

REVIEW ON DETERMINATION OF MECHANICAL PROPERTIES OF POLYMER MATRIX COMPOSITE MATERIAL AT HIGH TEMPERATURE AND CRYOGENIC ENVIRONMENT

A Project Report Phase – II

Submitted in partial fulfilment of requirements for the award of
Bachelor of Engineering degree in Aeronautical Engineering

by

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BONAFIDE CERTIFICATE

This is to certify that the Project Report is the Bonafide work **SANTHOSH KUMAR.S (39260032)** and **LINGESH.R (39260015)** who carried out the project entitled "**REVIEW ON DETERMINATION OF MECHANICAL PROPERTIES OF POLYMER MATRIX COMPOSITE AT HIGH TEMPERATURE AND CRYOGENIC ENVIRONMENT**" under my supervision from November 2022 to March 2023.

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We, **SANTHOSH KUMAR.S (39260032)** and **LINGESH .R (39260015)** hereby declare that the Project Report entitled "**REVIEW ON DETERMINATION OF MECHANICAL PROPERTIES OF POLYMER MATRIX COMPOSITE AT HIGH TEMPERATURE AND CRYOGENIC ENVIRONMENT**" done by us under the guidance of **Mr GOKULNATH .R M.E.**, Head of the Department, Department of Aeronautical Engineering, **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY, CHENNAI**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

DATE: 25.04.2023

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ABSTRACT

In today's trend, natural fibers have attracted the interest to engineers, researchers, professionals and scientists all over the world as an alternative reinforcement for fiber reinforced polymer composites, because of its superior properties such as high specific strength, low weight, low cost, fairly good mechanical properties, nonabrasive, eco-friendly and biodegradable characteristics. In this point of view, a brief review has been carried out to make use of natural fibers abundantly available in India. Glass FIBER Reinforced Polymers are mixing with natural fibers to increase Engineering and Technology applications. Due to their environmentally favourable features, Basalt and E-Glass fiber composites are gaining popularity these days. Artificial fibers could be replaced with natural fibers. Natural fibers are potential alternatives to artificial fibers. The Jute and E-Glass fiber reinforcement phase has a discontinuous shape. The features of composites are determined by factors such as fiber extraction, surface modification, and composite synthesis. To attain the needed strength, fiber length, orientation, concentration, dispersion, aspect ratios, matrix selection, and matrix chemistry must all be considered during synthesis. Due to their excellent strength/stiffness and lightweight, fiber-reinforced polymer composites (FRC) are widely used in a variety of applications

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LIST OF ABBREVIATIONS

MMC	Metal Matrix Composite
PMC	Polymer Matrix Composite
CMC	Ceramic Matrix Composite
FRP	Fiber Reinforce Polymer
BCF	Basalt Continuous Fiber
BSTF	Basalt Super Thin Fiber
CNG	Compressed Natural Gas
MPa	MegaPascal
GPa	GigaPascal
NFC	Nano Fibrillated Cellulose
MWCNT	Multiwalled Carbon NanoTubes
FRC	Fiber Reinforced Composite
ASTM	American Society of Testing Material
SEM	Scanning Electron Microscope
DSC	Differential Scanning Calorimetry
TGA	ThermoGracy metric Analysis
TMA	Thermal Machanical Analysis
WSM	Weighted Sum Method
AHP	Analytical Hierarchy Process
UTS	Ultimate Tensile Strength
UTM	Universal Testing Machine
NF	Natural Fiber
PLA	Polylactic acid
NFRPC	Natural Fiber Reinforced Composite
ILSS	Inter Laminar Shear Strength

RTM	Resin Transfer Moulding
EDS	Energy Dispersive X-ray Spectroscopy
VF	Volume Factor

CHAPTER 1 INTRODUCTION

1.1 PREFACES TO COMPOSITE

Two different substances one of which is the matrix phase and the other is the reinforcing phase combine to form a composite. Fibers, sheets, or particles could be used as reinforcement during this stage. As the matrix and reinforcing components, metal, ceramic, or polymer can be utilized. Commonly, the primary load-bearing elements of composites are composed of fiber or particle phases that are stiffer and stronger than the continuous matrix phases. The matrix acts as a medium for the transmission of loads between the FIBERS; under less ideal conditions, where the stresses are complex, the matrix may even need to support loads that are transverse to the axis of the FIBER. The matrix serves as a source of toughness for the composite since it is more ductile than the FIBERS. Prior to, during, and after the production of the composite, the matrix protects the FIBERS from environmental harm. The new composite material demonstrates more strength than each material alone when correctly constructed. Electrical, thermal, tribological, and environmental uses as well as its structural qualities make composites useful. The following are some of the reasons why the composites are selected for certain applications: high strength-to-weight ratio (low density, high tensile strength), enhanced creep resistance, High-temperature materials with high tensile strength, quite tough.

1.2 CHARACTERISTICS OF COMPOSITES

Composites are materials that are created by combining two or more different components in a way that produces a brand-new material with improved qualities. The following are some typical traits of composites: High Strength-to-Weight Ratio: Composites are frequently created to have a high strength-to-weight ratio, which means they are both strong and light. They are therefore perfect for industries like aerospace and automobiles where a concern for weight is present. Customizable: By adjusting the type, quantity, and orientation of the constituent materials, composites' qualities can be adjusted to fulfil particular needs. Corrosion and Chemical Resistance: Composites are frequently chemical and corrosion resistant, which makes them

perfect for usage in severe settings. **Good Durability:** Composites can be made to be strong, resistant to a variety of environmental factors, and exposed to various kinds of stress. **Versatility:** Composites are suitable for a variety of applications because they can be produced to take on a wide range of shapes and forms. Composites can also have high thermal and electrical insulation qualities, which makes them helpful in a variety of applications, such as electrical engineering and building. **Low Maintenance:** Because composites are resistant to corrosion and wear, they may require less maintenance than conventional materials like metals. Composites are beneficial in a multitude of sectors and applications because they generally provide a wide range of advantages over traditional materials.

1.3 COMPONENTS OF COMPOSITE MATERIAL

To create a new material with enhanced or distinctive features, composite materials are manufactured by mixing two or more existing materials, each with a separate set of properties. The matrix, which encloses and holds the reinforcing material in place in a composite, is one of the most prevalent components of composite materials. Polymers, metals, ceramics, or a combination of these materials are all possible. In addition to providing stiffness and toughness, the matrix material also resists outside forces. Reinforcement materials are typically fibers, particles, or flakes that are embedded in the matrix material to provide additional strength and stiffness. The most often used reinforcement materials are ceramic particles, glass FIBERS, and carbon FIBERS. At the interface, which is where the matrix and reinforcing materials collide, bonding occurs. The performance of the composite material as a whole depends on the interface quality because it impacts the stress transfer reinforcing components. In order to alter the physical properties of composite materials, fillers are added. They can be used to strengthen, lighten, or improve the conductivity of heat or electricity of the composite material. To facilitate processing, additives have been incorporated into the composite material. They can be used to speed up the curing process, decrease curing time, or increase flame retardancy of the composite material. different materials, each with a distinct set of qualities, are mixed to form composite components, which are made of a new material with distinctive attributes. These parts are frequently employed in manufacturing because they outperform components made of a single material in terms of strength, functionality, and longevity. The materials are

typically layered or mixed together in a specific pattern or ratio, and then bonded using heat, pressure, or adhesives.

1.3.1 MATRIX

Matrix refers to the substance that envelops and holds the reinforcing FIBERs together in composite materials. The matrix material is commonly a polymer, ceramic, or metal, while the FIBERs are normally formed of a strong, stiff substance like carbon, glass, or aramid. In composite materials, the matrix material performs a number of crucial tasks. It aids in the distribution of stresses evenly, the load transmission between the reinforcing FIBERs, the safeguarding of the FIBERs from harm, and the prevention of crack growth. The stiffness, strength, and toughness of the matrix material are significant characteristics that affect the composite material's overall performance. The specific application and the qualities that must be present in the composite material dictate the choice of matrix material.

1.3.2 REINFORCEMENT

Reinforcements are materials that are added to composite materials to enhance their mechanical qualities. FIBERs, which are often comprised of carbon, glass, or aramid, are the most widely used reinforcement materials in composites. A composite material is created by combining a matrix material and reinforcing FIBERs, and it has better mechanical properties than the component materials alone. Depending on the specific application and desired composite qualities, the choice of reinforcing and matrix materials is made. For instance, carbon FIBER reinforced composites are frequently used in aerospace applications that call for high strength and stiffness, whereas glass FIBER reinforced composites are frequently used in automotive and construction applications that place a premium on cost-effectiveness and durability.

1.3.3 INTERFACE

An interface in composite materials is the line or area where two different materials meet within the composite. The interface's characteristics may significantly affect the composite's overall performance. For instance, the strength, stiffness, and durability of a fiber-reinforced composite can be impacted by the interface between the FIBERs and the matrix material. The FIBERs may be unable to properly transfer stresses to

the matrix if the contact is weak, which could result in the composite failing sooner than expected. Therefore, one of the most important study areas for creating highperformance composites is enhancing the interface.

1.4 CLASSIFICATION OF COMPOSITES

1.4.1 BASED ON THE TYPES OF REINFORCEMENT

a) Fibrous composite

A material comprised of a polymer matrix reinforced with FIBERs is referred to as a fiberreinforced composite. Glass, carbon, or aramid are frequently used in the manufacture of the FIBERs. The matrix may be constructed from a range of polymers, such as thermosetting and thermoplastic resins. Combining these components can produce a material that is both stronger and lighter than conventional materials like metals. Sports equipment, automotive, construction, and aerospace are just a few of the industries that use fiber-reinforced composites. In areas where weight reduction is crucial, such as in racing automobiles and aircraft, they are very helpful.

b) Particulate composite

A particulate composite is a form of composite material in which tiny fillers or particles are distributed within a matrix material to improve its qualities. The matrix can be made of metal, polymer, or ceramic, and the particles can be any combination of sizes, shapes, and materials. Depending on the kind and concentration of the added particles, the matrix material's mechanical, thermal, electrical, or magnetic properties may be improved. For instance, adding carbon FIBERs to a polymer matrix can make it stiffer and stronger, while adding ceramic particles to a metal matrix can make it more resistant to wear. The matrix material can be a metal, polymer, ceramic or a combination of these. The particles can be made of a different material than the matrix, or they can be a modified form of the matrix material. The purpose of adding particles to the matrix is to improve the mechanical, thermal or electrical properties of the composite material.

1.4.2 BASED ON TYPES OF MATRIX MATERIAL

- Metal Matrix Composite (MMC)

- Polymer Matrix Composite (PMC)
- Ceramic Matrix Composite (CMC)

a) Metal Matrix Composite (MMC)

Metal matrix composites (MMCs) are cutting-edge materials made of a metal matrix reinforced by one or more additional constituents, like ceramic particles, FIBERs, or whiskers. The resulting substance is intended to possess qualities that are superior to those of the base metal, including heightened strength, stiffness, wear resistance, and thermal stability. When selecting the qualities of the MMC, the choice of reinforcing material and the volume fraction of reinforcement are crucial variables. As a reinforcement material, ceramic particles are frequently utilised because of their high strength, stiffness, and great thermal stability. Even stronger and more rigid FIBERs can be produced, however processing these FIBERs is more challenging. Typically, powder metallurgical processes like hot pressing or sintering are used to produce MMCs. In these processes, the metal matrix and reinforcement are mixed and then compressed under high pressure and temperature. A preform built of the reinforcement material can also be penetrated using a liquid metal as an alternative. Applications for MMCs are numerous and include the biomedical, automotive, and aerospace sectors. They are utilised in parts that need to be strong, rigid, and corrosion- and wear-resistant.

Engine components, prosthetic implants, and brake rotors are a few examples.

b) Ceramic Matrix Composite (CMC)

A composite material comprised of ceramic FIBERs encased in a ceramic matrix is known as a ceramic matrix composite (CMC). The CMC's strength and toughness come from its ceramic matrix, while its damage resistance comes from the FIBERs that reinforce the matrix.

Compared to other varieties of composite materials, CMCs have a variety of benefits. They can tolerate high temperatures and corrosive conditions, are incredibly lightweight, and have a high strength-to-weight ratio. They are perfect for use in industries like aeroplanes, automobiles, and industrial machines since they have a high level of wear and tear resistance. Working with CMCs can be difficult in part because of their manufacture process, which can be intricate and expensive. However,

improvements in manufacturing processes have resulted in the creation of more affordable production procedures for CMCs, increasing their applicability across a larger spectrum of industries. Due to their excellent thermal stability and strength, these composites are used in high-temperature applications including the aerospace and power generating industries.

c) Polymer Matrix Composite (PMC)

Polymer Matrix Modern life frequently includes composite materials, from gadget parts to a variety of automotive accessories. As suggested by their name, which means numerous repeating units, polymers are composed of carbon and hydrogen branches that have been chemically linked together to form a chain.

Polymers that are thermoplastic, thermosetting, or elastomeric are widely used as parts of composite materials. They are a source of a variety of affordable raw materials, which have various advantages, including as

There are several weaknesses, such rigidity and strength. Reinforcements are incorporated into polymer materials to improve their mechanical properties in order to make up for such shortcomings.

Polymeric matrix materials are the most widely used. For many structural applications, polymers' mechanical characteristics are generally insufficient. In comparison to metals and ceramics, they have poor strength and stiffness. By adding polymers to other materials, these issues are resolved. Second, manufacturing polymer matrix composites does not necessarily require high pressure or temperature. Additionally, the machinery needed to produce polymer matrix is much simpler.

For this reason, polymer matrix composites developed rapidly and soon became popular for structural applications. The two types are as follows:

d) Fiber Reinforced Composites

Fiber reinforced composites (FRCs) are materials made by combining a matrix material, such as resin or polymer, with reinforcing fibers, such as glass, carbon, or aramid fibers. The combination of these two materials results in a composite material that exhibits superior mechanical properties compared to the individual components.

The matrix material in FRCs provides a binding medium that holds the reinforcing fibers together, while the fibers themselves provide the material with strength, stiffness, and other mechanical properties. The matrix material can be selected to provide a specific set of properties, such as resistance to chemicals, heat, or impact, while the choice of reinforcing fibers determines the strength and stiffness of the composite.

FRCs are used in a variety of industries, including the aerospace, automotive, building, marine, and sports equipment. High strength-to-weight ratios, corrosion resistance, and fatigue resistance are all factors that are frequently taken into consideration while using them. FIBERglass, carbon FIBER reinforced polymers (CFRP), and composites reinforced with Kevlar are a few examples of FRCs that are frequently used. commonly consisting of a polymer matrix and reinforcing FIBERs that are commonly made of glass, carbon, or aramid, FIBER reinforced composites are a form of material. The FIBERs are incorporated into the matrix to increase the material's stiffness and strength. Aerospace, automotive, construction, and sports equipment are just a few of the industries that frequently use FIBER reinforced composites. They are renowned for their long lifespan, strong strength-to-weight ratio, and corrosion resistance.

The mechanical properties of fiber reinforced composites depend on several factors, including the type and orientation of the fibers, the type and composition of the matrix, and the manufacturing process used. Common methods of manufacturing fiber reinforced composites include hand layup, filament winding, and resin infusion. Overall, fiber reinforced composites offer a wide range of benefits and have proven to be a versatile and reliable material choice for many applications. To improve the production process, influence the unique features of composites, and/or lower the cost of the finished product, filler may occasionally be added. It has been intensively researched in a large number of research labs and professional organisations throughout the world whether FIBER Reinforced Polymer (FRP) reinforcements can be used in concrete structures as an alternative to steel bars or prestressing tendons. Natural FIBERs from sources including Sisal, banana, hemp, coconut coir, and pineapple leaf FIBER have already been employed in composite applications.

Because the plant's stem contains more cellulose than other parts of the plant, the FIBERs taken from it have higher mechanical characteristics and produce more. Research has recently focused on creating composite materials using novel types of FIBERs. In addition to using cellulosic FIBERs, several of the researchers have also pioneered the use of natural particles as reinforcements. It is possible to create new types of natural FIBERs and particles for use in polymer composites by combining the two, and there are research opportunities to do so. In this study, we analyse the various natural FIBER types and their function as reinforcement for the improved mechanical qualities. Also described here is the impact of particles acting as reinforcements to enhance mechanical characteristics.

e) Particle Reinforced Polymer

A particle reinforced composite (PRC) is a type of composite material that consists of a matrix material reinforced with particles. The particles can be made of a wide variety of materials, including metals, ceramics, and polymers. The matrix material is typically a polymer, metal, or ceramic.

The addition of particles to the matrix material can improve the mechanical properties of the composite, such as strength, stiffness, and toughness. The particles act as obstacles to crack propagation, which can increase the fracture toughness of the material.

A composite material known as a particle reinforced composite (PRC) is created when minute particles, often smaller than 100 micrometres in size, are added to a matrix material to improve its mechanical properties. The particles might be made of a material different from the matrix or they might be a tweaked version of the matrix substance. The particle concentration in a PRC can range from a few percent by volume to up to 50%, and the particles are typically equally distributed throughout the matrix.

A particle reinforced composite is a type of composite material in which small particles, typically ranging from nanometers to micrometers in size, are added to a matrix material to improve its properties. The particles can be made of a different material than the matrix, or they can be a modified form of the matrix material.

Due to its high strength, rigidity, and light weight, particle reinforced composites are employed in aircraft parts such the wings, fuselage, and engine components. Particularly in high-temperature applications like spacecraft and missiles, metal matrix composites are employed. To increase the strength, longevity, and crack resistance of building materials like concrete, particle reinforced composites are utilised. Polymer matrix composites are used in lightweight car body structures to improve fuel efficiency.

1.5 HYBRID COMPOSITE

A hybrid composite is a material composed of two or more different types of fibers or matrices that are combined to achieve specific properties. The combination of these different materials can result in a material that is stronger, stiffer, and more lightweight than its individual components. Hybrid composites can be made from a variety of materials, including carbon fiber, fiberglass, aramid fibers, and natural fibers like flax or hemp. They can also be made with different matrix materials, such as epoxy, polyester, or thermoplastics. The choice of fibers and matrices in a hybrid composite will depend on the specific properties that are required for the application. For example, a hybrid composite used in aerospace applications may be designed to be lightweight and strong, while a hybrid composite used in construction may be designed to be more durable and weather-resistant.

