die halves, using a movable mould part for applying pressure on the molten metal and force it to penetrate into a preformed dispersed phase, placed in the lower fixed mould part.

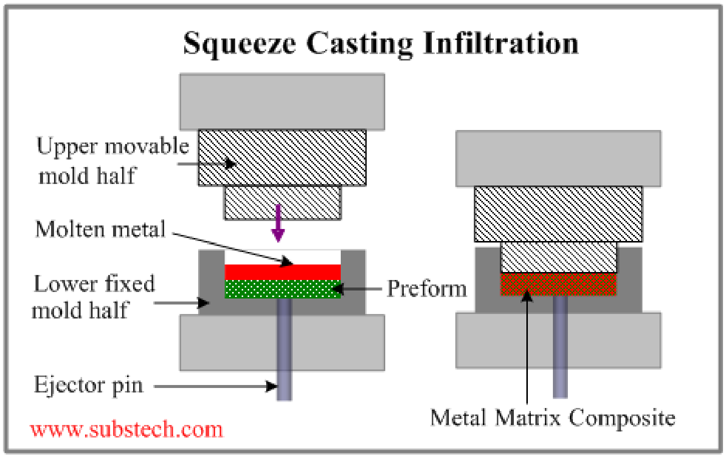


Fig 6. Schematic diagram illustrating the Squeeze Casting

3.1.8 Spray Forming:

Fabrication of composite by spray forming process involves melting of an alloy in a furnace, forcing the melt through a small orifice, passing a stream of compressed inert gas, injecting reinforcement through the jet and breaking the liquid metal into fine semi solid droplets. These semi solid droplets are deposited over a stationary substrate to form solid preform. It is difficult to attain uniform distribution of reinforcements into the metal matrix by this method but the composites formed by spray deposition process are not very expensive.

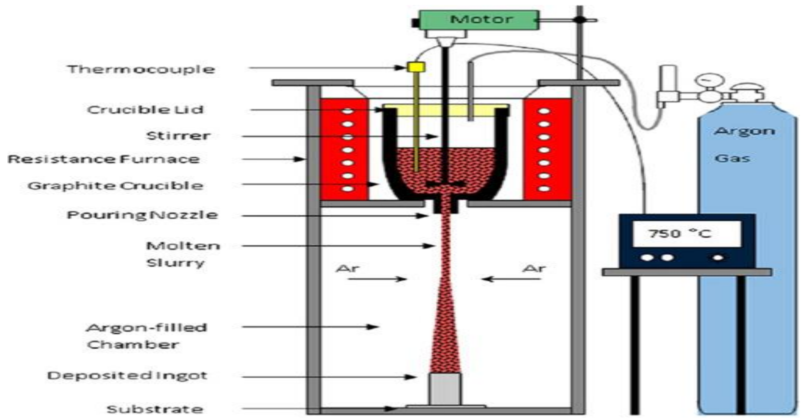


Fig 7. Schematic diagram of spray forming process

3.2 POLYMER MATRIX COMPOSITES:

Polymer matrix is the major component of the transdermal patch fabricated with multiple layers of polymer in which a reservoir is sandwiched between two polymeric layers. Polymer is composed of an outer impregnable layer preventing the loss of active substances and an inner polymeric layer functioning as a controlling membrane. The polymer matrix is designed based on the active substance used for the patch formulation, adhesion-cohesion balance, compatibility, and stability with other components of the patch.

3.2.1. Properties Of Polymer Matrix Composites:

The requirements of a good matrix material are that it can infiltrate between the fibres and form a strong interfacial bond. It is also essential that there is no chance of chemical reaction between the matrix material and fibres and that the matrix material does not cause damage to the fibres.

- Low specific weight
- High material stability against corrosion

- Good electrical and thermal insulation
- Ease of shaping and economic mass production
- Attractive optical properties

3.2.2. Applications of Metal Matrix Composites:

- Aerospace structures: The military aircraft industry has mainly led the use of polymer composites. In commercial airlines, the use of composites is gradually increasing. Space shuttle and satellite systems use graphite/ epoxy for many structural parts.
- Marine: Boat bodies, canoes, kayaks, and so on.
- Automotive: Body panels, leaf springs, drive shaft, bumpers, doors, racing car bodies, and so on. iv) Sports goods: Golf clubs, skis, fishing rods, tennis rackets, and so on.
- Bulletproof vests and other armour parts.
- Chemical storage tanks, pressure vessels, piping, pump body, valves, and so on.
- Biomedical applications: Medical implants, orthopaedic devices, X-ray tables.
- Bridges made of polymer composite materials are gaining wide acceptance due to their lower weight, corrosion resistance, longer life cycle, and limited earthquake damage.
- Electrical: Panels, housing, switchgear, insulators, and connectors

3.2.3. Fabrication Techniques of Polymer matrix composites:

- Hand Layup
- Open Contact Molding
- Resin Transfer Molding (RTM)
- Resin Film Infusion (RFI)
- Vacuum-assisted resin transfer molding (VARTM)
- Compression molding
- Injection molding
- Centrifugal casting
- Spray lay up

3.2.4 Hand Layup:

The most basic method for fabricating thermoset composites is the hand layup method. In this process, dry fabric layers (or “plies”) are laid by hand to form a laminate stack and then resin is applied once the stack is completed. In a variation of this method, known as wet layup, the plies are coated with resin before it is laid, and then the stack is “debulked” or compacted afterwards.

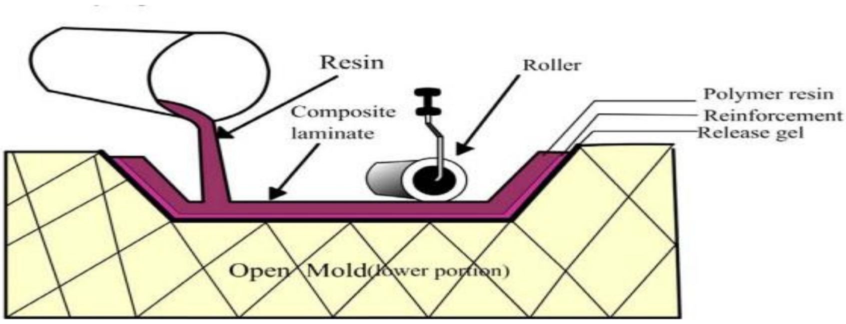


Fig 8. Hand layup technique in polymer matrix

3.2.5 Open Contact molding:

Open contact molding in one-sided molds is a low cost, common process for making fiberglass composite products. Typically used for boat hulls and decks, RV components, truck cabs and fenders, spas, bathtubs, shower stalls and other relatively large, noncomplex shapes, open molding involves either hand layup or a semi-automated alternative, spray up. In an open-mold spray up application, the mold is first treated with mold release. If a gel coat is used, it is typically sprayed into the mold after the mold release has been applied. The gel coat then is cured and the mold is ready for fabrication to begin. In the spray up process, catalysed resin (viscosity from 500 to 1,000 and glass fibre are sprayed into the mold using a chopper gun, which chops continuous fibre into short lengths, then blows the short fibres directly into the sprayed resin stream so that both materials are applied simultaneously. To reduce VOCs, piston pump-activated, non-atomizing spray guns and fluid impingement spray heads dispense gel coats and resins in larger droplets at low pressure. Another option is a roller impregnator, which pumps resin into a roller similar to a paint roller. In the final steps of the spray up process, workers compact the laminate by hand with rollers. Wood, foam or other core material may then be added, and a second spray up layer imbeds the core between the laminate skins. The part is then cured, cooled and removed from the reusable mold. Hand layup and spray up methods are often used in tandem to reduce labour.

3.2.6 Resin Transfer Molding (RTM):

Resin transfer molding (RTM) is an intermediate volume molding process for producing composites. In RTM, resin is injected under pressure into a mold cavity. This process produces parts with two finished surfaces.

In contrast to RTM, where resin and catalyst are premixed prior to injection under pressure into the mold, reaction injection molding (RIM) injects a rapid-cure resin and a catalyst into the mold in two separate streams. Mixing and the resulting chemical reaction occur in the mold instead of in a dispensing head. Automotive industry suppliers combine structural RIM (SRIM) with rapid preforming methods to fabricate structural parts that don’t require a Class A finish. Programmable robots have become a common means to spray a chopped fiberglass/binder combination onto a vacuum equipped preform screen or mold. Robotic spray up can be directed to control fiber orientation. A related technology, dry fiber placement, combines stitched preforms and RTM.

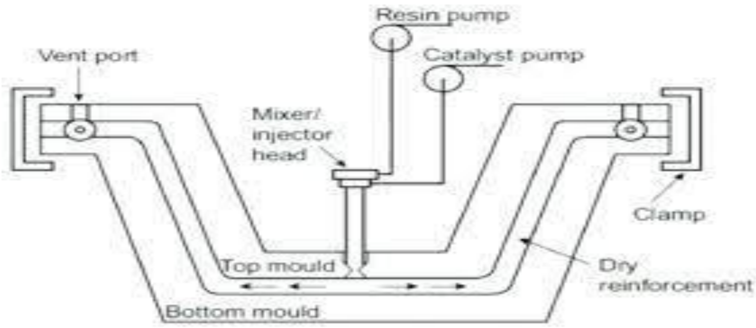


Fig 9. Resin Transfer Molding in polymer matrix

3.2.7 Injection molding:

It is a fast, high-volume, low pressure, closed process using, most commonly, filled thermoplastics, such as nylon with chopped glass fiber. In the past 20 years, however, automated injection molding of BMC has taken over some markets previously held by thermoplastic and metal casting manufacturers. For example, the first-ever BMC-based electronic throttle control (ETC) valves (previously moulded only from die-cast aluminium) debuted on engines in the BMW Mini and the Peugeot 207, taking advantage of dimensional stability offered by a specially-formulated BMC supplied by Tetra DUR GmbH (Hamburg, Germany), a subsidiary of Bulk Molding Compounds Inc. (BMCI, West Chicago, Ill.,).Injection speeds are typically one to five seconds, and as many as 2,000 small parts can be produced per hour in some multiple-cavity molds. Parts with thick cross-sections can be compression moulded or transfer moulded with BMC. Transfer molding is a closed-mold process wherein a measured charge of BMC is placed in a pot with runners that lead to the mold cavities. A plunger forces the material into the cavities, where the product cures under heat and pressure.