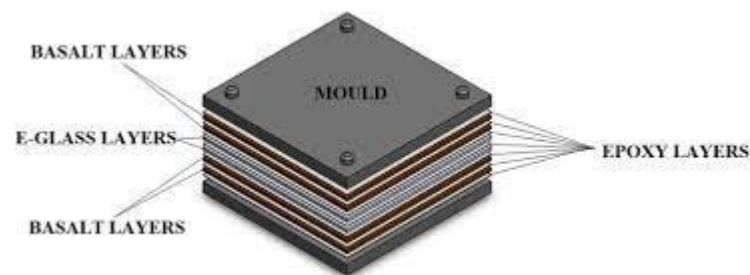


Fig.1.1 Structure of laminated hybrid composite

Glass FIBERs are initially utilised to prepare composite materials because of their lower cost than other synthetic FIBERs and excellent mechanical characteristics. because of the negative effects of synthetic FIBERs, such as their increased density, higher cost, nonbiodegradable nature, increased energy use, risk to human health, etc. Natural FIBERs are the subject of more study and industrial applications, though, as a result of their desirable advantages over synthetic FIBERs. These natural FIBERs

are widely accessible, inexpensive, recyclable, and biodegradable. The most often used plant sources of natural FIBERs for composites are jute, hemp, pineapple, sisal, ramie, abaca, banana, kenaf, bamboo, and other similar materials.

The advantages of natural FIBERs over synthetic ones are renewability, low density, availability, and cost. The main drawbacks of natural FIBERs are lower matrix adhesion and moisture absorption. The connection between the FIBER and matrix produces better mechanical qualities. If the link is strong, the composite ought to possess acceptable mechanical qualities. Some composite materials employ several FIBERs. Hybrid composites is the name for these substances. By stacking the FIBERs and matrix better, greater mechanical properties can be achieved.

As the FIBER content is increased, the mechanical qualities should also improve, but only until the FIBER content is less than the matrix's weight percentage. The composite's mechanical properties are improved by adding more FIBER to it. The form of the FIBER has an impact on the composites' mechanical characteristics as well. Natural fiberreinforced composite materials are not appropriate for outdoor application because of their propensity to absorb moisture.

The composite's mechanical properties are improved by adding more FIBER to it. The form of the FIBER has an impact on composites' mechanical properties as well. Natural FIBERs don't have as good of mechanical properties as synthetic FIBERs do. Hybridization is one technique for raising the mechanical qualities of composite materials reinforced with natural FIBERs. One of the most significant downsides of natural FIBERs is moisture absorption. Their capacity to absorb moisture increases as the proportion of natural FIBERs increases. Silane, NaOH, and infrequently even water can be used in chemical therapy to lessen it. The surface treatment affects the weight and diameter of the FIBERs.

1.5.1 ADVANTAGE OF HYBRID COMPOSITE

Hybrid composites offer several advantages over traditional materials, including:

- Improved strength and durability: By combining these fibers, the resulting composite material can have improved strength, stiffness, and durability compared to single-fiber composites.
- Tailored properties: With hybrid composites, designers can tailor the properties of the material to meet specific performance requirements. For example, by

combining different types of fibers, it's possible to create a composite that is both strong and lightweight, making it ideal for use in aerospace and automotive applications. Cost-effectiveness: Hybrid composites can be more cost-effective than using a single type of fiber. For example, it may be less expensive to combine a high-strength, high-cost fiber with a lower-cost, lower-strength fiber to create a composite material that meets performance requirements, rather than using only the high-cost fiber. Increased design flexibility: Hybrid composites offer designers increased flexibility in creating products with unique shapes and sizes. Greater control over the material's mechanical properties is made possible by the ability to blend several FIBER kinds, which can be useful for creating intricate structures. Hybrid composites are an appealing alternative for a variety of industries, including aerospace, automotive, and sporting goods, because to their benefits overall.

1.6 NATURAL FIBER

Natural FIBER reinforced polymers are growing in demand for theoretical research as well as practical applications. They are accessible, fully or partially recyclable, renewable, and biodegradable. There are also many plants, including cotton, hemp, flax, bananas, sisal, kenaf, pineapple, bamboo, and bamboo. Given that wood has long been a source of lignocellulosic FIBERS, it is used as the reinforcement in composite materials more frequently.

Bio-based polymer composites are becoming more and more well-liked because they are not only strong and affordable but also recyclable and biodegradable. Due to their biodegradability, combustibility, nontoxicity, Because they have well defined structures and come from renewable sources like plants and animals, natural FIBERS are FIBER polymeric composite materials that are referred to as "green" FIBERS.

Natural fibers have been used by humans for thousands of years and have many benefits. They are biodegradable, renewable, and generally require less energy to produce than synthetic fibers. Natural fibers can also be more breathable and comfortable to wear than synthetic fibers, making them a popular choice for clothing and textiles.

However, natural fibers can also have some drawbacks. They may be more prone to shrinkage, wrinkling, and fading than synthetic fibers, and some may require special care during washing and handling.

Natural FIBERS can be grown without the use of pesticides or hazardous chemicals because they are renewable resources. They do not cause environmental contamination and are biodegradable. Wearing clothes made of natural FIBERS is cosy and breathable. They draw moisture from the air and permit airflow, which lowers body warmth. Some natural FIBERS, like wool, have inherently antibacterial qualities that can aid in limiting the development of bacteria and fungi. People who have allergies or respiratory problems may benefit from this.



Fig.1.2. Natural fibers available for reinforcements.

Natural FIBERS are a material that is widely accessible and relatively simple to obtain. The advantages of NF-reinforced composites over composites composed of synthetic FIBERS appear to include for modern applications, natural FIBER composites (NF composites) are preferred to synthetic fiber-reinforced composites due to their economic and environmental advantages. Despite having differing compositions, all natural FIBERS have comparable structures. Due to these advantages, natural fibers are becoming increasingly popular in industries such as fashion, textiles, and construction.

They are also being used in the development of sustainable and eco-friendly products.

1.7 SYNTHETIC FIBER REINFORCED COMPOSITE

Synthetic fibers are man-made fibers that are produced from chemicals, often derived from petroleum. They are created through a process called polymerization, in which small molecules are combined to form long chains of polymers. Synthetic fibers are used in a wide range of applications, including clothing, textiles, and industrial materials.

Synthetic FIBERs and a polymer matrix combined together produce a material that is more robust and long-lasting than either material used alone. Composites reinforced with synthetic FIBERs also have high corrosion and fatigue resistance and are affordable. Many different industries, particularly automotive, aerospace, construction, and sports equipment, use these materials in a variety of ways. For instance, glass FIBER reinforced composites are frequently used in the construction business to strengthen concrete structures, whereas carbon FIBER reinforced composites are frequently utilised in the aerospace sector to make aircraft structures.



Fig.1.3 Synthetic fiber available for reinforcement

Glass, carbon, and boron-based synthetic FIBERs have grown in popularity during the past 20 years. The automotive and aerospace industries frequently use composites made of synthetic FIBERs to create products with high stiffness and strength. Due to environmental concerns, natural FIBERs are now replacing synthetic FIBERs as the reinforcing component in polymer composites used to make technological objects. Hybrid mixtures of synthetic and natural components are a frequent method for increasing the mechanical strength of polymer composites. The diversity of synthetic FIBER is less than that of natural FIBER.

Rayon is a synthetic fiber that is made from cellulose, a natural material found in plants. It is commonly used in clothing and textiles and is valued for its softness and draping

qualities. Acrylic is a synthetic fiber that is often used as a substitute for wool in clothing and textiles. It is lightweight, warm, and resistant to moths and mildew.

Synthetic fibers have a number of advantages over natural fibers, including their durability, versatility, and affordability. However, they also have some drawbacks, such as their reliance on non-renewable resources, their potential to release microplastics into the environment, and their lack of breathability.

1.8 BASALT FIBER

Basalt fiber is a type of fiber made from the natural volcanic rock known as basalt. The rock is melted down and then drawn into fibers using a process similar to that used to create fiberglass. Basalt fiber has several advantages over other types of fibers, including high strength and stiffness, excellent resistance to heat and chemicals, and good durability. It also has a lower density than many other types of fibers, which makes it attractive for use in lightweight composite materials. Basalt fiber is commonly used in the production of composite materials for the construction, automotive, aerospace, and marine industries. It can be used to create highperformance materials that are strong, lightweight, and resistant to damage from harsh environmental conditions.



Fig.1.4: Basalt Fiber

Basalt is melted, homogenised, and the FIBERs are extracted in a single step in the manufacturing of continuous basalt FIBERs. Basalt is heated just once. BCF is further

processed using "cold technologies" that use little to no energy to create materials. To create basalt FIBER, crushed basalt from a well-chosen quarry source is used. Basalt with a high silica content (over 46%) and a low iron level is preferable for the production of FIBER. Almost no materials are added while it is being manufactured, unlike other composites like glass FIBER. Before melting, basalt is just cleaned. To create basalt FIBER, the cleaned and crushed basalt rock must be heated at a temperature of roughly 1,500 °C (2,730 °F).

Basalt fiber is a type of fiber made from the natural volcanic rock, basalt. It is a high-performance material that offers a unique combination of strength, durability, and resistance to environmental factors such as moisture, UV light, and chemical exposure. The manufacturing process of basalt fiber involves melting the basalt rock at high temperatures, then extruding it through small nozzles to create fine fibers. \

Basalt fiber is known for its excellent mechanical properties, including high tensile strength, high modulus of elasticity, and good thermal stability. It is used in a wide range of applications, including construction, automotive, aerospace, marine, and sports equipment. Some of the advantages of basalt fiber over other traditional materials like steel or fiberglass include its lower weight, resistance to corrosion, and non-conductivity. Additionally, it is eco-friendly, as it is made from a naturally occurring material that is abundant and sustainable

1.8.1 CHEMICAL COMPOSITION OF BASALT FIBER

Table 1.1: Chemical properties of Basalt Fiber

Chemical components	Percentage by mass
SiO_2	51.6 - 59.3
Al_2O_3	14.6 - 18.3
CaO	5.9 - 9.4
MgO	3.0 - 5.3
$Na_2O + K_2O$	3.6 - 5.2
TiO_2	0.8 – 2.25

$Fe_2O_3 + FeO$	9.0 – 14.0
Others	0.09- 0.13

Table 1.1 displays the compositions of basalt FIBERs. In many aspects, the method utilised to create glass FIBERs is similar to how basalt FIBERs are formed, which is a continuous process. Basalt rock from quarries must be melted at a temperature of roughly 1400 °C (2500 °F) in order to produce basalt FIBER. The molten rock is then forced out of tiny nozzles to create the incredibly fine strands. Basalt fiber is a type of fiber made from basalt rock, which is a common volcanic rock. The process of producing basalt fiber involves melting the rock at high temperatures and then extruding it through small nozzles to create long, continuous fibers. Silica: Basalt rock contains high levels of silica, which is the primary component of the fibers. Silica is a naturally occurring mineral that is also found in sand and quartz. Alumina: Basalt rock also contains alumina, which is an oxide of aluminum. Alumina provides the fibers with increased strength and resistance to high temperatures. Calcium oxide: Calcium oxide, also known as lime, is another component of basalt rock. It helps to lower the melting temperature of the rock, making it easier to extrude the fibers. Magnesium oxide: Magnesium oxide is also present in basalt rock and helps to improve the thermal and mechanical properties of the fibers.

1.8.2 PROPERTIES OF BASALT FIBER

Table 1.2: Physical Properties of Basalt Fiber

Physical Properties	Value
Density (μm)	2.63 - 3.05
Tensile Strength (MPa)	3000 – 4840
Elastic Modulus (GPa)	79.3 - 110
Elongation at Break (%)	3.1 – 3.2
Maximum Service Temperature (°C)	650

1.8.3 APPLICATIONS OF BASALT FIBER

- the creation of industrial filters
- Basalt textile thermal barriers
- sporting and leisure items constructed of composite materials
- wind generator blades
- pipes with high pressure that can survive rusting
- A maritime application involves the production of surfboards, boat, yacht, and jet boat hulls, among other things.
- Cryogenics
- Production of reinforcements and composites.
- Insulation for pipelines and cables.
- Ballistics
- Thermal and dielectric insulation.
- Wind turbine blades, athletic goods, cars, boats, and civil engineering are just a few uses for basalt and its by-products.
- It can be employed because it is widely used in sound-insulating building components including tubes, bars, pipe fittings, internal heat and floors, walls, frame walls, boiler shells, tanks, chimneys and fire protection structures.
- Toyota automobile exhaust systems are made of heat-resistant basalt FIBER.
- The elastic power and modulus of basalt FIBER are 15% to 20% higher than those of other FIBERs.
- High-quality basalt roving, cloth, and cutting strands are used in the production of CNG cylinders, brake pads, mufflers, headliners, and other internal automotive components. Its products can be used to create protective coatings that are chemically and wear-resistant for tanks,

1.9 E- GLASS FIBER

Glass fiber reinforced composites (GFRP) are composite materials that consist of glass fibers embedded in a polymer matrix, such as epoxy or polyester. The mass production of glass FIBER was only made practical with the development of finer machine tooling, after centuries of experimentation with the material by glassmakers.

The material known as "glass wool," which is one of the items referred to as "FIBERglass" today, was created by Games Slayter of Owens-Illinois between 1932 and 1933 as a means of thermal building insulation. The trade name Fiberglas, a trademark that has been overused, is used to sell it. The distinctively air-filled low-density "glass wool" family of products is produced by carefully manufacturing glass FIBER with a bonding agent to trap many small air cells when it is used as a thermal insulating material.

Glass fiber's mechanical characteristics are similar to those of other FIBERs like carbon FIBER and polymers. GFRP composites are lightweight and strong, making them ideal for applications where weight is a critical factor, such as in aerospace, automotive, and marine industries. Table 1.3 illustrates these benefits.

Glass FIBERs are mostly employed as reinforcement for polymers. E-glass, highstrength (HS)-glass, and corrosion-resistant (CR)-glass are the three most popular forms of glass FIBERs. The first significant synthetic composite reinforcement, e-glass FIBERs, was first created for electrical insulation uses. Their affordability and rapid development when compared to other FIBERs are the main causes of this. Multifilament bundles are the product form of glass FIBERs. The sizes of the filaments range from 3 to 20 μ m.

When compared to other reinforcements, the elastic moduli of E-glass FIBERs are comparably low. E-glass FIBERs can also experience creep and creep (stress) rupture. HS-glass is stiffer and stronger than E-glass and has better resistance to fatigue and creep. Glass fiber-reinforced PMCs are frequently utilised as thermal and electrical insulators since glass FIBERs have low thermal and electrical conductivities. In comparison to most metals, glass FIBERs have a low CTE.



Fig.1.5: E-GLASS FIBER

Glass FIBER is produced by extruding silica-based or other glass formulation-based thin glass strands into small glass FIBERs with small diameters that are suitable for textile processing. Egypt and Venice both employed the technique of heating and drawing glass into fine FIBERs for thousands of years.

1.9.1 PROPERTIES OF E-GLASS FIBER

Glass FIBER is a term used to describe a material comprised of several tiny glass strands. The product is one of the most adaptable industrial materials available today. It possesses mechanical properties, just like other FIBERs like polymers and carbon FIBER. Numerous polymer combinations that include glass FIBER as a reinforcing component are used to create FIBERglass, a material that is exceptionally strong and lightweight.

Table 1.3: Physical properties of E-Glass Fiber

S.NO	Physical Properties	Value
1	Diameter (μm)	13
2	Density (g/cm^3)	2.54
3	Tensile strength (MPa)	3400 Mpa
4	Young's modulus (GPa)	76

5	Thermal Expansion($10^{-7}/^{\circ}\text{C}$)	54
6	Elongation at break (%)	2.75

1.9.2 APPLICATIONS OF E-GLASS FIBER

Industrial gaskets profit from an effective thermal barrier that materials with hightemperature insulation provide. FIBERglass is one of the materials that industrial gaskets are made of most frequently because it is sturdy, reliable, and offers superior thermal insulation. They contribute to enhanced insulation, energy efficiency, machinery protection, and professional worker safety in addition to helping to safeguard machinery. The following industries frequently use FIBERglass, perhaps because of this:

- **Electrical insulation:** E-glass fiber is widely used in the electrical industry to insulate wires, cables, and other electrical components. Its high dielectric strength and low dielectric constant make it an ideal material for insulating electrical equipment.
- **Composite materials:** E-glass fiber is often used as a reinforcing material in composite materials. When embedded in a resin matrix, it can provide strength, stiffness, and durability to the resulting composite product. E-glass fiberreinforced composites are used in a wide range of applications, including aerospace, automotive, marine, and construction.
- **Textiles:** E-glass fiber can also be used to produce textiles, including fabrics and yarns. These textiles are typically used in high-temperature applications, such as thermal insulation for furnaces and boilers.
- **Filtration:** E-glass fiber can be used as a filtration medium due to its ability to trap particles and contaminants. It is often used in air and water filtration systems.
- **Medical applications:** E-glass fiber is sometimes used in medical applications, such as in the production of surgical mesh and prosthetic devices.

- **Reinforcement in Composites:** E-glass fibers are widely used as a reinforcing material in composites due to their high strength and stiffness. They are used in a variety of applications, including automotive, aerospace, marine, and construction industries.
- **Electrical Insulation:** E-glass fibers are used as electrical insulation in electrical components such as circuit boards, transformers, and motors. They have excellent dielectric properties and can withstand high temperatures and electrical stress.
- **Thermal Insulation:** E-glass fibers are also used as thermal insulation in buildings and industrial applications. They have low thermal conductivity, which makes them an excellent insulating material.
- **Filtration:** E-glass fibers are used in various filtration applications due to their high porosity and small pore size. They are used in air filters, water filters, and oil filters.

These fibers are made by drawing molten glass through a small hole or spinneret, creating long, thin strands that are then woven or laid down in layers to create the final product. The main components of glass fiber are:

- **Glass filaments** - The glass filaments are the main component of glass fiber. These are made from various types of glass, such as E-glass, S-glass, or Cglass, which are chosen for their specific properties such as strength, durability, or chemical resistance.
- **Sizing** - Sizing is a chemical coating that is applied to the surface of the glass filaments to protect them during processing and handling. The sizing also provides a bonding surface for the resin that is used to form the final composite material.
- **Binder** - A binder is a material that is added to the glass fiber to help hold the fibers together during processing. The binder is typically a thermosetting resin, such as epoxy or polyester, which is cured to form a solid matrix that surrounds and binds the glass fibers together.
- **Coatings** - Coatings are sometimes applied to the surface of the glass fiber to provide additional protection or to improve its performance. For example, a

silicone coating may be applied to improve the fiber's resistance to heat, while a water-resistant coating may be applied to improve its resistance to moisture.

Due to its special qualities, such as strength, durability, and resistance to corrosion and fire, glass FIBER is a material with many uses in a variety of industries.

1.10 MATRIX MATERIAL

Although it is undeniably true that the high strength of composites is primarily attributable to FIBER reinforcement, the role of the matrix material cannot be understated because it supports the FIBERs and helps them sustain the stresses. Additionally, the composite material gains stability from it. Most often found in fiber-reinforced plastics, polymers are the most common matrix. The most prominent polymer-based composite materials, including carbon FIBER, FIBERglass, and kevlar, are typically made up of two components: the resin and the substrate. Roadways are typically constructed using asphalt concrete, which contains bitumen as its matrix. It has been widely used to build with mud or wattle and daub.

The main role of the matrix in a fiber-reinforced composite is:

- To hold the fibers together.
- To transfer stresses between the fibers.
- To provide a barrier against an adverse environment, such as chemicals and moisture.
- To protect the surface of the fibers from mechanical degradation.
- It binds the fiber reinforcement.
- It provides the composite component its shape and directs its surface quality.

1.10.1 EPOXY

Epoxy is a type of thermosetting polymer that is created by mixing two components: a resin and a hardener. When the two components are mixed together, they undergo a chemical reaction that results in a hard, strong, and durable material. Epoxy has a wide range of uses and can be used as an adhesive, a coating, or a composite material. Epoxy is known for its excellent bonding properties, as it can bond strongly to a variety of materials, including metals, plastics, wood, and concrete. It is also resistant

to water, chemicals, and heat, making it a popular choice for applications where durability is important, such as in construction, aerospace, automotive, and marine industries.

Table 1.4. Epoxy, polyesters, and vinyl esters are among the thermoset matrices that are frequently utilised in electrical, automotive, infrastructural, aerospace, and marine applications. Epoxy outperforms polyester in terms of mechanical qualities. Vinyl ester adheres well to many different types of FIBERs and other substrates. For the majority of engineering applications, epoxy works extremely well as a laminating resin and as an adhesive. It bonds to FIBERs incredibly well, making fiber-reinforced polymer composites possible.



Fig. 1.6: Epoxy resin and Epoxy hardner

Epoxy is available in different formulations, each designed for specific applications. For example, there are epoxy coatings that are used for flooring, and there are structural adhesives that are used for bonding metal parts. Epoxy can also be modified with fillers to give it specific properties, such as increased strength, improved adhesion, or increased flexibility. Epoxy is a type of thermosetting polymer that is known for its strong adhesive properties and resistance to heat and chemicals. Epoxy is typically made by mixing two components - a resin and a hardener - which react chemically to form a hard, rigid material.

Epoxy is commonly used as an adhesive for bonding materials like metal, glass, and ceramics, as well as for coating surfaces like floors, countertops, and walls. It is also used in a variety of industrial and commercial applications, such as in the manufacture of electronics, aerospace components, and structural composites.

One of the main advantages of epoxy is its high strength and durability. Epoxy can form strong bonds between different materials, and can resist a wide range of environmental conditions, including temperature extremes, moisture, and chemicals.

Additionally, epoxy is relatively easy to work with and can be formulated to have a range of properties, depending on the application.

Table 1.4: Properties of epoxy Resin

Matrix	Fiber	Vf	Temperature range, ΔT , K	Fiber residual stress, MPa	Matrix residual stress, MPa
Epoxy (High T cure)	T300 carbon	0.65	120	-19	36
Epoxy (Low T cure)	E glass	0.65	100	-15	28
Epoxy (Low T cure)	Kevlar-49	0.65	100	-16	30
Borosilicate Glass	T300 carbon	0.50	520	-93	93
CAS glass-ceramic	Nicalon SiC	0.40	1000	-186	124

1.10.2 APPLICATIONS OF EPOXY RESIN

- Excellent adhesion to different materials.
- Easy Processing.
- Good Adhesion to all types of fibers.
- Great strength, toughness and resistance.
- Low Shrinkage during cure.
- Good Strength and highly versatile.
- Thermosetting and Easy to apply.

CHAPTER 2

LITERATURE SURVEY

Agnivesh Kumar Sinha et al has put a lot of work into developing natural FIBER composites during the past ten years. This innovation made it possible for scientists and engineers to create natural FIBER composites (NFCs) with improved mechanical characteristics. The mechanical characteristics of composites reinforced with jute, abaca, coconut, kenaf, sisal, and bamboo FIBERs are the foundation of the current review. It is important to understand any NFC's suitability for a given application before choosing it, and this can be done by learning about its mechanical characteristics, including as its tensile, flexural, and impact strengths. This review study focuses on the elements that affect the mechanical characteristics of NFCs, such as the kind of matrix and FIBER, interfacial adhesion, and FIBER and matrix compatibility.

Ashothaman A et al Finding novel materials for use in the industrial and medical sectors is necessary for the environment to be sustained and the rate of environmental degradation to be slowed. Reduced environmental damage from harmful polymers is possible with the usage of biodegradable polymers. Because it has disadvantages over other polymers, such as a lower glass transition temperature, weaker heat stability, and lower impact resistance, polylactic acid (PLA), the most used ecological polymer, is not appropriate for high temperature applications. By incorporating reinforcements, materials can now be used in more biomedical and automotive applications while also exhibiting improved mechanical, thermal, wear, and corrosion behaviour.

Borrego L P et al Nanoparticle In order to enhance mechanical qualities, particularly the interlaminar strength, the reinforcing of the matrix in laminates has lately been investigated. The fatigue behaviour of glass/epoxy laminates improved with nanoclay and multiwalled carbon nanotubes is examined in this study. The epoxy resin Bersin CR120 and hardener CH120-3 were mixed to create the matrix. Utilised materials include organo-montmorillonite nanometre 130 E nonclay and multiwalled carbon nanotubes (MWCNTs) 98%. Vacuum moulding was used to create composite plates. Under both tension-tension and three points bending loadings, fatigue tests were conducted with constant amplitude. According to the results of the fatigue tests, composites with tiny amounts of nanoparticles added to the matrix must have a bend

fatigue strength comparable to that of a pristine glass FIBER reinforced epoxy matrix composite. The fatigue strength, on the other hand, tends to decline with higher additions of carbon nanotubes or nanoclays, which are factors in poor nanoparticle dispersion and agglomeration formation. A tiny number of particles added to the material has a minimal impact on its tensile fatigue strength. With the inclusion of multiwalled carbon nanotubes and nanoclays, the fatigue ratio under tension-tension loading increases, indicating that both nanoparticles may serve as inhibitors of the spread of fatigue cracks.

Sameer F Hamad et al Natural fiber-reinforced polymer composites have a number of advantages over traditional composite materials, including accessibility, affordability, light weight, and high specific mechanical characteristics. But because it's difficult to get a suitable interface between the FIBERs and matrix, there are presently only a few uses for these materials. Consequently, in For the creation of composites comprising FIBERs that have undergone plasma treatment, a fresh technique for creating mats from randomly arranged, short E-Glass FIBERs was created All composites had their flexural characteristics tested, and the fracture surfaces that resulted from those tests were examined using LV-SEM. According to the findings, the fiber-matrix interface and, as a result, the flexural properties of the composites are influenced by both plasma treatment and cure cycle conditions.

V. Mohanavel et al. Depending on the stacking order, the core layer's FIBERs may be made of jute or madar since they are placed perpendicular to the adjacent plies that surround it. As can be seen from the load versus deflection curves, stress and strain are linear, and all samples fail suddenly with the exception of the sample with a significant amount of madar FIBERs. Jute and madar FIBER layers gave the composites greater strain and toughness, whereas madar FIBER layers gave the composites greater strength and energy-absorbing capacity. Research revealed that the core and skin layers of glass FIBER composites with intercalation had a substantial impact on the samples' mechanical characteristics. Matrix and reinforcement compatibility may be seen in the morphology of the shattered samples.

Nirmal Kumar K. et al There are many applications for FIBER reinforced concrete (FRC). FIBERs are used in concrete cracks where a reduction in physical property protection, a decrease in drying, better strength and toughness, an extension of

service life, and a reduction in concrete permeability and construction value are required. the use of jute, a naturally occurring FIBER with higher mechanical efficiency, as reinforcement in a cement-supported matrix. The percentage of jute FIBER used in concrete ranged from 0.1% to 2%, and the fiber's length in concrete had an aspect ratio of 50mm to 60mm. Tensile strength, thaw resistance, impact resistance, and concrete brittleness can all be increased by introducing short FIBERs.

Borrego L P et al Nanoparticle Recently, efforts have been made to research ways to strengthen the matrix in laminates to enhance their mechanical qualities, particularly their interlaminar strength. This study examines how glass/epoxy laminates improved with nanoclay and multiwalled carbon nanotubes fatigue over time. Biresin_ CR120 epoxy resin and CH120-3 hardener were mixed to create the matrix. We employed organo-montmorillonite nanoclay with a diameter of 130 nm and multiwalled carbon nanotubes (MWCNTs) 98%. By moulding in a vacuum, composite plates were created. Three-point bending and tension-tension loadings were used in the fatigue tests, which were conducted with a constant amplitude. According to the results of the fatigue tests, composites with tiny amounts of nanoparticles added to the matrix must have a bend fatigue strength comparable to that of a pristine glass FIBER reinforced epoxy matrix composite.

Palanisamy Manjula et al This century has seen a rise in Consequently, a significant area of green composites is natural fiber-reinforced composites. This study's primary goal is to examine the impact of Jute FIBER reinforcement on epoxy composites with random orientation. The FIBER from sisal is plentiful, inexpensive, biodegradable, and strong. Using the proper methods, sisal FIBER is extracted from jute leaf, and the FIBER surface is changed using an alkali treatment with 5% NaOH solution. A matrix of epoxy is reinforced with pre-treated FIBER that is of a fixed length and volume. The hand lay-up method is used to create composites made of pure epoxy and Jute FIBER reinforcement. According to ASTM standards, the manufactured composites are tested. Examining the composite are tests for its tensile strength, compression strength, and water absorption. Pure epoxy is used as a comparison between the created composites' characteristics. In comparison to ordinary epoxy composites, experimental data demonstrate that fiber-reinforced composites had improved mechanical characteristics.

Jeyapragash R et al Among the numerous resources found in nature, natural FIBERs are one. They are cheap, efficient, and readily biodegradable and renewable. Many plant and animal resources can be used to extort it. In order to create natural-fiber composites, they are utilised as reinforcement materials in polymers. In this work, several natural FIBER materials and agricultural by-product particles are used to reinforce epoxy resin and compare its mechanical properties. This review aims to provide fundamental and background knowledge on natural FIBERs and their composites in order to spark fresh research initiatives and aid in the creation of a new range of polymer composites.

Tatara R.A et al One of the earliest methods of material processing is compression moulding. It was one of the first industrial processes for plastics and is also referred to as matching die moulding. When put under pressure, resin flows and liquefies, taking the form of the mould cavity before hardening into the final product. The part is taken from the mould once it has properly cooled and become sturdy. While cooling to room temperature, the curing procedure proceeds. Numerous rubbers and elastomers, as well as phenolic (phenol-formaldehyde), urea-formaldehyde, melamine-formaldehyde, vinyl ester, silicone, alkyds, and epoxy are examples of common resins.

Cavalcanti D.K.K. et al A new intralaminar natural FIBER hybrid composite was the subject of this study to determine how chemical treatments and hybridization affected its mechanical properties. The flexural characteristics of the jute-curau and jute-sisal composites were both affected favourably by the mixed (alkalization and silanization) treatment, but not in the same way.

Sathiyamurthy. S et al Improved mechanical physical properties were observed in hybrid fiber-polymer composites and fiber-reinforced particulate-impregnated polymer composites. Additionally, there are various benefits to using natural FIBER and agricultural byproducts as reinforcement materials in polymer composites, including waste material utilisation, non-toxicity and decomposability, low reinforcement cost, and good specific strength behaviour. The use of rice husk and boiled eggshell particles in a coir polymer composite was studied. In terms of tensile strength (31.5 MPa), flexural strength (33 MPa), and impact strength (43.5 kJ/m²), the hybrid reinforcement performed better than the component reinforcements. In recent

years, the majority of academics have advocated using natural particles in addition to natural FIBERs as reinforcements.

Venkateshwaran Swaminathan et al One of the significant research areas that is gaining recognition is fiber-reinforced concrete. FIBERs allow concrete to increase its tensile qualities without sacrificing its compressive strength.

Senthilkumar K. et al The development of environmentally friendly composite materials for use in a variety of industries, including the automotive, marine, chemical, infrastructure, sporting goods, and others, Other natural FIBERs include kenaf, jute, oil palm, cotton, flax, banana, and hemp. The fabrication of a wide variety of structural and non-structural industrial goods using various polymer matrices will heavily rely on sisal FIBER. Additionally, efforts have been made to look into how the mechanical properties of the hybrid configuration are affected by water absorption, chemical concentration, exposure period, filler weight percentage, and individual FIBER loading percentage. Overall, the goal of this review article was to investigate, highlight, and compile previously published studies that focused on the mechanical characteristics of sisal FIBER and its polymer composites in order to provide an ideal source of information and literature for conducting future research to reveal it as a construction and building material comparable to synthetic FIBERs.

Chandramohan D. et al an experiment on the creation of polymer bio-composites. To create hybrid composite specimens, bio epoxy resin is employed as reinforcement with powdered coconut shell, walnut shells, and rice husk. Each specimen has a 1:1 FIBER composition and a 10:1 resin to hardener ratio. The constructed composites were tested in accordance with ASTM standards to assess their mechanical qualities, including tensile strength, flexural strength, shear strength, and impact strength, both with and without moisture. The test's findings demonstrate that hybrid composites have much superior mechanical qualities over single FIBER glass reinforced composites. However, it has been discovered that adding FIBER from walnut and coconut shells can improve the characteristics.

Mohit Sood et al [14] Researchers in the field of composites have used FIBER treatments and coupling agents to enhance the performance of natural fiber-reinforced composites under flexural loads. The impact of FIBER treatments on the flexural strength and modulus of natural FIBER composites between 2000 and 2016 is

examined in this research. Chemical processes enhanced the adhesion of the FIBER to the matrix at the interface and increased the strength of composites. Additionally, combining substances improve flexural qualities, and the combination of therapies is equally snobby. Additionally, the detrimental effects of physical treatments on FIBER on the flexural characteristics of natural FIBER composites were examined. Finally, a number of angles have been finished in the hopes that our study may succeed in improving the flexural strength of natural FIBER composites going forward.

Navaranjan et al [15] This technique Recent years have seen an increase in the usage of various impact test techniques to gauge the impact resistance of natural FIBER composites (NFCs). Following an analysis of the literature, the impact resistance of composites made from flax, hemp, jute, wool, and jute FIBERs that was determined using various test techniques has been compared and analysed. It has come to light that the test procedures were chosen based on the research's potential, industry standards, or test-equipment availability. Every technique had benefits and drawbacks. One test's result could be compared to another test's result, but not the other way around. The majority of impact test techniques were created to evaluate the metals' transition from ductile to brittle.

Sanjay M R et al Because of their superior qualities, such as high specific strength, low weight, low cost, reasonably good mechanical properties, non-abrasive, ecofriendly, and biodegradable attributes, natural FIBERs have drawn the interest of engineers, researchers, professionals, and scientists from all over the world as a substitute reinforcement for FIBER reinforced polymer composites. To expand the use of engineering and technology, glass FIBER reinforced polymers are being blended with natural FIBERs. In this essay, the mechanical characteristics of composites made of natural FIBERs and glass FIBERs are reviewed.

M. K. Gupta et al compared the article's presentation of the mechanical characteristics of composites reinforced with hybrid FIBERs. Many benefits, including high strength, low density, and simplicity of production, come with fiber-reinforced polymer composites. In various industries, including aerospace, automotive, and construction, fiber-reinforced polymer composites are used. The construction of a hybrid composite results from the integration of two or more FIBERs into a single polymer matrix. In a single FIBER reinforced polymer composite, hybridization can

enhance the mechanical characteristics. This study demonstrates how adding comparable high elongation FIBERs increases the mechanical properties of natural fiber-reinforced polymer composites.

N. Saba et al is a flexible methodology that enhances the knowledge offered by more conventional thermal analysis methods including The increase in FIBER length and loading, but not in a geometric progression, had a menacing impact on the dynamic characteristics. Due to sound, storms, earthquakes, ocean waves, and live loads, dynamic loading conditions regularly cause civil infrastructure systems to fail. To improve the dependability, performance, comfort of buildings, and to lessen the risks associated with bridges, vibration damping parameters are of utmost relevance for structural applications. The viscoelastic performance of polymer sealants in various settings is also predicted by DMA in terms of the impacts of time and temperature. The current review article is intended to serve as an exhaustive source of information about the documented literature relating to the dynamic mechanical properties of natural FIBER reinforced polymer composites, hybrid, and nano composites, as well as their applications. For conducting additional research on this subject, this review article will offer the ideal information to examine its industrial application, especially as less expensive building and construction materials.

G. Hemath Kumar et al explains how much of India's production of rice husk, jute, stalk, bagasse, and coconut FIBER is done there. These all have outstanding physical and mechanical qualities, making it easier to incorporate them into the creation of composite materials for numerous industrial purposes. The current work focuses on how natural FIBERs affect a few mechanical parameters of epoxy composites. In this study, glass FIBER and natural FIBER (FIBERs made from cane sugar) were used to reinforce the epoxy resin matrix. Before reinforcing, the natural FIBERs underwent chemical processing. A hand layup technique was used to create the hybrid composites reinforced with chopped glass and cane sugar FIBERs. In this study, glass FIBER and natural FIBER (FIBERs made from cane sugar) were used to reinforce the epoxy resin matrix. Before reinforcing, the natural FIBERs underwent chemical processing.

Mehdi Kalantari et al This research presents The analytical hierarchy process

(AHP) was used to calculate the weighting factors for the weighted sum method (WSM), which was then employed to discover the best answer. Five distinct scenarios for the relative objective preferences were looked at as an example of the approach, and the corresponding best possible solutions were found.

Ashik K P et al In terms of technical applications and the scientific community, this study demonstrates the significance of natural FIBER reinforced composites, which is quickly growing. utilising static test techniques in accordance with ASTM standards. Epoxy is utilised as a matrix, together with coconut coir FIBER, glass FIBER, and reinforcement. Various volume fraction percentages are used while creating composites. The investigation's findings show that adding coconut coir to glass FIBER laminate can increase strength and be utilised as a replacement for glass FIBER reinforced composites.