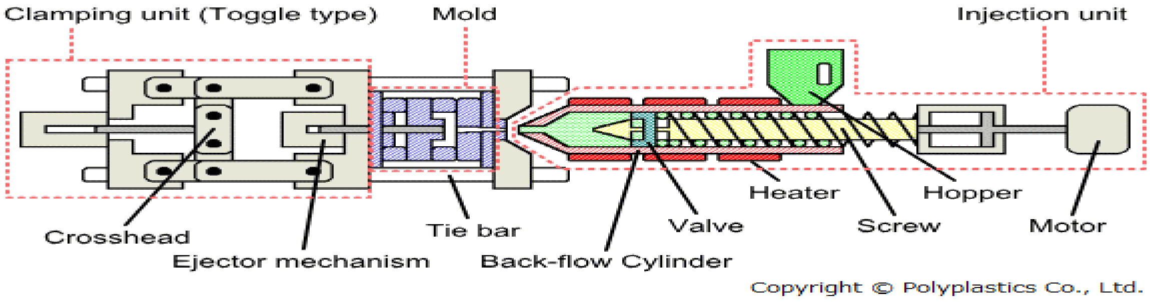


Fig 10. Injection molding

3.2.8. Centrifugal casting:

In centrifugal casting, reinforcements and resin are deposited against the inside surface of a rotating mold. Centrifugal force holds them in place until the material cures or hardens. Centrifugal casting is used to produce hollow parts (like pipes with two smooth surfaces). It's especially well-suited for producing structures with large diameters, such as pipes for oil and chemical industry installations and chemical storage tanks. Centrifugal casting is increasingly being used to produce telephone, street light and other poles.

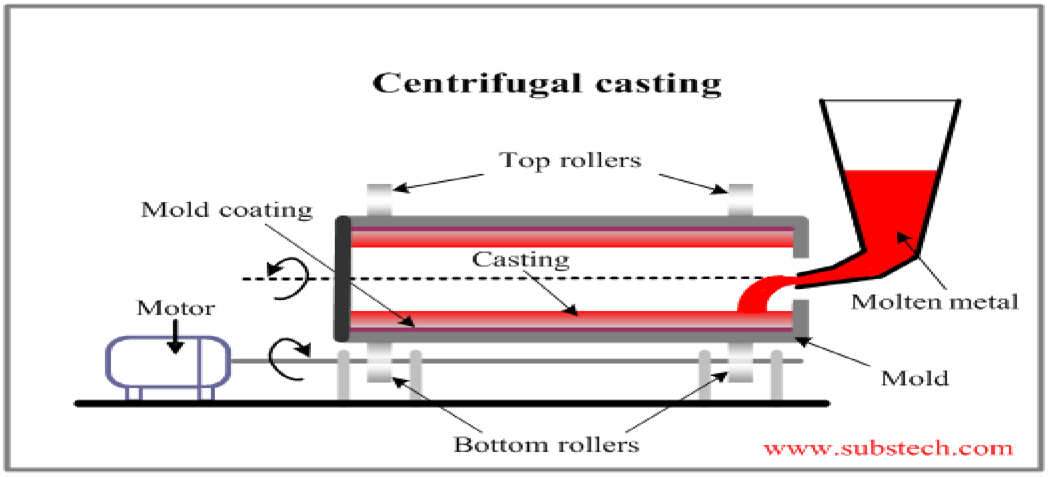


Fig 11. Centrifugal casting technique

The casting of pipe from 1 inch/25 mm to 14 inches/356 mm in diameter is an alternative to filament winding for high-performance, corrosion resistant service. In cast pipe, 0°/90° woven fiberglass provides both longitudinal and hoop strength throughout the pipe wall and brings greater strength at equal wall thickness compared to multiaxial fiberglass wound pipe. In the casting process, epoxy or vinyl ester resin is injected into a 150G centrifugally spinning mold, permeating the woven fabric wrapped around the mold's interior surface. The centrifugal force pushes the resin through the layers of fabric, creating a smooth finish on the outside of the pipe, and excess resin pumped into the mold creates a resin-rich, corrosion- and abrasion resistant interior liner. Fiber-reinforced thermoplastic components now can be produced by extrusion, as well. A huge market has emerged in the past decade for extruded thermoplastic/wood flour (or other additives, such as bast fibers or fly ash) composites. These wood plastic composites, or WPCs, used to simulate wood decking, siding, window and door frames, and fencing.

3.2.9. Spray Lay Up:

In the spray-up process, the operator controls thickness and consistency, therefore the process is more operator dependent than hand lay-up. Although production volume per mold is low, it is feasible to produce substantial production quantities using multiple molds. This process uses simple, low-cost tooling and simple processing. Portable equipment permits on-site fabrication with virtually no part size limitations. The process may be automated.