Jagannatha T D et al This demonstrates the enormous potential of hybrid composite materials as an engineering material for a variety of applications. By choosing the right FIBERs and matrix, the designer of a hybrid polymer composite material has a significant number of options for obtaining the desired qualities. By selecting various FIBER types to be integrated in the same resin matrix, the qualities of the material can be customised. The present analysis looked at the mechanical characteristics of an epoxy hybrid composite reinforced with carbon and glass FIBERs. The production of hybrid composite materials was done using the hoover bagging technique. According to ASTM standards, the mechanical characteristics of the hybrid composites, including hardness, tensile strength, tensile modulus, ductility, and peak load, were assessed.

Mohammad ZR Khan et al The following FIBER parameters affect how well NFRPCs operate mechanically: FIBER loading, surface treatments, interfacial adhesion, FIBER orientation, physical and chemical qualities, etc. The method and environment used to manufacture the composite, together with process factors like the curing temperature and pressure, also have an impact on the mechanical qualities and overall effectiveness of NFRPCs. Tensile, compressive, impact, flexural, creep resistance, hardness, and other mechanical properties are used to characterise NFRPCs mechanically. The interfacial adhesion between the FIBER and matrix, FIBER strength, FIBER physical characteristics, FIBER volume fraction, FIBER

orientation and moisture uptake resistance, and material characteristics of the constituents are the key factors influencing these qualities.

Sanjay M R et al In order to expand their applications in the sphere of engineering and technology, natural/glass FIBER reinforced polymer composites have been developed. The current work focuses on recent advancements in hybrid natural FIBER reinforced polymer composites created using manual lay-up and compression moulding techniques. An overview of the findings on the inclusion of natural FIBER with glass FIBER reinforced polymer composites is being investigated in this study. It focuses attention on the physical and mechanical properties of hybrid composites and cites publications that are connected to this topic. Compared to natural/glass FIBER, hybrid composites comprised of two separate natural FIBERs and glass FIBER are less common, but they are seeing an increase in use.

Shaikh Shahid vakeel et al In order to produce a new class of hybrid composite, this initiative aims to blend natural and synthetic FIBERs. The synthetic FIBER reinforced composite has a high specific strength and outstanding mechanical qualities, but because to their higher overall production costs, they are exclusively employed in aircraft and military applications. It is also difficult to develop appropriate disposal methods for these materials. Due to a number of environmental concerns, recycling glass FIBER and disposal techniques have attracted a lot of attention. Natural FIBER is an exciting option that is currently the most often utilised FIBER in composite technology.

Venkateshwar Reddy C et al The primary objective of the study was to determine the effects of various filler materials on the interlaminar shear properties of glass/epoxy composite materials. For the high strength and stiffness applications in this investigation, SiO₂, TiO₂, and glass powder were the three filler materials utilised. The physical characteristics of the composites are also studied. The volume fraction of the material's FIBERs is important when making composite laminates. The conventional hand lay-up production method employed hot temperature cure and room temperature curing techniques depending on the resin system. The short beam shear test was used to assess interlaminar shear strength (ILSS).

Sicong Yu et al described as a preform-based RTM (Resin Transfer Moulding) technology, in which a liquid nonreactive resin with an intrinsically low viscosity is

pumped into the mould to infiltrate and moisten the preloaded preform after the solid curing agent has been preloaded onto the preform. With the separation of resin and hardener, naturally high viscosity resins were processed more easily. As a result, epoxies made from rosin that were typically considered to be inappropriate for liquid composite moulding were created.

Alessandro Fraleoni-Morgera et al The creation of effective thermal insulating materials is fueled by the rising demand for energy efficiency. Nano-composites, which offer both considerable energy savings and specific usage where thermal insulation must be combined with mechanical robustness and lightness, such as in automotive and aerospace applications, are an important class of materials that can achieve these needs. In view of recent developments, this study summarises the topic of polymerbased nano-composites for thermal insulation. The topic is started by giving a general review of the matrix-filler interface properties, the current thermal conductivity models, and mentioning the most prevalent categories of polymeric matrices. The main three types of polymer-based nano-composites for thermal insulation are then briefly described.

Sabari Narayanan g. e al The topic that is included in our project is concerned with the mechanical characterization of animal FIBERs (wool) utilised in the production of composite materials. The recycling potential of composite materials is a topic that is brought up by the use of wool FIBER. We offer wool composite material that is all-natural, of the finest quality, and environmentally beneficial. Hardness tests are used to determine a material's hardness. To evaluate a material's capacity for compression resistance, compression tests are used.

Sunil Kumar et al A prominent area of current study and development in the field of nanotechnology is polymer-based nanocomposites. The manufacturing methods and properties of polymer-based nanocomposite materials in a number of applications—including flammability resistance, electrical, electronic, mechanical, and fuel cell applications—are thoroughly discussed in this paper. The objective of this review is to provide a comprehensive source for current research in polymer matrix nanocomposites and applications in the mechanical, electrical, and electronics industries. Review of the mechanical and physical properties of conducting polymer

matrix nanocomposites for energy storage, field-effect transistors, field-emission supercapacitors, and nanodiodes.

Anindya Nag et al the development of composite materials and highly efficient graphene FIBERs for use in applications that track human activity. It explains how graphene FIBERs were produced and employed in a variety of applications for activity monitoring. Because of their exceptional mechanical and functional qualities for sensing applications, graphene FIBERs are important. Liquid crystals and graphite, among other carbon-based allotropes, were processed to produce these materials.

Since they are used to make a variety of invasive and non-invasive sensing prototypes in both their pure and composite forms, these FIBERs play a key role in the applications they are chosen for. Electrochemical, strain, and electrical sensing were used by these graphene fiber-based sensors to successfully detect even the tiniest changes in the input analyte.

The determination of mechanical properties of Polymer Matrix Composites (PMC) at high temperature and cryogenic environment has been extensively studied by researchers. In this literature survey, we will discuss some of the important works in this field.

"Mechanical Properties of Polymer Matrix Composites at High Temperatures" by S. Kim and J. Koo (Journal of Materials Science, 2014) - This paper focuses on the mechanical properties of PMC at high temperatures. The authors investigated the effect of temperature on the tensile strength, flexural strength, and compressive strength of PMC. The study showed that the properties of PMC are greatly affected by the temperature, and the compressive strength decreases with increasing temperature.

"Mechanical Properties of Polymer Matrix Composites Reinforced with Carbon Nanotubes at High Temperatures" by C. Wang and Y. Zhang (Journal of Reinforced Plastics and Composites, 2015) - This paper investigates the effect of carbon nanotubes on the mechanical properties of PMC at high temperatures. The authors found that the addition of carbon nanotubes improved the tensile strength, flexural strength, and impact strength of PMC at high temperatures.

"Effect of Fiber Orientation on the Mechanical Properties of Polymer Matrix Composites at Cryogenic Temperatures" by D. Zhang and X. Cao (Composites Science and Technology, 2017) - This paper investigates the effect of fiber orientation on the mechanical properties of PMC at cryogenic temperatures. The authors found that the mechanical properties of PMC are greatly affected by fiber orientation, and the tensile strength and flexural strength are highest when the fibers are aligned with the loading direction.

In conclusion, the mechanical properties of PMC at high temperature and cryogenic environment have been extensively studied by researchers. The results showed that the mechanical properties of PMC are greatly affected by the temperature and fiber orientation. The addition of carbon nanotubes and carbon fibers can improve the mechanical properties of PMC at high temperatures and cryogenic environments.

The first step in the fabrication process of carbon fiber is precursor preparation. The precursor is typically made from polyacrylonitrile (PAN) or rayon fibers, which are chemically treated to create long, continuous strands. The precursor fibers are then spun into yarns, which are wound onto bobbins for further processing.

The next step is stabilization, where the precursor fibers are heated in an oven to a temperature of around 200-300°C in the presence of oxygen. This process oxidizes the fibers, creating a cross-linked structure that stabilizes the fibers and prevents them from shrinking or melting during subsequent processing steps.

After stabilization, the fibers are carbonized by heating them to a temperature of around 1000-3000°C in a furnace in the absence of oxygen. This process removes all non-carbon atoms from the fibers, leaving behind a pure carbon material. The carbonization process is critical in determining the final properties of the carbon fiber, including its strength, stiffness, and thermal conductivity.

After carbonization, the carbon fibers are surface-treated to improve their adhesion properties. This involves applying a thin layer of sizing or coupling agent onto the surface of the fibers. Sizing is a chemical compound that improves the bonding between the carbon fibers and the matrix material, while a coupling agent is a chemical that helps to bond the carbon fibers with the resin matrix.

Once the carbon fibers have been prepared, they can be used for various applications, such as making composites. In the composite fabrication process, the carbon fibers are combined with a resin matrix to create a high-performance material. The resin matrix can be made from various materials such as epoxy, polyester, vinyl ester, or other polymers.

In conclusion, the fabrication process of carbon fiber involves several steps, including precursor preparation, spinning, stabilization, carbonization, and surface treatment. Each step is critical in determining the final properties of the carbon fiber, and careful control of the process parameters is required to produce high-quality carbon fiber. The resulting carbon fiber is a high-performance material with excellent strength, stiffness, and thermal conductivity, making it ideal for a wide range of applications.

CHAPTER 3

AIM AND SCOPE

The aim of determining the mechanical properties of Polymer Matrix Composites (PMC) at high temperatures and cryogenic environments is to understand how these materials behave under extreme conditions. This information is critical in the design and engineering of structures and components that will operate in these environments. At high temperatures, PMCs may experience thermal degradation and reduced mechanical strength, which can compromise their performance and safety. By studying their mechanical properties at high temperatures, engineers can design components that can withstand these conditions and ensure the longevity and reliability of the structure. On the other hand, at cryogenic temperatures, PMCs can become brittle and may exhibit reduced toughness and ductility. Overall, the determination of mechanical properties of PMC at high temperature and cryogenic environment is crucial in the development of new materials and structures for a wide range of industries, including aerospace, automotive, and energy.

3.1 PROBLEM IDENTIFICATION

- Jute and Ramie fiber reinforced composites have been used in industries as they are low strength and low modulus with high-cost applications.
- The Reinforcement of Jute and Ramie Fiber which exhibits discontinuous matrix form. It usually has more strength compared to the matrix phase.

- Improper fiber volume fraction and orientation of natural fiber with the addition of epoxy and hardener decreases the strength and stiffness of the specimen.

3.2 PROBLEM SOLUTION

- Basalt and E-Glass FIBER composites have recently gained popularity due to their high properties. This composite can be replaced with carbon fibers.
- Since epoxy resin is used, there is little shrinkage and good adhesion, and the in-plane shear strength and interlaminar shear strength are improved.
- The cost and weight of composites are reduced and analysed for specific applications such as being used in the automotive industry and for construction works.

CHAPTER 4

MATERIAL SELECTION AND FABRICATION

This chapter describes the details of processing of the composites and the experimental procedures followed for their mechanical characterization.

4.1 MATERIAL USED

1. Epoxy resin (LY-556)
2. Hardener (HY-951)
3. Synthetic fiber (Glass fiber cloth)
4. Natural fiber (Basalt fiber cloth)

4.1.1 EPOXY RESIN

Epoxy resin is a type of thermosetting polymer that is widely used as an adhesive, coating, and molding compound. It is composed of two components - a resin and a hardener - that are mixed together in a specific ratio to initiate a chemical reaction that results in a strong, durable, and rigid material. Epoxy resins are known for their excellent bonding properties and high mechanical strength, as well as their resistance

to moisture, chemicals, and heat. They are commonly used in the manufacturing of composites, such as fiberglass and carbon fiber, as well as in the construction of boats, airplanes, and other structural components.

Epoxy resins are also used in a variety of household applications, such as coatings for floors, countertops, and tabletops, as well as in the production of jewelry and crafts. However, it is important to note that epoxy resins can be hazardous if not used properly, and can cause skin irritation and respiratory problems if inhaled. It is important to follow all safety precautions and instructions when working with epoxy resin. An epoxy resin having the following outstanding properties has been used:

- Excellent adhesion to different materials
- High strength, toughness resistance
- Excellent resistance to chemical attack and moisture
- Excellent mechanical and electrical properties.
- Odorless, tasteless, and completely non-toxic.
- Negligible shrinkage.

4.1.2 HARDNER

In the present work Hardener (Araldite) HY 951 is used. This has a viscosity of 1020 poise at 250°C. The Araldite HY 951 Epoxy Hardener is mixed with epoxy resin for coating or encapsulating electronic components which work at low voltages. Hardner HY 951 is a curing agent commonly used in the manufacture of epoxy resins. It is a modified aliphatic amine that is known for its fast cure rate, low viscosity, and good chemical resistance. When used in combination with epoxy resins, it can produce tough, high-strength composite materials with excellent adhesive properties.

Hardner HY 951 is often used in applications such as coatings, adhesives, and composites in industries such as aerospace, automotive, and construction. It is important to handle this chemical with care and follow all safety precautions and guidelines provided by the manufacturer.

4.2 HAND LAYUP PROCESS

Hand layup process is a manufacturing technique used to create composite materials by laying fiber reinforcement materials, such as carbon fiber or fiberglass, onto a mold by hand. The process involves the following steps:

1. Prepare the mold: The mold is first cleaned and coated with a release agent to prevent the composite material from sticking to it.
2. Cut the reinforcement material: The fiber reinforcement material is cut into the desired shape and size.
3. Mix the resin: The resin, which serves as a bonding agent, is mixed according to the manufacturer's instructions.
4. Apply the resin: The resin is then applied to the mold using a brush or roller.
5. Lay the reinforcement material: The cut reinforcement material is then laid onto the resin-covered mold, ensuring that there are no air pockets.
6. Apply more resin: More resin is then applied over the reinforcement material until it is fully saturated.
7. Consolidate the composite: The composite is then consolidated by using rollers or brushes to remove any excess resin and to ensure that the reinforcement material is fully embedded in the resin.
8. Allow to cure: The composite is then allowed to cure according to the manufacturer's instructions.
9. Demold: Once the composite has cured, it can be demolded and trimmed to the desired shape and size.

Hand layup is a versatile process that can be used to create a wide range of composite products, from small parts to large structures. However, it is a labourintensive process that requires skilled workers and can be time-consuming.

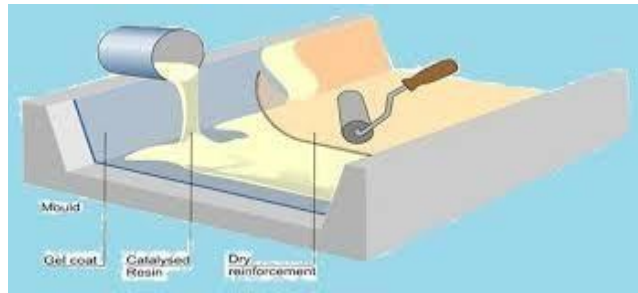


Fig.4.1: Hand-Layup process

4.2.1 MATERIAL REQUIRED

4.2.1.1 MOULD

The various composite materials are made using the hand lay-up method. The mould for making composite materials is two rectangular sheets of mild steel that have had their chromium coating removed. Four beadings were utilised to preserve the 5 mm thickness of the mould plates. These plates cover the composite parts while they are curing, compress the FIBER after epoxy application, and keep debris out of the composite sections.

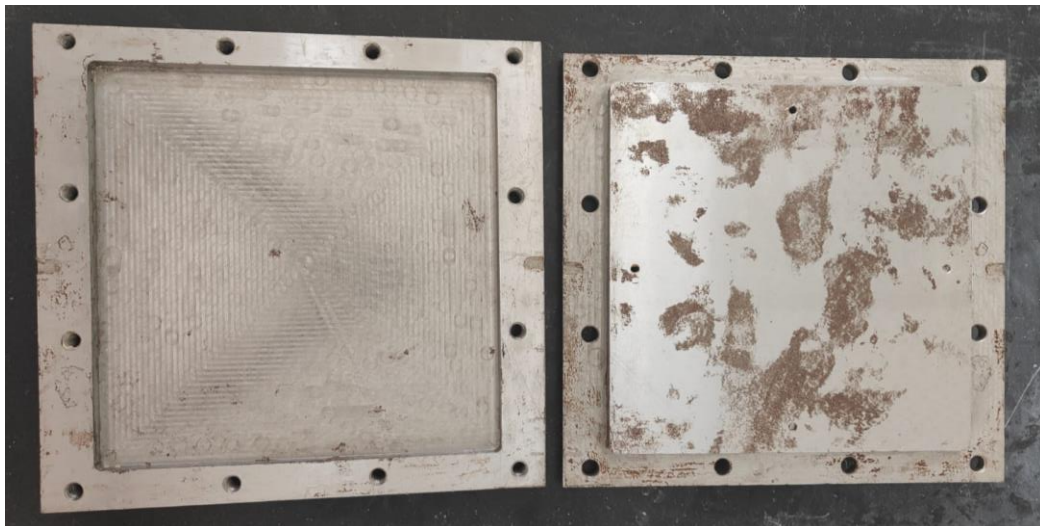


Fig.4.2: Mould used for process

In order to position the layer in or on and produce the correct shape, a mould is typically needed when using the lay-up process to create parts. In this lab, a tabletop will be used instead of a mould to hold the flat shape of the layup.

4.2.1.2 RELEASING AGENT

prevents resin from adhering to the mould. To serve as the releasing agent in this experiment, plastic sheeting will be placed over the surface. certain more releasing agents employed in industry are;

- Waxes
- spray releases
- release films
- internal releases (added to gel coat or resin system).

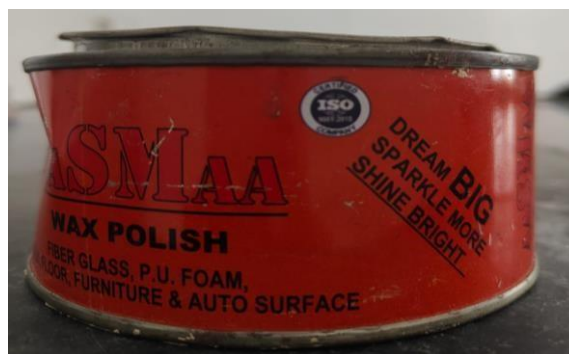


Fig.4.3: Wax

4.2.1.3 RESIN

In order to 'glue' the materials together and transfer component stresses to the composite's FIBERs, the resin acts as the matrix for the material. The FIBERs are selected and created to bear the desired stresses. This experiment will use a two-part epoxy and hardener resin system. Various speed (set up time) hardeners may be used, depending on the needs of the project. Here are a few resins that are frequently employed in industry:

- Unsaturated polyesters
- Specialty and High-performance Thermosets (vinyl esters)
- Epoxies



Fig.4.4: PVA

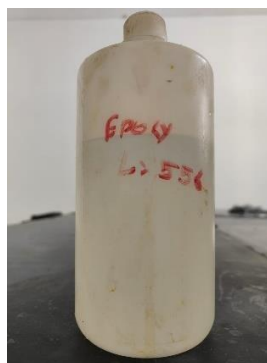


Fig.4.5: Epoxy

4.5.a CARBON NANO TUBES



CNT

Carbon nanotubes (CNTs) are hollow tubes of single-layer graphene (an allotrope of carbon) that possess extremely beneficial nanotechnology properties. Here an sp^2 -bonded atomic-scale hexagon-like structure results in making a stronger carbon structure. Its structure is similar to that of fullerenes and, when spread out, looks like a honeycomb lattice. The size and shape of the carbon nanotubes alter, which is dependent upon the type of CNTs. Typically, its size varies from 1 nanometer to 100-200 nanometers in diameters, and it can be infinite in length, with an average length of 1000 nanometers.