As with hand lay-up, gel coat is first applied to the mold and allowed to cure. Continuous strand glass roving and initiated resin are then fed through a chopper gun, which deposits the resin-saturated "chop" on the mold.. Additional layers of chop laminate are added as required for thickness. Roll stock reinforcements, such as woven roving or knitted fabrics, can be used in conjunction with the chopped laminates. Core materials of the same variety as used in hand lay-up are easily incorporated. Molds can range from small to very large and are low cost in the spectrum of composites molds.

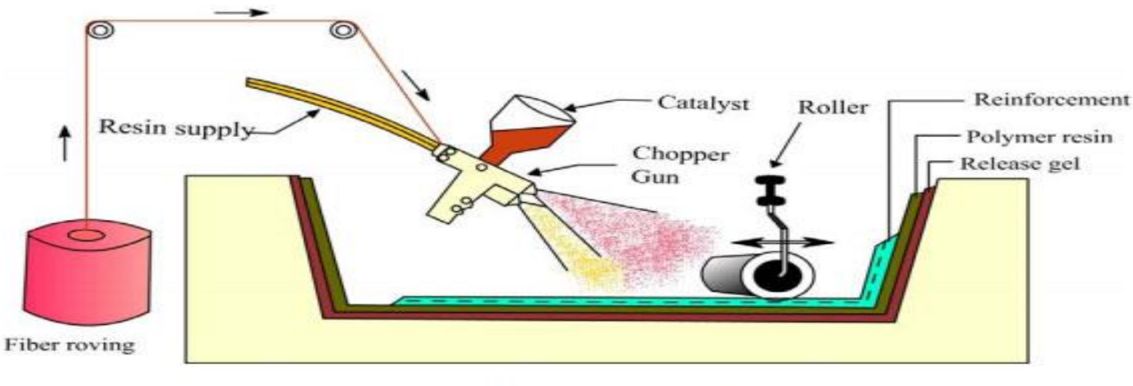


Fig 12. Spray Lay Up technique in polymer matrix

3.3. 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.

3.3.1. Materials Of an Ceramic Matrix Composites:

The matrix materials used with the addition of non-oxide, ultra-high-temperature (UHT) ceramics used for special applications. The advanced ceramics are commonly used in the production of ceramic matrix composites to overcome the main disadvantage of traditional ceramics; namely, their brittleness. The most commonly used CMCs are non-oxide CMCs, such as carbon/silicon carbide (C/SiC), carbon/carbon (C/C), and silicon carbide/silicon carbide (SiC).

3.3.2. 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

3.3.3. Applications of Ceramic Matrix Composites:

Common applications of ceramic matrix composites are:

- Heat exchangers and burner components
- Gas turbine components – these include turbine blades, combustion chambers, stator vanes and turbine engines, where coated silicon carbide fibres are embedded in a ceramic matrix to impart temperature resistance, toughness, and low density.
- Aerospace industry – including body flaps, shrouds and space shuttle shielding, where coated ceramic tiles provide protection from extreme heat.
- Engine exhaust systems – including ceramic exhaust nozzles for commercial aircraft to increase component life and reduce weight and engine noise.
- Hypersonic vehicles – these utilise structural materials such as ultra-high-temperature ceramics, which make good candidates for high heat flux areas.
- Nuclear power industry – including internal reactor structures made from MAX phase composites that can withstand high temperatures and have high mechanical damage tolerance and good chemical compatibility with coolants such as sodium and molten lead.

3.3.4 Fabrication Techniques of Ceramic matrix composites:

The fabrication methods of ceramics are classified in three categories: glass-forming, particulate forming, and cementation. In glass-forming processes, the raw materials are heated until they melt. There are five glass-forming processes: blowing, pressing, drawing, fiber-forming, and sheet-forming.

3.3.5 Glass-Forming Ceramics:

The glass- forming ceramics are polycrystalline materials produced through controlled crystallization of base glass, producing a fine uniform dispersion of crystals throughout the bulk material. Crystallization is accomplished by subjecting suitable glasses to a carefully regulated heat treatment schedule, resulting in the nucleation and growth of crystal phases. In many cases, the crystallization process can proceed to near completion, but in a small proportion of processes, the residual glass phase often remains. Glass-ceramic materials share many properties with both glasses and ceramics. They are glass-forming ceramics are

- Blowing
- Pressing
- Drawing
- Fiber-forming and sheet-forming

3.3.6 Particulate Forming:

Typical ceramics have relatively high melting point and are brittle. They are NOT processed via casting or forming (via machining or working) techniques as metals. Instead, they go through “particulate forming” to obtain “green bodies”, which are then heat treated (sintered) to obtain final products.

Cementation:

- Hardening of a paste – paste formed by mixing cement material with water.
- Formation of rigid structures having varied and complex shapes.

Hardening process – hydration (complex chemical reactions involving water and cement particles.)