Another name for carbon nanotubes is buckytubes. Researches promise that the buckytubes are more substantial than any materials in the world. There are three ways to produce this product: arc discharge, laser ablation of graphite, and chemical vapor deposition (CVD). We manufacture it by the catalytic chemical vapor deposition (CVD) method. We offer the CNTs powder in 1, 5, 10, and 25 grams, or our client's requirements. At Techinstro, researchers can request to customize the products per their requirements.

Properties of Carbon Nanotubes.

- **Electrical conductivity:** The CNTs have high electrical conductivity. However, this varies considering the types of it. The SWCNTs exhibit better conducting electricity. When the nanotube's walls increase from single to double and multiple,

the rate of conduction falls. The Multi-walled Carbon Nanotubes are semiconductors.

- Higher resistance to chemicals: The allotrope of sp^2 -hybridized carbon makes the product highly resistant to chemicals.
- Lightweight and strength: It consists of graphene as its primary compound; it is light in weight. However, the structure makes composite strong; hence, it is one of the most robust materials and can sustain damages from higher physical forces.
- Heat insulation: It showcases higher thermal conductivity; therefore, suitable for instruments or gadgets that tend to heat faster. It acts as an excellent insulator and creates a barrier that does not let the devices heat up.

Carbon Nanotubes Applications.

- Chemical Applications – It is helpful in gas sensors as it is sensitive to gases such as H_2 , NO_2 , O_2 , or NH_3 , dielectrics. It is also beneficial in field-emission displays and photovoltaics. It also acts as unique catalyst support in chemical processes.
- Fibers and Fabrics – Displaying immense strength helps make bulletproof vests and armors, transmission line cables, stain-resistant fabrics, etc.
- Composite of Structures – It displays excellent mechanical properties such as toughness, strength, and stiffness. It is used in various compositions of various structures such as wind turbines, marine paints, composite polymers, and many more.
- Energy – It helps make another energy powerhouse, field-effect transistors, solar cells, reusable batteries, electrical wires, and cables.
- Biomedical Application – Other biomedical processes benefit from this technology, such as Cancer Treatment, Hip Replacement, Gene Therapy, Tissue engineering, Drug Delivery, and many more.
- Aviation and Automobile Applications – It is lightweight, making parts for rockets, airplanes, and a vehicle body, tires, handlebars, seats, aero bars, and coating of all types.
- Like graphene sheets, the CNTs sheet has been manufactured through the same process. This sheet of carbon is generally made of MWCNTs.

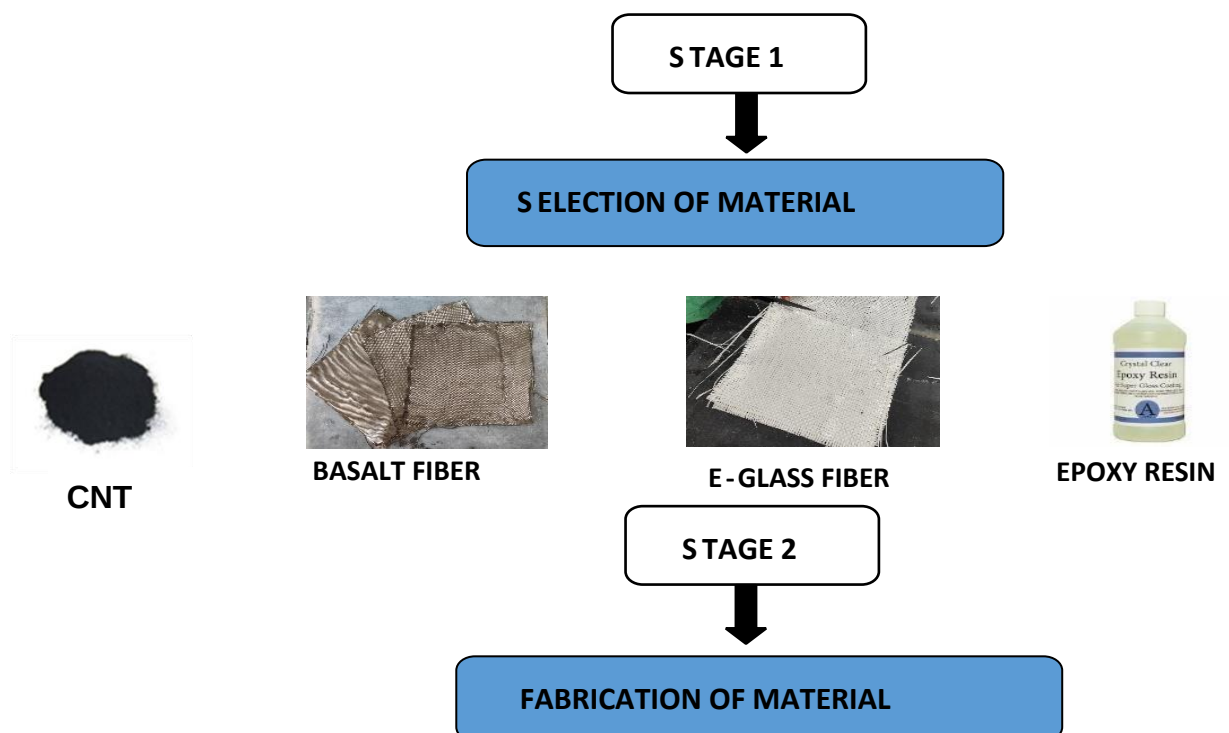
- Use in carbon conductive ink, which is entirely nanotube-based.

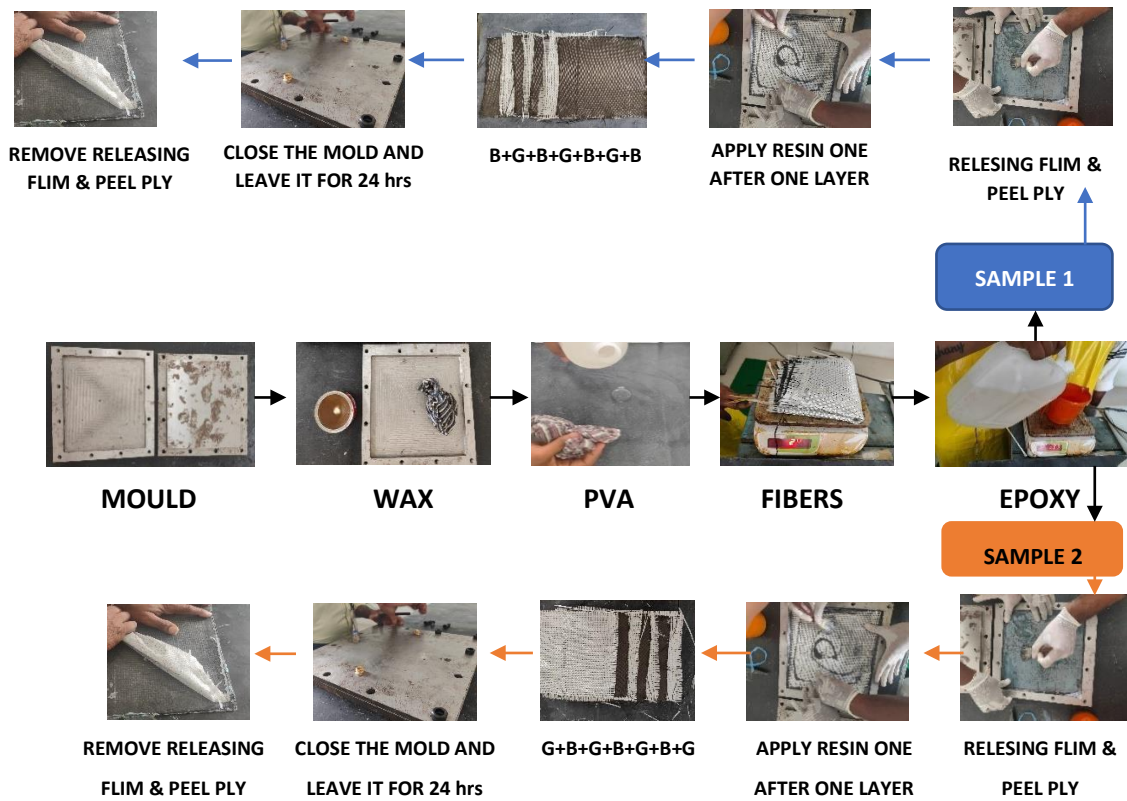
4.2.1.4 REINFORCING FIBER

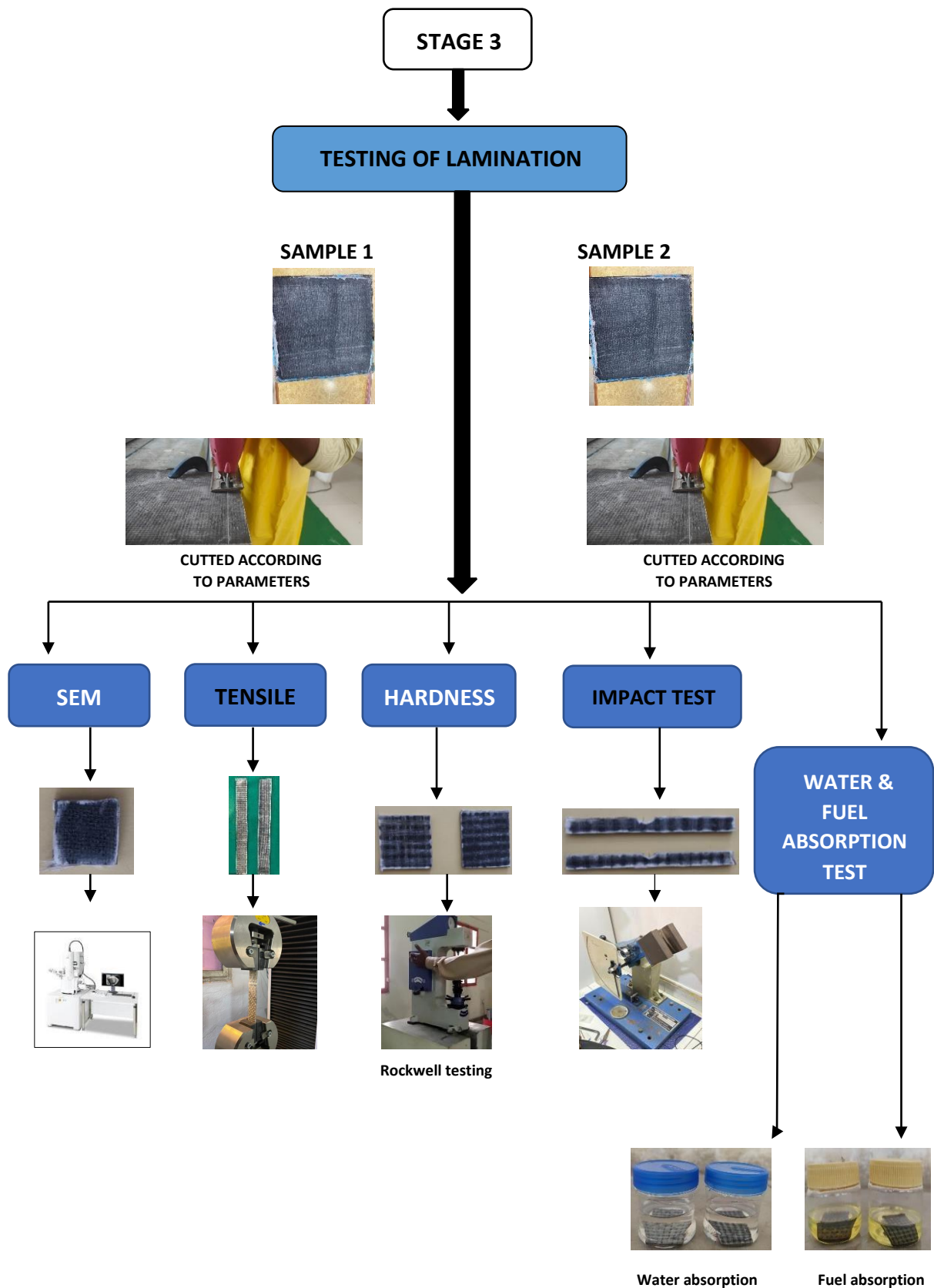
There are numerous FIBERs that can be used to create composites, and each material is available in a range of shapes. These two design-optional variables, which are both crucial in the selection of materials, are available based on the design constraints of the finished product. The reinforcing FIBERs used in this experiment are pieces of clothes and paper cards. Other reinforcing FIBERs include:

The type of reinforcing fiber used depends on the desired mechanical properties of the final product, as well as factors such as cost and availability. For example, carbon fibers are often used in aerospace applications where high strength and stiffness are required, while glass fibers are commonly used in construction for their low cost and good performance.

4.3 METHODOLOGY







4.4 EXPERIMENTAL PROCEDURE

4.4.1 WORK PREPARATION

Hand layup is a common process for fabricating composite parts. The following is a general experimental procedure for the hand layup process:

- Composite material (such as fiberglass or carbon fiber)
- Resin system (such as epoxy or polyester resin)
- Mold or tool
- Release agent (if required)
- Mixing cups and stir sticks
- Gloves and safety glasses

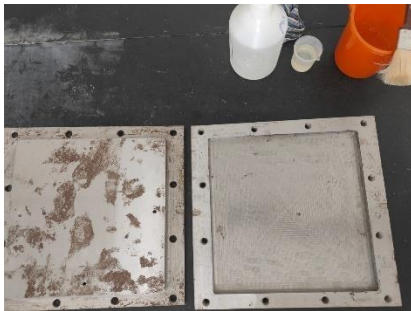


Fig.4.6: Prepared Mould



Fig.4.7: Measuring weight of fiber



Fig.4.8 Epoxy



Fig.4.9 Fibers to make sample

4.4.2 MOULD PREPARATION

The mould needs to be properly ready before starting the lay-up process. The key elements of this preparation include washing the mould and applying a release agent

to its surface to stop glue from sticking. In this experiment, we prepare the mould by simply taping the plastic sheeting to the tabletop. To get rid of the mould instead, do the following:

- Clean the mould with a clean cloth
- Apply and spread release agent in the surface of the mould
- Wait certain to set up the release agent
- Buff with clean cloth



Fig.4.10: Wax applied on mould

4.4.3 LAYUP PROCESS

The initial procedure involves mixing the resin and hardener. On the resin or hardener container, the ratios are frequently indicated by the provider. Care must be used when combining with the mixing stick in the mixing containers to prevent overadding air bubbles to the resin. To prepare for application, carefully blend for two minutes. An object with a "flat" surface, such as a tongue depressor, works well; a circular object does not work well since it cannot effectively "paddle" the mixture to blend it.

Because plastic containers could melt during the exothermic reaction, it is advised to use ones made specifically for mixing epoxy resin. The proper volume of combined resin and hardener is then added to the mould, and it is spread uniformly using a brush or roller. The entire surface is then reinforced with pieces of paper and card. It's critical to avoid either adding too much resin, which could leave holes on the surface of the item once it cures, or too little resin, which could provide a covering that is too thin.

The initial stage is to lay the release film, after which resin is loaded (1:2) into each layer, the next layer is peel ply, and so on until the fiber's surface is perfectly smooth and finished. The initial layer of FIBER reinforcement is then applied.

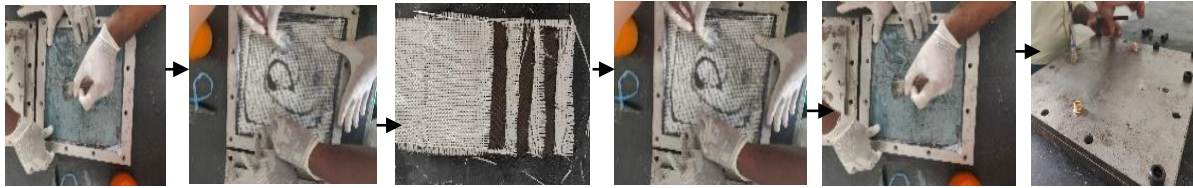


Fig.4.11: Hand-layup process of sample

At this point, adding a second layer of Basalt FIBER necessitates special care to guarantee that there are no air bubbles left. This can be accomplished by either rolling out any air bubbles with a small hand rolling tool or brushing out any air bubbles with a paintbrush. Continue doing this until the necessary 5mm thickness is obtained. Both samples 1 and 2 are constructed of four layers of glass FIBER, three layers of basalt FIBER, and two layers of glass FIBER. Above and below the seven layers, a layer of peel ply and a layer of releasing film are positioned.



Fig.4.12: (a) Schematic diagram of Basalt –GFRP composite is prepared by replacing intermediate layers (b) Schematic diagram of GFRP-Basalt the composite is prepared by replacing intermediate layers.

When the individual glass FIBER layers are combined to create laminates and overall part thickness, they may be oriented at various angles to provide a

predetermined strength in the direction of the reinforcing weave; this is referred to as "clocking." A cover sheet of plastic may occasionally be laid over the layup when more reinforcing layers are stacked on top of one another to reduce mess and squeeze out surplus resin. The remaining resin in the cup must be placed on and in an area where there is nothing combustible after the proper amount of resin has been used for the layup, such as a concrete washbasin or slab.

Table.4.1: Material Proportion

Sample	Natural Fiber (Basalt Fiber) (g)	Glass Fiber (EGlass Fiber) (g)	Epoxy Resin(ml)	Hardener (ml)
1	100	100	200	50
2	100	100	200	50

The plate was removed with the help of a chisel and hammer. The final output of the moulded plate is shown in Fig.4.13

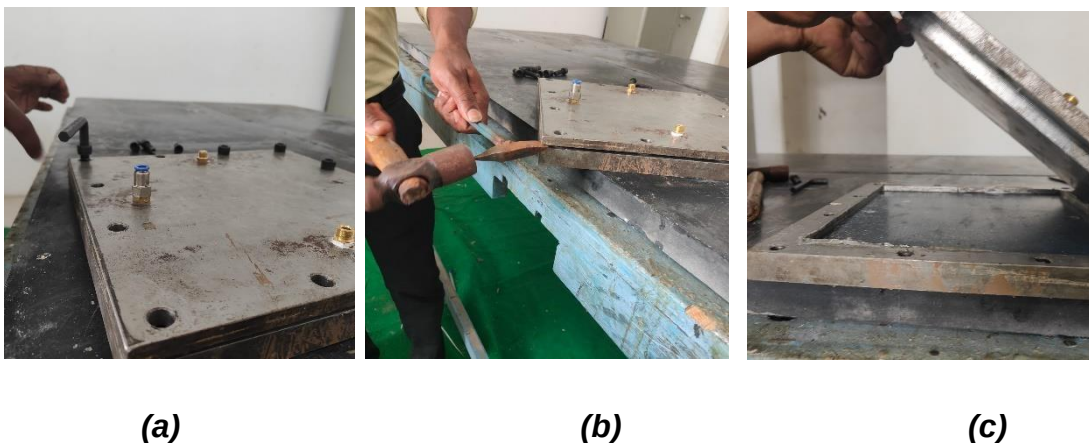


Fig.4.13: (a) opening of the mould using allen key (b) By using the hammer and chisel (c) opened mould.



(a)



(b)

Fig.4.14: (a) Sample 1 glass-Basalt fiber reinforced Composite (b) Sample 2 Basalt-glass fiber composite.

4.4.4 CURING

The component can be dried out in an oven at a higher temperature or at room temperature. On the back of the containers, the supplier will typically write the working time and necessary curing time for each type of resin-hardener. Both the experiment's usage of epoxy resin and room temperature drying are appropriate.

4.4.5 CLEANING

The component must be transported to the proper location for curing once it is ready to be finished. This can either be done by transferring it to a curing oven or by leaving it where it is till the following day. A cleaning is then required. Cleaning the table with acetone and cloth is necessary before using any of the instruments (brushes, rollers, mixing tools, or scissor).

4.5 TESTING METHOD

4.5.1 SCANNING ELECTRON MICROSCOPY TEST

SEM stands for scanning electron microscope. The SEM is a type of microscope that uses electrons rather than light to produce pictures. The scanning electron microscope

has many advantages over regular microscopes. Focusing on more of a specimen at once is feasible thanks to the SEM's wide depth of field. Small specimens can be efficiently expanded because the SEM has a noticeably superior resolution. 3 cm × 3 cm is the measurement used to perform SEM on the samples.

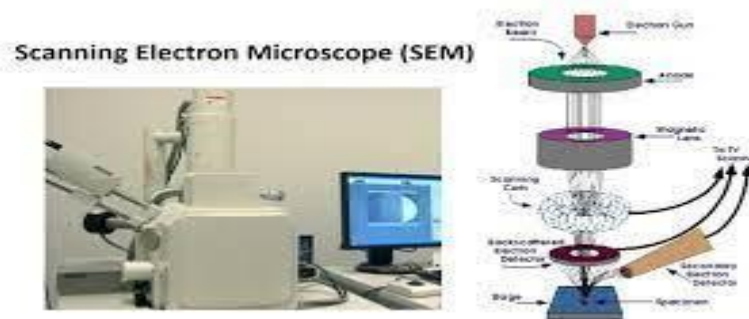


Fig.4.15: Scanning electron Microscope

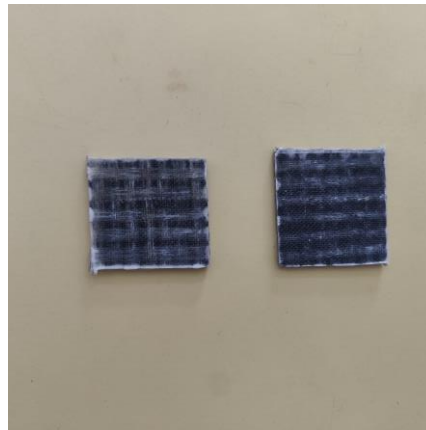


Fig.4.16:Glass/Basalt and Basalt/Glass Sample for SEM

4.5.2 IMPACT TEST

Impact testing is an important method to assess the mechanical properties of composite materials. The impact behavior of composite materials is influenced by several factors such as the type and volume fraction of reinforcement, the type and properties of the matrix material, the fabrication process, and the test conditions. The Impact test is shown in Fig.4.17

Izod impact test: This test is similar to the Charpy test, but the specimen is not notched. Instead, a V-shaped groove is cut into one side of the specimen, and the hammer

strikes the uncut side. The energy absorbed by the specimen is measured and used to determine its toughness



Fig.4.17: Impact Test Setup

Casing diameter, wall thickness, casing material properties, and environmental temperature are taken into consideration when assessing the appropriate casing to be used in a given situation. ASTM D256 Standard. The result is usually reported as the energy in J required to fracture the test piece is shown in Fig.4.18.

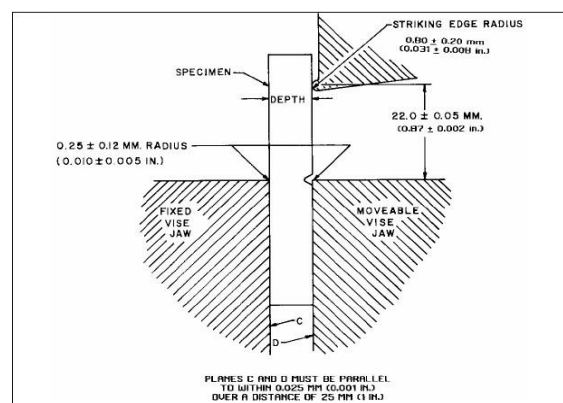


Fig.4.18: ASTM Standard D 256 Impact Test

A testing is performed according to ASTM D 256. The specimens were cut to meet the specifications of 64mm length, 6.4 mm width and 5mm thickness and small narrow cut about 45° . The Izod test is commonly used in quality control and material selection processes, particularly for plastics and polymers. The test provides valuable information about a material's ability to absorb energy in an impact event and can help

to identify potential failure points in a material. The results of the test can also be used to compare the impact strength of different materials and to identify the best material for a particular application.

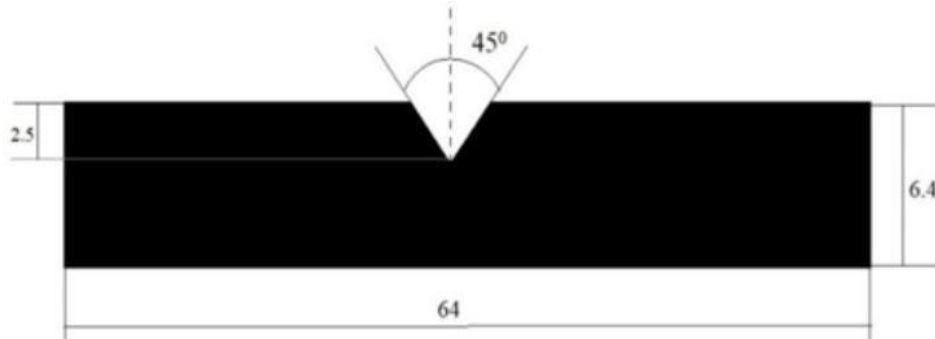


Fig.4.19: Dimensions of notched impact test specimen under ASTM D256



Fig.4.20: Glass/Basalt and Basalt/Glass Samples for impact test

4.5.3 HARDNESS TEST

The results of the Rockwell hardness test may be related to tensile strength, wear resistance, ductility, and other physical properties of metallic materials, and they may be helpful for material selection and quality control. We offer close-loop load cell-based Rockwell hardness tests for all types of components, from entry-level to high-end models. Measurement which is taken to preform Rockwell of the samples: 3 cm × 3 cm.



Fig.4.21: Dimensions of notched Rockwell test

4.5.4 WATER ABSORPTION

Water absorption is used to determine how much water will be absorbed in a certain situation. The amount of water that is absorbed is affected by the type of plastic, the additives used, the temperature, and the exposure period. The details make it clear how the materials work in damp or humid conditions. A 3 cm × 3 cm measurement is used to do the water analysis on the samples. Weight measurements are taken every eight hours while the sample is submerged in water for a week.

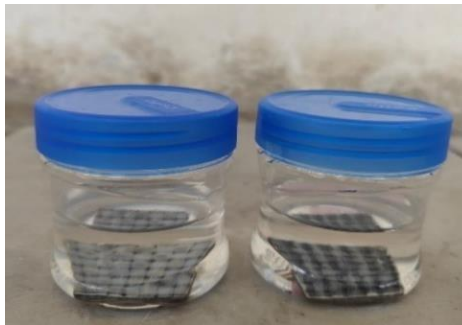


Fig.4.22: Glass/Basalt and Basalt/Glass Samples are kept for water absorption test.

4.5.5 FUEL ABSORPTION

Fuel absorption is used to calculate the amount of fuel absorbed under specific conditions. The amount of fuel absorbed depends on the type of plastic, the additives used, the temperature, and the exposure time. The details make it clear how the substances work in damp or humid conditions. The samples are measured using a 3 cm 3 cm grid to do biodiesel. The sample is stored in biofuel for a week, with weight measurements taken every eight hours.

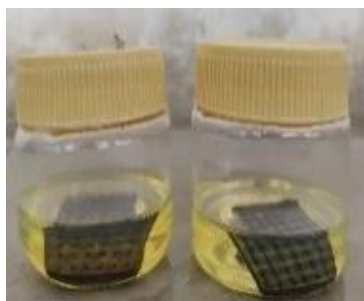


Fig.4.23: Glass/Basalt and Basalt/Glass Samples are kept for water absorption test

4.5.6 TENSILE TESTING

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. ASTM D 3039 is a standard test method for tensile properties of polymer matrix composite materials. The test method provides information on the tensile strength, tensile modulus, and elongation at break of composite materials. During the test, a specimen of the composite material is clamped in a testing machine and subjected to a uniaxial tension load. The load is gradually increased until the specimen fractures or breaks. The load and displacement of the specimen are continuously monitored during the test, and this data is used to calculate the tensile properties of the material. The test method specifies several parameters such as the specimen dimensions, the testing speed, and the environmental conditions to ensure accurate and repeatable results. The results obtained from the test can be used to evaluate the mechanical performance of composite materials under tensile loading conditions and to compare the performance of different materials or material systems. It is important to note that ASTM D 3039 is just one of several standard test methods used for characterizing the mechanical properties of composite materials, and different test methods may be more appropriate depending on the specific application and requirements of the material. It is customarily measured in units of force per crosssectional area as shown in Fig 7.3.



Fig.4.24: Tensile Test Setup

Tensile strength is the amount of load or stress that can be handled by a material before it stretches and breaks. As its name implies, tensile strength is the material's resistance to the tension that is caused by mechanical loads applied to the material. The ability to resist breaking under tensile stress is one of the most important and widely measured properties of materials used for structural applications.

The fiber was produced and mechanically moulded according to the ASTM D3039 standard. The properties of the specimens were examined and tracked after they were sliced from the produced composite.

A tensile testing is performed according to ASTM D 3039. The specimens were cut to meet the specifications of 250mm length, 25 mm width and 5mm thickness.

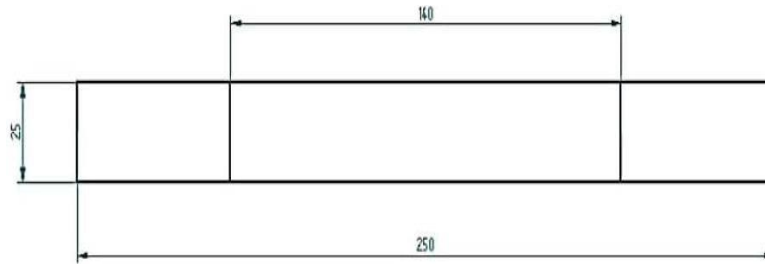


Fig.4.25: Dimensions of notched impact test specimen under ASTM D 3039

After manufacture, tensile and constant amplitude fatigue tests were performed on the test specimens. As required by ASTM D 3039, a tensile test is conducted. As illustrated in Fig. 4.25, the specimens were cut to the required specifications of 250 mm in length, 25 mm in width, and 3 mm in thickness. The test is run at a constant head-speed pace for 4 minutes per millimetre. Three specimens tested in three different orientations were used to get the average tensile characteristics.

CHAPTER 5

RESULT AND DISCUSSION

5.1 SCANNING ELECTRON MICROSCOPY TEST OF SAMPLE 1

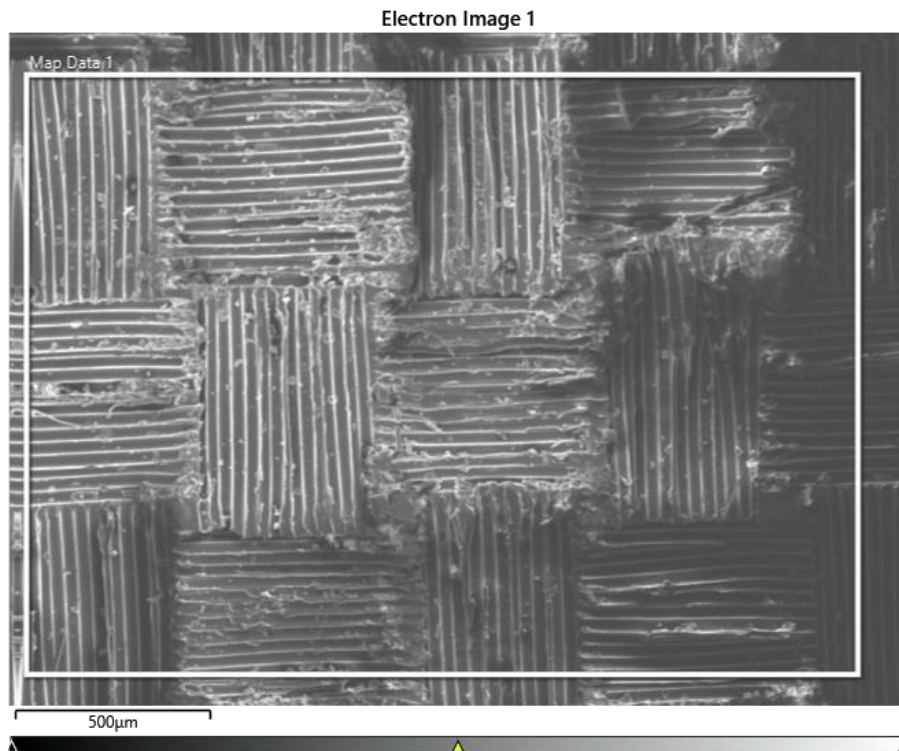


Fig.5.1: surface image of Glass/ Basalt sample

By analysing the SEM and EDS images that clearly confirms the presence of Oxygen, carbon, Sodium, Calcium. The EDS table explain the percentage of element present on it. From Fig.5.11 small cylindrical rod like structures is visible. From Fig.5.6 small bulges are clearly visible.

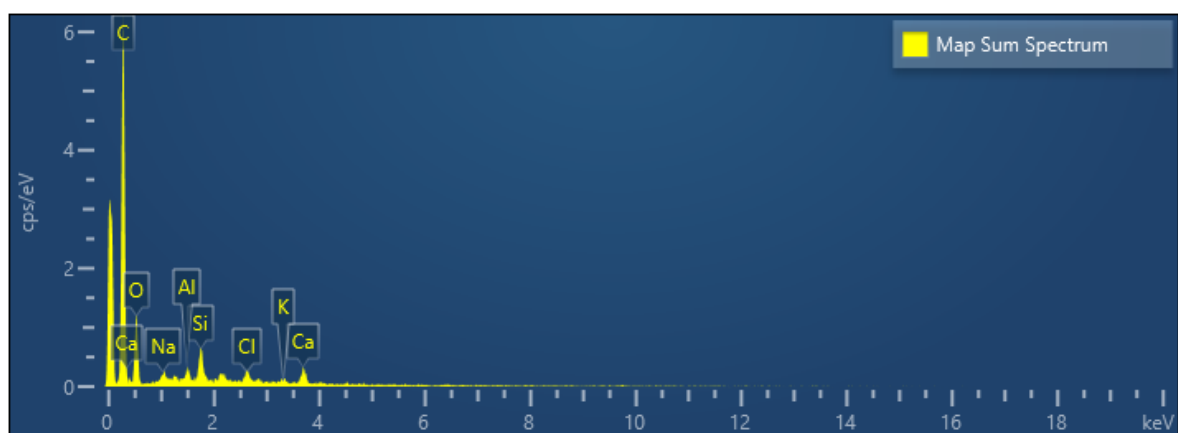


Fig.5.2: Composition in Sample1

Table .5.1: Elements in sample 1

Map Sum Spectrum				
Element	Line Type	Weight %	Weight % Sigma	Atomic %
C	K series	74.66	0.88	80.84
O	K series	21.70	0.85	17.64
Na	K series	0.44	0.10	0.25
Al	K series	0.42	0.06	0.20
Si	K series	1.08	0.08	0.50
Cl	K series	0.52	0.06	0.19
K	K series	0.21	0.06	0.07
Ca	K series	0.97	0.08	0.32
Total		100.00		100.00