CHAPTER - 4

RESULT AND DISCUSSION

4.1 TENSILE TESTING

The tensile test procedure involves attaching the sample to the testing machine and applying force until the material fractures. The results are typically recorded in a stress-strain diagram. The most important parameters measured in the test are the ultimate tensile strength, yield strength, and elongation at break.

A tensile test is used to determine the yield point or yield strength, tensile strength or ultimate tensile stress, and percentage elongation of a metal. The tensile Testing method measures the force required to break a metallic, composite, or plastic specimen and the extent to which the specimen stretches or elongates to that breaking point.

4.1.1. Tensile Test Procedure

A tensile specimen of standard dimensions machined from the metal is inserted in a tensile testing machine. The machine consists essentially of two parts: the straining or pulling device and an arrangement to measure and register the load on a dial. A gradually increasing tensile load is applied to the specimen and the resultant extension (or strain) of the specimen is observed.

Fig 13. Tensile Testing machine

The relation between applied stress (i.e., load divided by cross-section) and extension or elongation is indicated by a stress-strain curve such as the one shown in the below figure, which is typical of ductile carbon steel. Up to point P on the curve, the stress is proportional to the strain as indicated by a straight line. It is termed the limit of proportionality. Beyond P, the curve deviates from the straight line. Point E on the curve is the elastic limit. This means that up to this point the specimen returns to its original dimensions when the load is removed and thus exhibits elasticity.

As the load is increased beyond the elastic limit, there comes a point at which there is a sudden extension, indicated by the drop of the beam and continued extension with a lower load. If the load is removed, the specimen does not recover its original dimensions and it is said to have undergone plastic deformation or plastic flow.

4.1.2. Tensile Test Specimens Dimensions

In the tensile specimen, gauge length and parallel length are standard dimensions. These are shown in the Figure below. Gauge length which is usually 50 mm is marked by two points on the specimen before testing, and the final gauge length after fracture is measured.

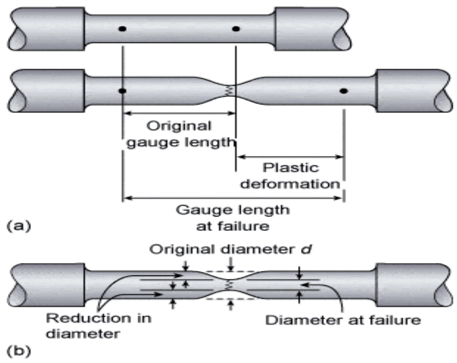


Fig 14. Tensile Test Specimens

Tensile Test Calculations

During the test, the value of applied load (F) & change in total length ((ΔL) of the test specimen is measured continuously. The value of stress (force/ unit area, denoted by σ) either Yield Stress or Tensile Stress, and the strain (percentage elongation, denoted by ε) is obtained by the tensile test result. The cross-sectional area (at the center of the test specimen) of the test specimen is required to calculate the value of stress or tensile strength.

Tensile Strength formula & calculation

Tensile test based on the tensile test data is calculated by using the below formula:

Stress (σ) = Force (F) / cross-sectional Area of the test specimen (A)

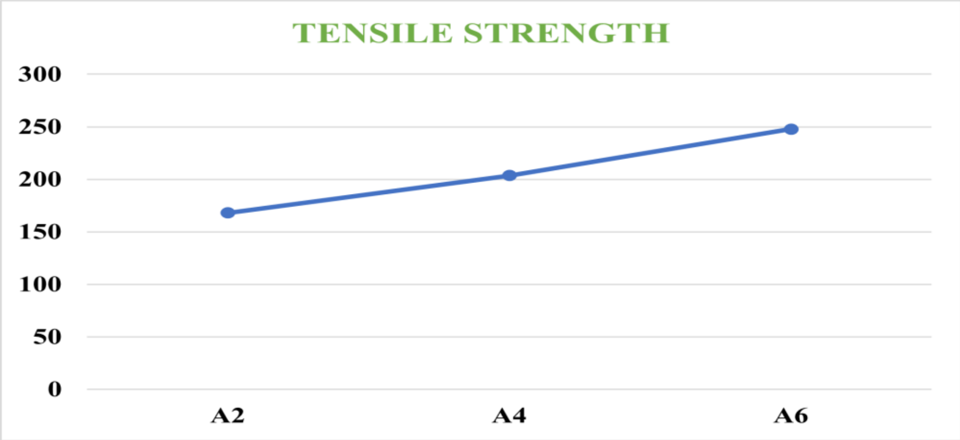
Cross sectional area of the specimen is $A = \pi r^2$ = 3.14*6*6 = 113.04 mm^2

r = radius of the circular cross section = 6 mm

Tensile strength

S. No	Material	Gauge length(mm)	Diameter 2r(mm)	Area of the cross section	Breaking load (Kgf)	Breaking strength (KPa)
1	A2	100	12	113.04	190	168
2	A4	99	12	113.04	230	203.46
3	A6	98	12	113.04	280	247.69

Table 6. Tensile Strength



Graph 1. Specimen vs Tensile strength

Percentage reduction of area is another measure of ductility which can be measured in a tensile test. It is obtained by carefully fitting together the ends of the fractured tensile specimen and measuring the dimensions of the smallest cross-section. The difference between this area and the original cross-sectional area, divided by the original cross-sectional area and multiplied by 100 gives the percentage reduction of area. Strain or percentage elongation or percentage reduction in area can be calculated by the below formula:

Strain (ε) = ΔL/L*100

Where:

ΔL is the final gauge length,

L is the initial gauge length

The percentage elongation or elongation after fracture in a tensile test is the remaining length variation (ΔL-L) referred to as the initial measuring length (L) after a fracture..

Tensile Testing Standards & Specification

The main tensile testing standards and specifications are listed below. These standards are applicable for material and weld joint testing.

1. **ASTM E8/E8M** – Tensile Testing of Metallic Materials
2. **BS EN ISO 4136**: Destructive tests on welds in metallic materials. Transverse tensile test
3. **BS EN 895:** Destructive tests on welds in metallic materials. Transverse tensile test
4. **ISO 6892** – Tensile Testing of Metallic Materials
5. **ASTM D412** – Tensile Testing of Elastomers
6. **ISO 37** – Tensile Testing of Elastomers
7. **ASTM D638** – Tensile Testing of Plastics
8. **ISO 527-2** – Tensile Testing of Plastics
9. **ASTM A370 –** Standard Test Methods and Definitions for Mechanical Testing of Steel Products

4.2. COMPRESSION TEST

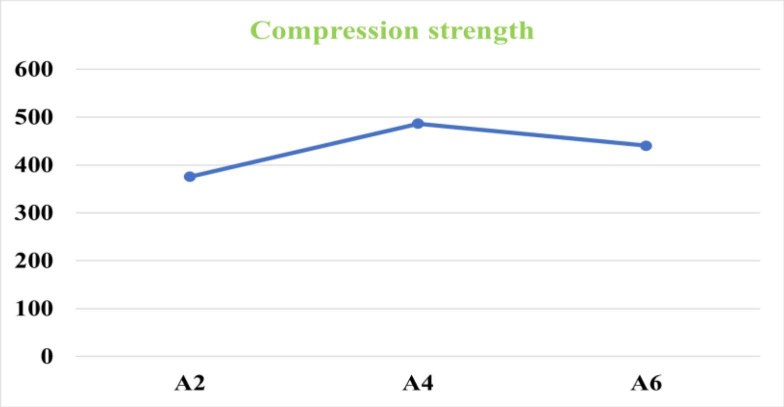
In compression testing, the sample or the component is compressed between two moving platens. A load cell and an extensometer or strain gauge are used to measure load and displacement. Compression tests are useful for testing material or component load-bearing capabilities under compressive loads. Compression pressure, for example, is taken into account in the design of tower structures, columns, bridge structures, and other load-bearing structures. The test is quite simple to conduct as well as the preparation of samples for testing. According to ASTM E9-09 solid cylindrical specimens of varying dimensions (short, medium, and long) can be used based on the availability of the sample materials.

Fig 15. Compression Test machine

AMMCs are potential materials for a wide variety of applications, such as aerospace, transportation, and defense due to their lightweight and excellent mechanical properties. Some of these applications, especially in aerospace and defense, the structural components are subjected to dynamic loadings such as bird hit or missile attack during their service life. Compression load conditions are encountered in structural sections such as fuselage/pressure cabin lower skin, upper wing skin stringers, and lower horizontal stabilizers of a typical aircraft. Compressive yield strength is the leading engineering property required for these aircraft applications. Not much literature reports the compressive response of AMMCs, and among the available literature on compression strength, most of them focus on the static mode, especially the axial-load compression testing and very few on the dynamic conditions.

S. No	Diameter	Length	Area A(mm^2)	Load(P) KN	Compression strength(N/mm^2)
A2	20	40	314.15	118	375.61
A4	19.48	39.5	298.03	145	486.52
A6	19.54	39	299.87	132	440.19

Table7. Compression Strength



Graph 2. Specimen vs Compression strength

4.3. IMPACT TEST

Toughness is, broadly, a measure of the amount of energy required to cause an item - a test piece or a bridge or a pressure vessel - to fracture and fail. The more energy that is required then the tougher the material. The area beneath a stress/strain curve produced from a tensile test is a measure of the toughness of the test piece under slow loading conditions. However, in the context of an impact test we are looking at notch toughness, a measure of the metal's resistance to brittle or fast fracture in the presence of a flaw or notch and fast loading conditions. It was during World War II that attention was focused on this property of 'notch toughness' due to the brittle fracture of all-welded Liberty ships, then being built in the USA. From this work the science of fracture toughness developed and gave rise to a range of tests used to characterize 'notch toughness' of which the Charpy-V test described in this article is one. There are two main forms of impact test, the Izod and the Charpy test. Both involve striking a standard specimen with a controlled weight pendulum travelling at a set speed. The amount of energy absorbed in fracturing the test piece is measured and this gives an indication of the notch toughness of the test material. These tests show that metals can be classified as being either 'brittle' or 'ductile'. A brittle metal will absorb a small amount of energy when impact tested, a tough ductile metal a large amount of energy. It should be emphasized that these tests are qualitative, the results can only be compared with each other or with a requirement in a specification - they cannot be used to calculate the fracture toughness of a weld or parent metal, such as would be needed to perform a fitness for service assessment. Fracture toughness tests that can be used in this way are covered in other Job

Knowledge article. The Izod test is rarely used these days for weld testing having been replaced by the Charpy test and will not be discussed further in this article. The Charpy specimen may be used with one of three different types of notch, a 'keyhole', a 'U' and a 'V'. The keyhole and U-notch are used for the testing of brittle materials such as cast iron and for the testing of plastics. The V-notch specimen is the specimen of choice for weld testing and is the one discussed here.