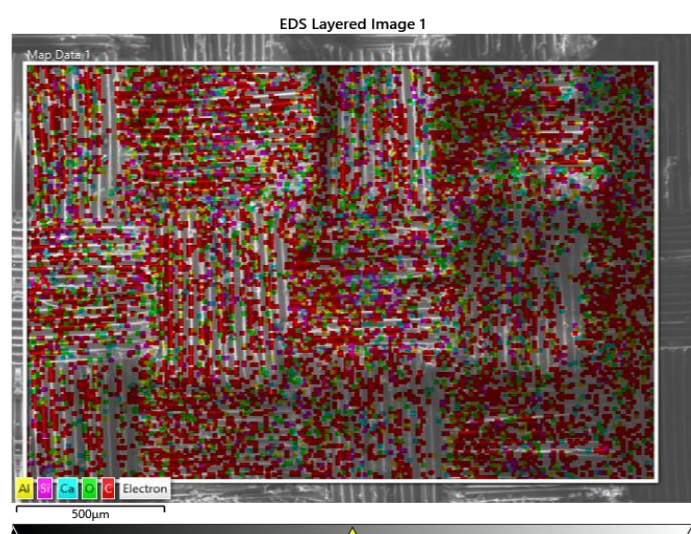


Fig.5.3: Representation of EDS layered Image

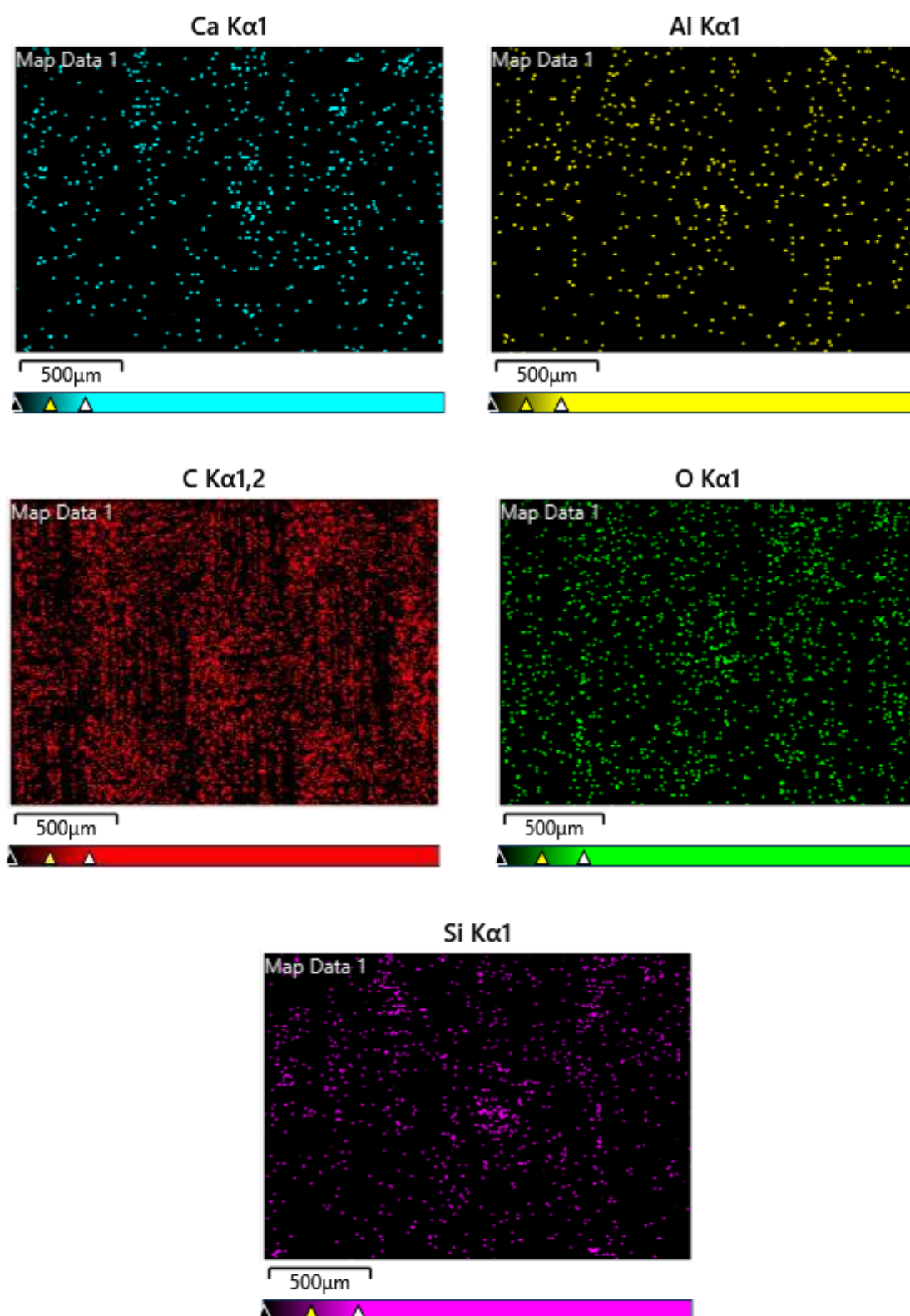


Fig.5.4: Representation element composition of Sample 1

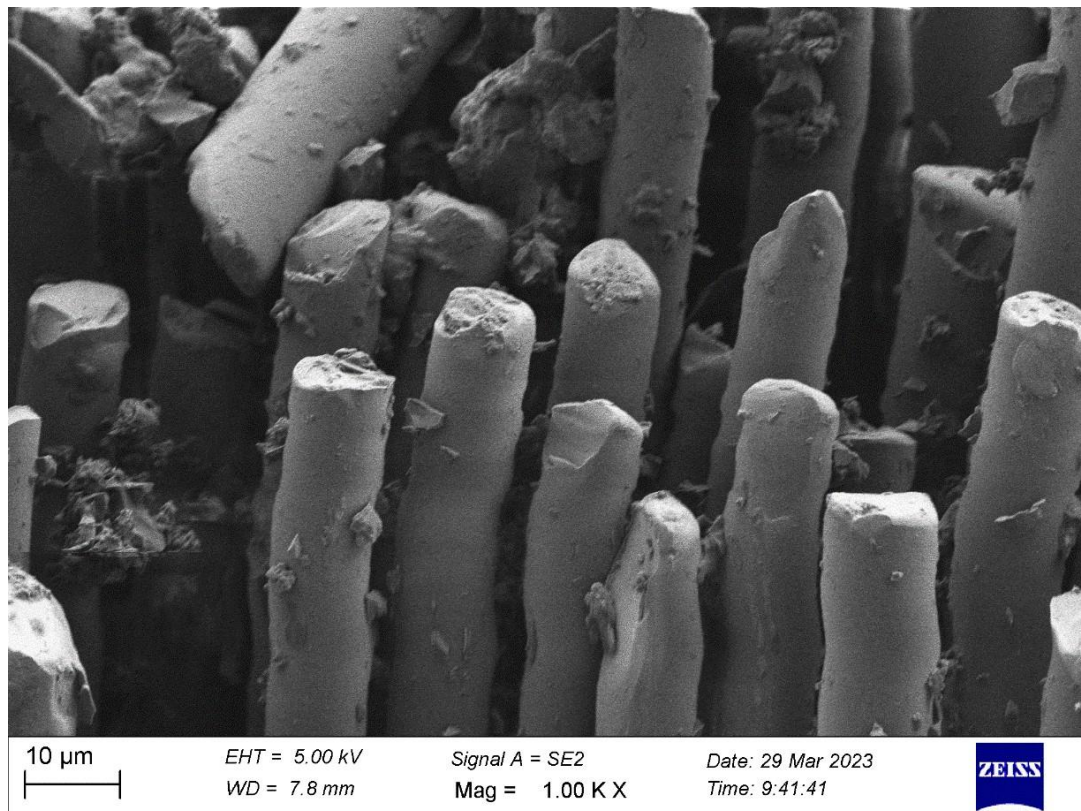


Fig.5.5: Surface image of Glass/basalt reinforced composite

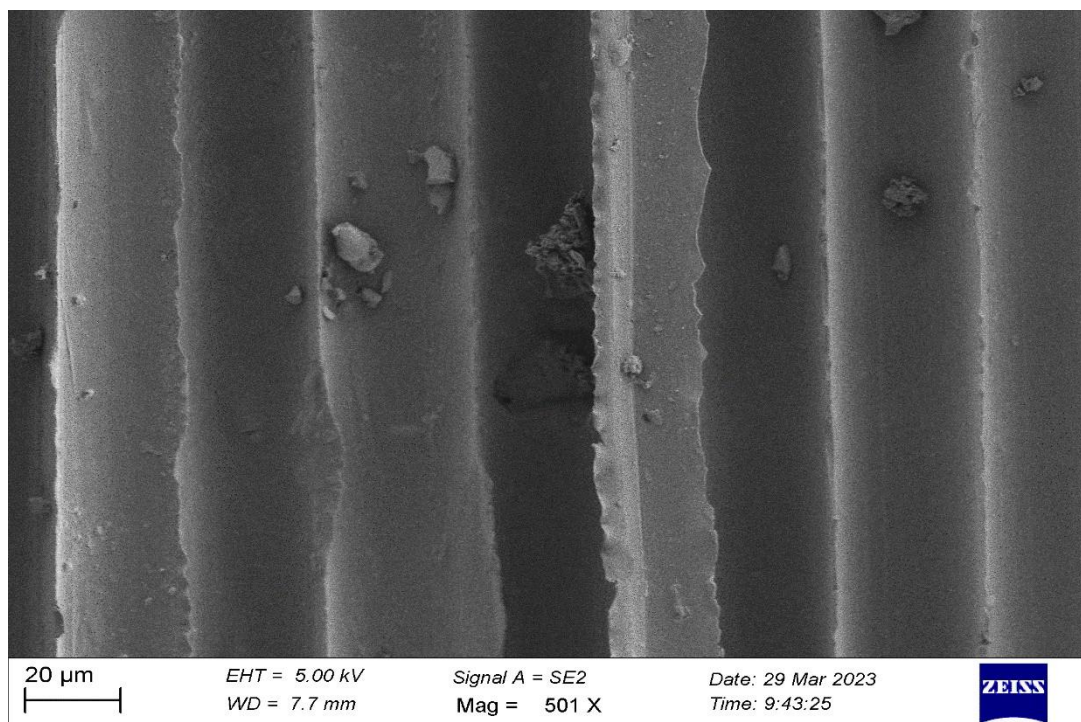


Fig.5.6: Surface image of Glass /Basalt reinforced composite

5.2 SCANNING ELECTRON MICROSCOPY TEST OF SAMPLE 2

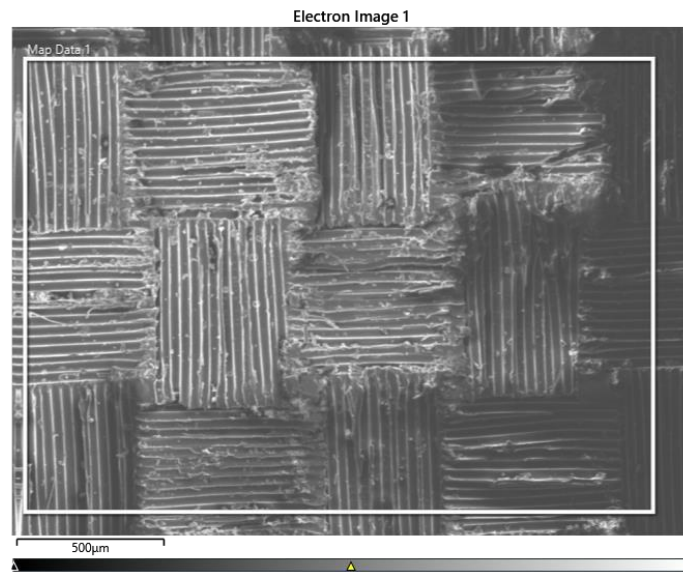


Fig.5.7: Surface image of basalt/Glass reinforced composite

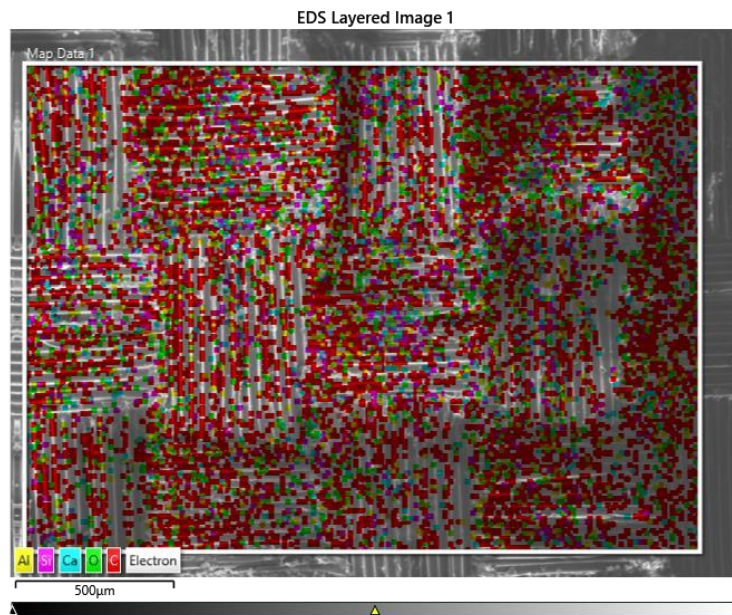


Fig.5.8: Representation of EDS layered Image

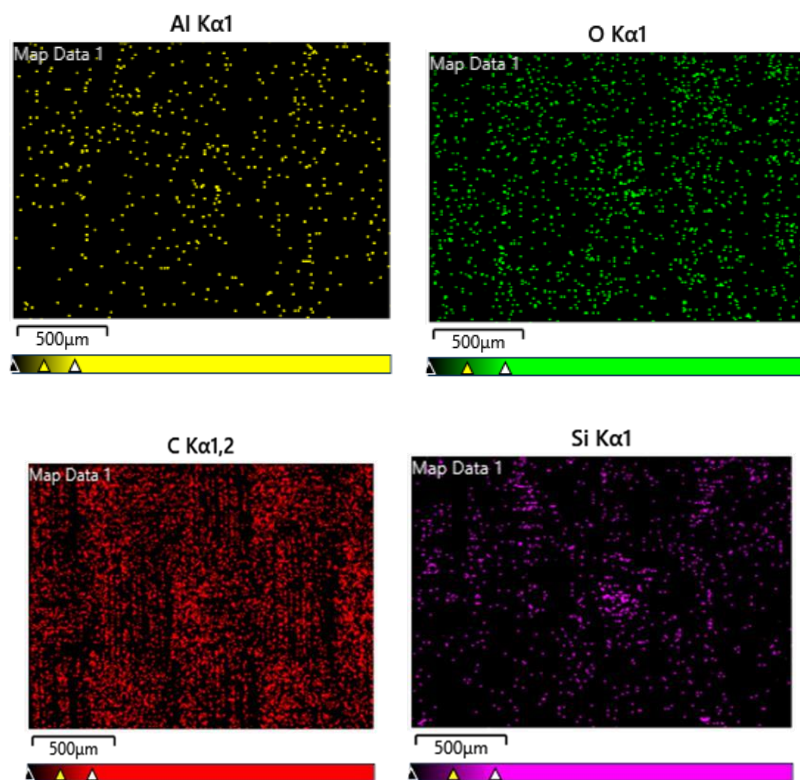


Fig.5.9: Representation element composition of Sample 2

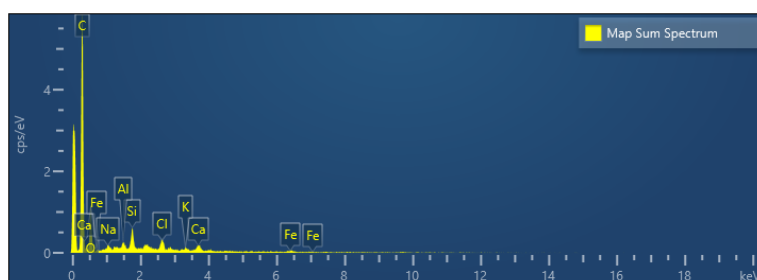


Fig.5.10: Representation element composition

Table.5.2: Elements in Sample 2

Map Sum Spectrum				
Element	Line Type	Weight %	Weight % Sigma	Atomic %
C	K series	74.71	0.73	80.84
O	K series	21.86	0.70	17.76
Na	K series	0.35	0.07	0.20
Al	K series	0.33	0.05	0.16
Si	K series	1.04	0.06	0.48
Cl	K series	0.71	0.06	0.26
K	K series	0.18	0.05	0.06
Ca	K series	0.51	0.06	0.17

Fe	K series	0.32	0.10	0.07
Total		100.00		100.00

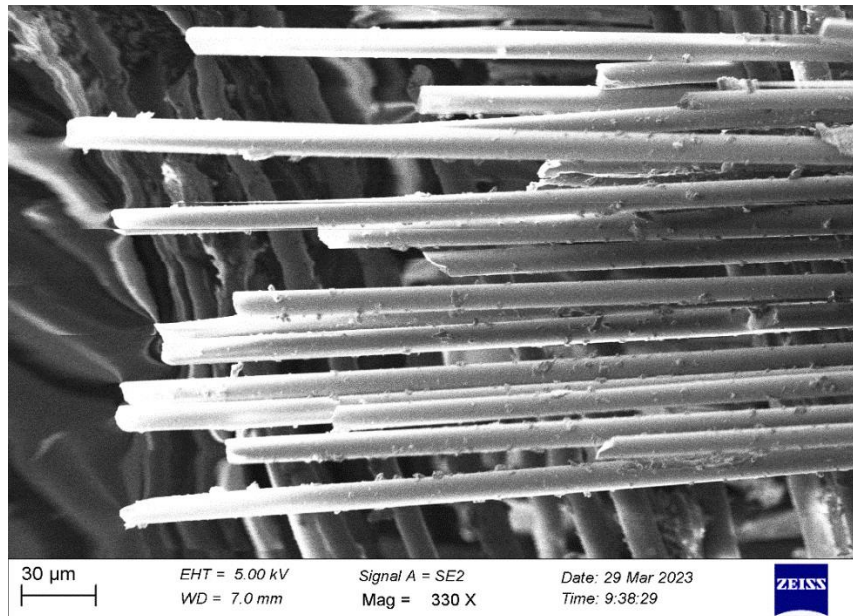


Fig.5.11. Surface image of basalt/Glass reinforced composite

5.3 FUEL ABSORPTION

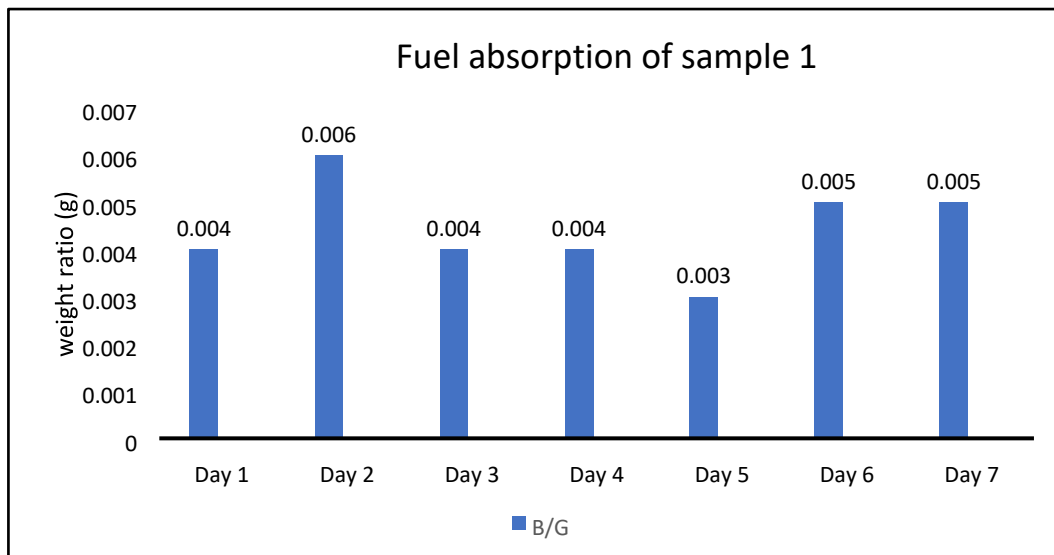


Fig.5.12. Fuel absorption test of Sample 1

For seven days, the fuel solutions were applied to the samples while the fuels were stored in a glass container. The containers were stored in a chamber that was maintained at 32°C. Based on volume, the fuel mixture used is 80% kerosene and

20% biodiesel, with palm oil serving as the feedstock for the biodiesel fuel. This mixture has properties similar to those of pure kerosene fuel. More biodiesel must be added, necessitating the use of an extra ingredient, in order to prevent biodiesel from crystallising at low temperatures.