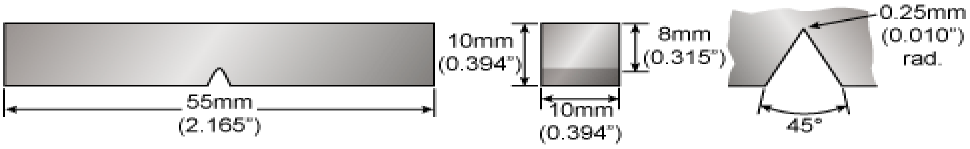


Fig 16. Standard Charpy-V notch specimen

To carry out the test the standard specimen is supported at its two ends on an anvil and struck on the opposite face to the notch by a pendulum. The specimen is fractured and the pendulum swings through, the height of the swing being a measure of the amount of energy absorbed in fracturing the specimen. Conventionally three specimens are tested at any one temperature.

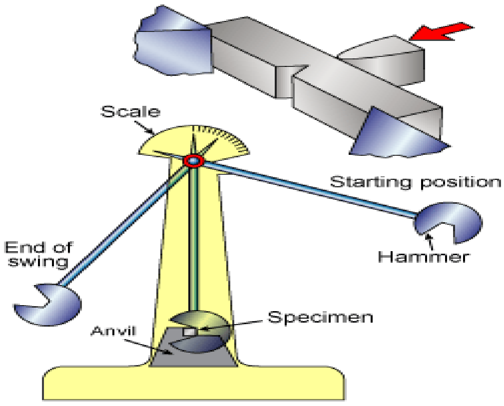


Fig 17. Charpy testing machine

Observations of impact testing machine;

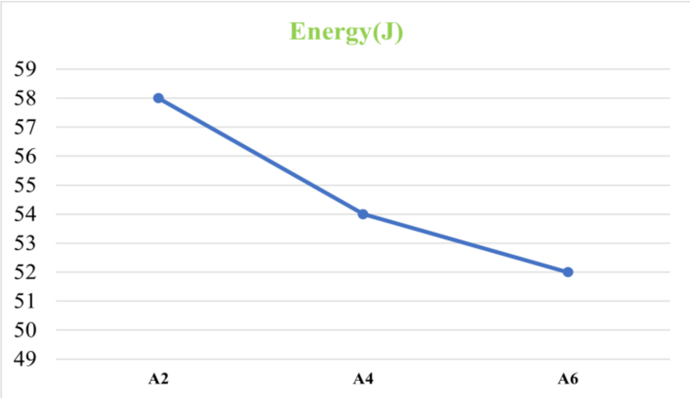
One division on scale = 2 joules

Charpy scale range = 0 – 300 joules

Angle drop of pendulum = 120^0

S. No	Material	Energy(j)
1	A2	58
2	A4	54
3	A6	52

Table 8. Impact Test



Graph 3. Specimen vs Energy

4.4. Hardness Test

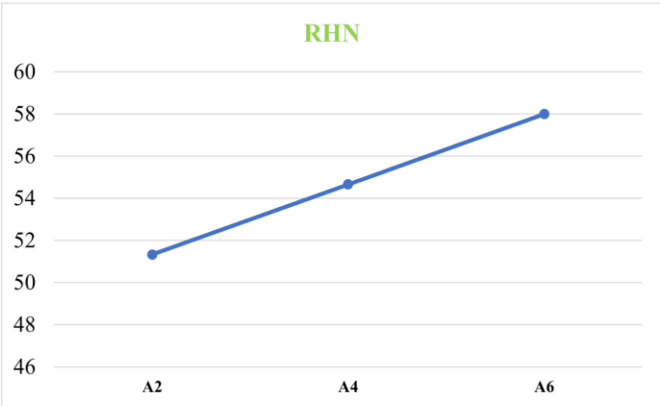
Heat treating has evolved into a highly complex, precise process that improves characteristics of metal parts. A critical component of quality heat treating is employing the correct hardness testing method to show manufacturers their parts achieve design requirements. Hardness testing methods vary based on the material and heat treatment chosen. It's important that engineers specify hardness testing methods correctly to ensure timely heat treatment and avoid costly delays. Common hardness testing methods are introduced below.