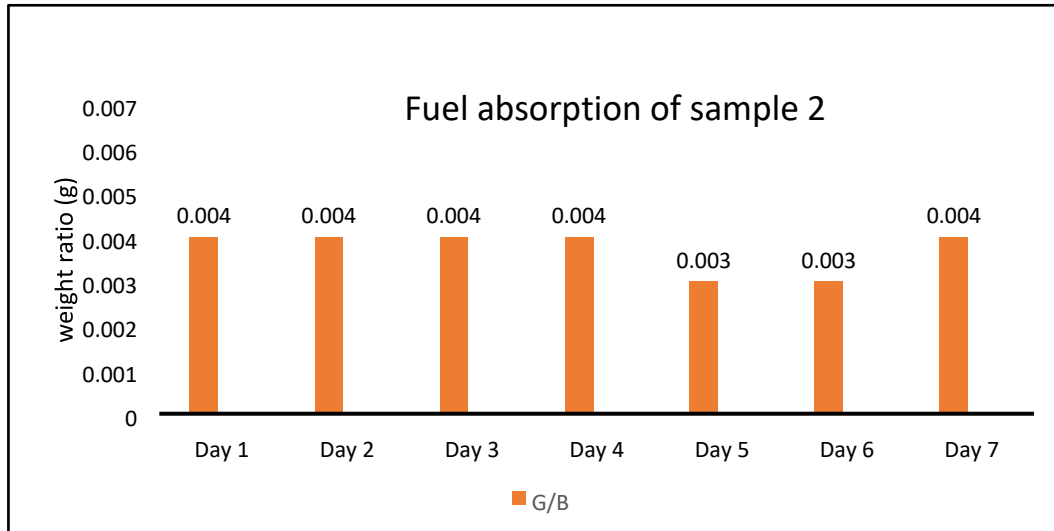


Fig.5.13: Fuel absorption of Sample 2

5.4 WATER ABSORPTION

In a glass container, the water was stored while being applied to the samples daily for seven days. In a room with a 32°C temperature, the containers were maintained.

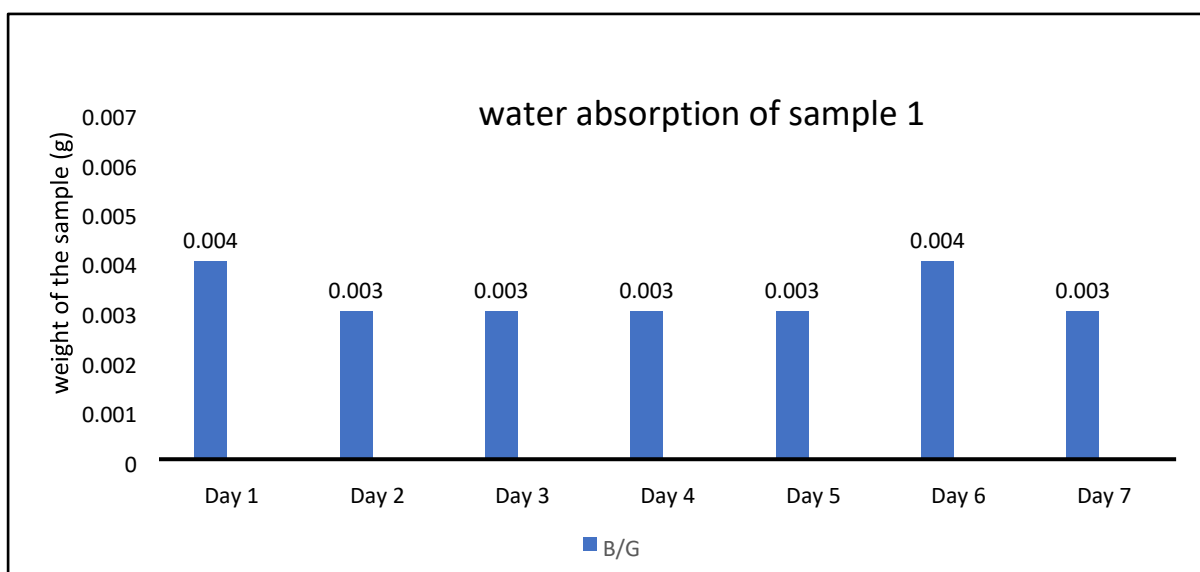


Fig.5.14: water absorption of sample 1

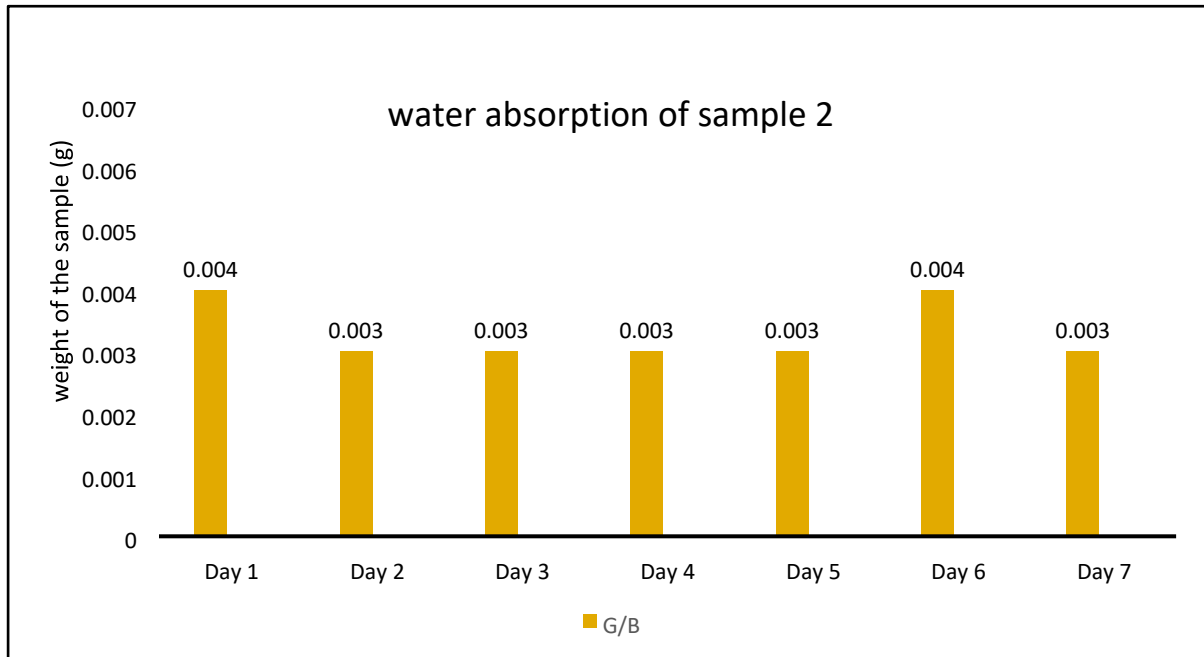


Fig.5.15: water absorption of sample 2

Fig.5.14 and Fig.5.15 shows the water ratio of the sample day by day as a result there is a loss of weight in the sample due to the molecular structure got affected and swollen.

5.5 IMPACT STRENGTH

A specimen must be 64 x 12.7 x 3.2 mm (212 x 12 x 1/8 inch) in size in order to meet ASTM D256 requirements. The most typical specimen thickness is 3.2 mm (0.125 inches), but 6.4 mm (0.25 inches) is favoured because it is less likely to be crushed or bent. The notch on the specimen is 10.2 mm (0.4 inches) deep. Impact testing is conducted using sample 1's value of 3.4 J and sample 2's value of 2.4 J.

Table.5.3: impact strength of sample 1 and sample 2

SAMPLE ID	Impact value (Joules)
G+B+G+B+G+B+G +CNT	1.1
B+G+B+G+B+G+B +CNT	2.4

5.6 HARDNESS TEST

On the Rockwell Hardness tester's surface, a standard specimen is inserted. The gauge is zeroed once a light load is applied. Tripping a lever applies the main load. The main burden is eliminated after 15 seconds. After giving the specimen 15 seconds to recover, the hardness is measured while the light load is still being applied.

Table.5.4: Rockwell test of sample1 and sample 2.

SAMPLE ID	ROCKWELL		
	Zone -1	Zone-2	Zone-3
G+B+G+B+G+B+G +CNT	80	76	78
B+G+B+G+B+G+B +CNT	79	78	80.5

5.7 TENSILE TEST

The evaluation of the mechanical properties has been examined in this manner. Tensile, flexural, and impact qualities of the material's strength were evaluated. The samples were cut from the production plate into 165 mm long, 19 mm wide, and 3 mm thick sections in accordance with ASTM D3039 specifications.

The amount of load or stress that a material can withstand before stretching and breaking is known as its tensile strength. Tensile strength, as its name suggests, refers to a material's resistance to tension brought on by mechanical loads. One of the most significant and frequently measured qualities of materials used for structural purposes is their capacity to resist breaking under tensile stress.

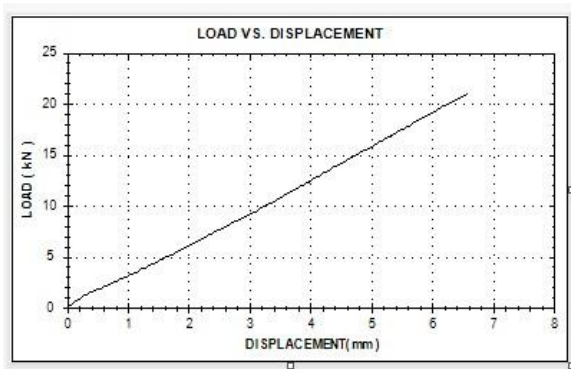


Fig. 5.16: Tensile test setup

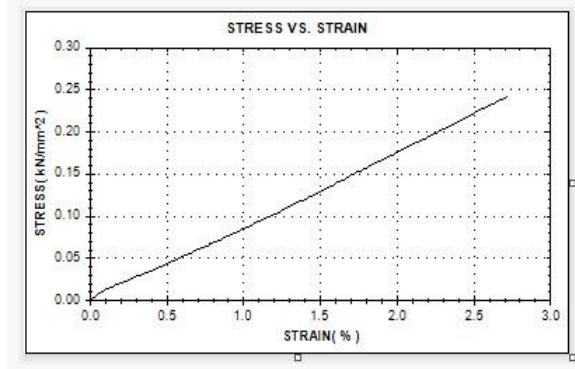
The fiber was produced and mechanically molded according to the ASTM D 3039 standard. The properties of the specimens were examined and tracked after they were sliced from the produced composite.

Table.5.5: Tensile Stress of sample1 and sample 2.

SAMPLE ID	Tensile Stress Mpa
G+B+G+B+G+B+G+CNT	170
B+G+B+G+B+G+B+CNT	100

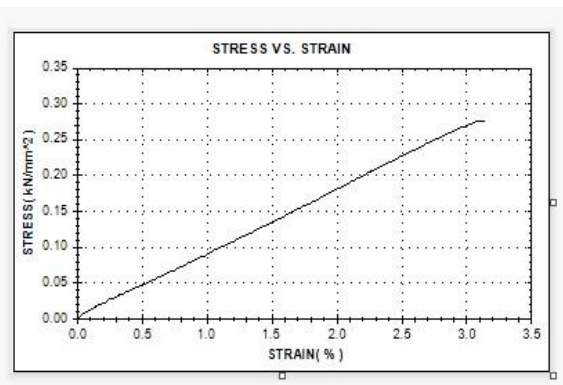


(a)

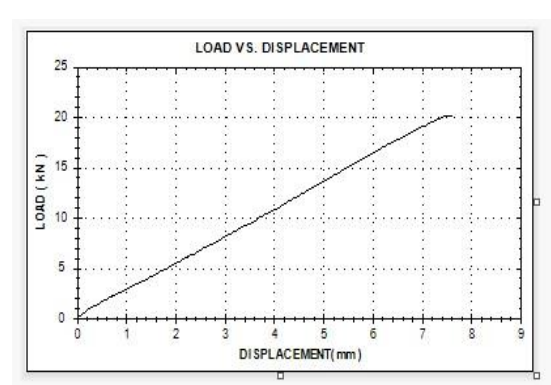


(b)

Fig.5.17. (a) Load Vs Displacement graph of Sample 1 (b) Stress Vs strain graph of Sample 1.



(a)



(b)

Fig.5.18. (a) Load Vs Displacement graph of Sample 2 (b) Stress Vs strain graph of Sample 2.

5.8 DISCUSSION

The opportunity exists to modify the properties of created composite materials even during the design phase in order to fulfil the requirements of the intended application thanks to the availability of various matrix and reinforcement types. To measure the characteristics of composite materials, "FIBER volume fraction" (vf), which is defined as the ratio of FIBER volume to matrix volume, is utilised. The "FIBER loading level" is also known as this, and in daily life it manifests as a weight fraction. Estimating the properties of composite materials, including density, coefficient of thermal expansion, modulus of elasticity, shear modulus, Poisson's ratio, and tensile strength, requires knowledge of the FIBER volume percentage and the identical properties of each component.

Important considerations include how much and what kind of resin is needed for the polymer layers to adhere to one another. If the resin is not robust enough, the layers may separate once the resin has hardened. Air bubbles between the layers must also be eliminated because they can lead to a range of issues.

5.9 APPLICATIONS

More study is being done on composite-based goods, particularly natural composites, in an effort to develop alternatives for reinforcing FIBERs that are both natural and synthetic. Natural composites have a number of advantages for the environment, including a reduction in the consumption of fossil fuels and greenhouse gas emissions. They additionally offer functional benefits because to their adequate tensile strength, stiffness, and low cost. These are being researched as potential replacements for polymers made from petroleum. Stronger natural FIBERs like cotton, jute, flax, hemp, sisal, and more recently, kenaf, hemp, and corn are gradually displacing synthetic FIBERs. The main markets for hybrid composites right now are the building and automotive sectors.

Automakers like Mercedes-Benz, Audi, BMW, and Volkswagen already employ these composites to create interior and exterior parts for the building and healthcare sectors. Tables, chairs, and bathtubs have all been turned into furniture. used in the manufacture of briefcases and headgear. used to design interiors for aeroplanes by the railway industry These are also in use.

Currently, intricate thermoset and thermoplastic natural fiber/resin composites are being made. A broad range of industries, including medical devices, industrial, automotive, maritime, and construction, were included in the definition of "challenging". Additionally, it has great mechanical qualities (stiffness, impact, strength, etc.), good chemical resistance, surface polish, complex manufacture, and high mechanical properties. A number of model goods and demonstrators were made and tested structurally and model-wise to verify these composites. Due to their low weight, design flexibility, corrosion resistance, and cost-effectiveness, automotive sector in recent years.

CHAPTER 6

CONCLUSION AND SUMMARY

6.1 SUMMARY

Polymer matrix composites (PMC) are widely used in various industrial applications due to their unique properties such as low density, high strength, and stiffness. To ensure their safe and effective use, it is important to determine their mechanical properties at different environmental conditions, including high temperature and cryogenic temperatures. To determine the mechanical properties of PMC at high temperature, a combination of testing and modeling techniques are used. Tensile, compressive, and flexural tests are performed on PMC specimens at elevated temperatures to determine their strength, modulus, and ductility. Additionally, dynamic mechanical analysis (DMA) is used to investigate the viscoelastic properties of PMC under different temperature conditions. These experimental results are then used to develop constitutive models for PMC, which can predict their mechanical behavior at high temperatures. Similarly, to determine the mechanical properties of PMC at cryogenic temperatures, testing and modeling techniques are also used. Tensile, compressive, and flexural tests are performed on PMC specimens at cryogenic temperatures to determine their strength, modulus, and ductility. DMA is also used to investigate the viscoelastic properties of PMC under cryogenic conditions. These experimental results are then used to develop constitutive models for PMC, which can predict their mechanical behavior at cryogenic temperatures. Overall, the determination of mechanical properties of PMC at high temperature and cryogenic environments requires a combination of experimental testing and modeling techniques. The results obtained from these tests and models can provide valuable insights into the behavior of PMC under extreme temperature conditions, which can be used to optimize their use in various industrial applications.

6.2 CONCLUSION

The determination of mechanical properties of Polymer Matrix Composites (PMC) at high temperatures and cryogenic environments is crucial for understanding the behavior of these materials under extreme conditions. At high temperatures, the mechanical properties of PMCs tend to degrade due to thermal expansion and softening of the matrix material. The mechanical properties that are affected include the stiffness, strength, and toughness. On the other hand, at cryogenic temperatures, the mechanical properties tend to improve due to reduced thermal expansion and increased stiffness.

To determine the mechanical properties of PMC at high temperatures and cryogenic environments, various testing techniques such as tensile testing, flexural testing, compression testing, and impact testing can be employed. Additionally, advanced techniques such as scanning electron microscopy (SEM) can also be used to study the microstructure and crystallographic properties of the composites.

For applications such as door panels, seat backs, head liners, package trays, dash boards, and interior pieces, hybrid composite is the optimum material. When a material with a high impact strength is required, jute composite might be employed. This work can be expanded in real time to include car parts like bumpers and engine covers. The mechanical properties of composites are features that are examined under various operating conditions, and better design may be a means to implement the concept of a green environment.

In conclusion, the determination of mechanical properties of PMC at high temperatures and cryogenic environments is essential for understanding the behavior of these materials in extreme conditions. This information can be used to design and optimize these materials for specific applications in aerospace, automotive, and other industries.

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