Fig18. Hardness Testing machine

Rockwell Hardness Test

Material	Load applied (kgf)	Reading on the indicator scale			Average RHN
		Trail 1	Trail 2	Trail 3	
A2	100	51	53	50	51.33
A4	100	56	55	53	54.66
A6	100	55	58	61	58

Table 9. Rockwell Hardness

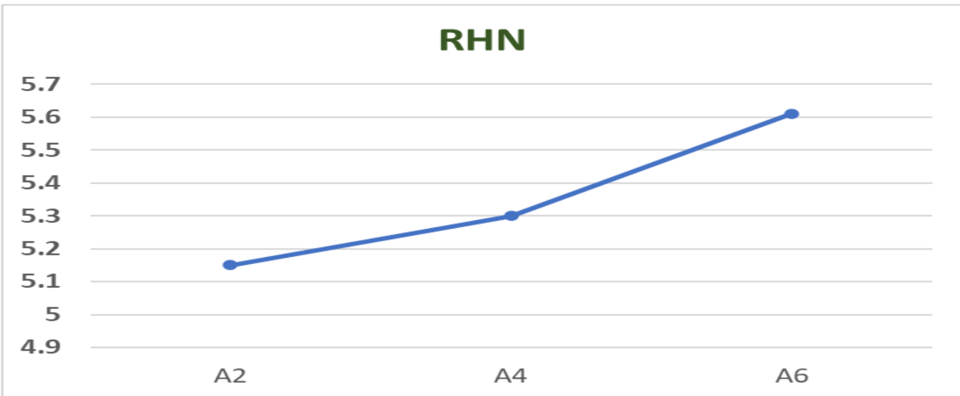


Graph 4. Specimen vs RHN

Brinell's hardness Test

Modules S. No	Indent diameter Trail 1	Indent diameter Trail 2	Indent diameter Trail 3	Average
A2	5.12	5.15	5.18	5.15
A4	5.24	5.29	5.36	5.3
A6	5.55	5.61	5.68	5.61

Table 10. Brinell's Hardness



Graph 5. Specimen vs RHN

CHAPTER 5

CONCLUSION

CONCLUSION

The fabrication of hybrid metal matrix composites reinforced with silicon carbide and graphite by stir casting method was completed successfully. According to the results,

- In Tensile test, we observed that as increasing the SiC percentage, the tensile strength increases gradually. We observe the highest strength in our investigation A6 specimen i.e., 247.69 KPa.
- In Compression test, we observed that as increasing the SiC percentage, the compression strength increases first and decreases gradually. We observe the highest strength in our investigation A4 specimen i.e., 486.52 N/mm^2.
- In Impact test, we observed that as increasing the SiC percentage, the energy decreases gradually. We observe the highest energy in our investigation A2 specimen i.e. 58 J.
- In Rockwell hardness test, we observed that as increasing the SiC percentage, the hardness value increases gradually. We observe the highest hardness value in our investigation A6 specimen i.e., 58.
- In Brinell hardness test, we observed that as increasing the SiC percentage, the hardness value increases gradually. We observe the highest hardness value in our investigation A6 specimen i.e., 5.61.

CHAPTER - 6

REFERENCE

[1] Ramesh CS, Keshava Murthy R, Channabasappa BH, Pramod S. Friction and wear behaviour of Ni–P coated Si3N4 reinforced Al6061 composites. Tribal Int 2001; 43(March (3)):623–34.

[2] Tjong SC, Tam KF. Mechanical and thermal expansion behaviour of hipped aluminum-TiB2 composites. Mater Chem. Phys 2006; 97(May (1)):91–7.

[3] William C, Harridan J. Commercial processing of metal matrix composites. Mater Sic Eng A 1998; 244(75):79.

[4] Kahlah F, Lajevardi A, Maghanaki HM. Effects of casting temperature on the microstructure and wear resistance of compost A356/Sic composites: a comparison between SS and SL routes. J Mater Process Technol 2004; 155–156:1874–80.

[5] Rosso M. Ceramic and metal matrix composites: routes and properties. J Mater Process Techno 2006; 175(June (1–3)):364–75.

[6] Seyed Reihani SM. Processing of squeeze cast Al6061-30 vol. % Sic composites and their characterization. Mater Des 2006; 27(3):216–22.

[7] Estrada-Guel I, Carreno-Gallardo C, Mendoza-Ruiz DC. Graphite nanoparticle dispersion in 7075 aluminum alloy by means of mechanical alloying. J Alloys Comp 2009; 483(August (1–2)):173–7.

[8] Habibur Rahmana Md, Mamun Al Rashedb HM. Characterization of silicon carbide reinforced aluminum matrix composites. In: 10th International Conference on Mechanical Engineering (ICME 2013). 2014. p. 103–9.

[9] Ramakoteswara Rao V, Ramanaiah N, Sacra MMM. Tribological properties of Aluminum Metal Matrix Composites (AA7075 Reinforced with Titanium Carbide (TiC) Particles). Int J Adv Sic Techno 2016; 88:13–26.

[10] M.Vamsi Krishna, Anthony. M. Xavier, An Investigation on the Mechanical Properties of Hybrid Metal Matrix Composites,12th Global Congress on Manufacturing and Management, (GCMM 2014), Procedia Engineering 97918 (2014) - 924, doi: 10.1016

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