EXPERIMENTAL INVESTIGATION OF PROPERTIES OF EPOXY GLASS FIBER COMPOSITE REINFORCED WITH SiO_2& Al_2O_3 AND TiO_2

A Project report submitted

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

BACHELOR OF TECHNOLOGY

In

MECHANICAL ENGINEERING

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2022

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ACKNOWLEDGMENT

We express immensely our deep sense of gratitude to **Mr. S. PHANI KUMAR,** Assistant Professor, Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences, Sangivalasa, Bheemunipatnam Mandal, Visakhapatnam district for his valuable guidance and encouragement at every stage ofwork for the successful fulfillment of students.

We are very thankful to **Prof. T.V. Hanumantha Rao**, Principal and **Prof. B. Nagaraju**, Head of the Department, Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences for their valuable suggestions.

We express our sincere thanks to the non-teaching staff of Mechanical Engineering for their kind co-operation and support to carry on work.

Last but not the least, we like to convey our thanks to all who have contributed directlyor indirectly for the completion of our work.

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ABSTRACT

With the concept of eco-materials in mind, this project deals with the of previous research in the mechanical properties of fiber reinforced composites. Fiber reinforced composite is an important material for structural applications. Many fibers fabricated from thermosetting polymers reinforced with synthetic fiber possess better mechanical properties when compared with natural fiber.

In the present work evaluation of mechanical properties of a composite is achieved. The composite is prepared using epoxy resin as matrix and glass fiber as reinforcement. This composite was chosen as it has wide range of application in the manufacturing of gears. The composite was analyzed for variation of properties by changing the quantity of filler materials. The filler materials used in the work are Sio_2& Al_2o_3 and Tio_2..The composite samples are prepared by varying the weight percentages of filler material powders. The percentage of metal powders chosen are successively 0%,0.5%,1%,1.5%,2% respectively. The composites were fabricated by using the well-known process if Hand lay-up moldings.

The samples were subjected to destructive testing procedures to evaluate their tensile, impact and flexural strengths respectively. Comparison of these different samples vis-à-vis their properties done with an composite made of only epoxy resin as matrix reinforced with glass fiber .It was observed through experimentation that all these selected properties retained the maximum values for the sample which contained 1% of filler materials drawn from the present study are highlighted as here under.

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Chapter-1
INTRODUCTION

CHAPTER I

INTRODUCTION

Introduction of Composite Materials

A composite material is made by combining two or more materials are together to create a superior, unique material properties, minimizes their weakness and chemically distinct phases. A composite material is heterogeneous at a microscopic scale but statistically homogeneous at macroscopic scale. The composite materials have significantly different properties.

The composites materials can be naturally or artificially made materials. There are many researches for new materials which will satisfy the specific requirements for various applications like aerospace, marine, industrial, structural, electrical, house-hold, etc. It is impossible of any material to fulfill all properties. Hence, newer materials are developed for more required properties. Composites are used in place of metals because they are equally strong but much lighter.

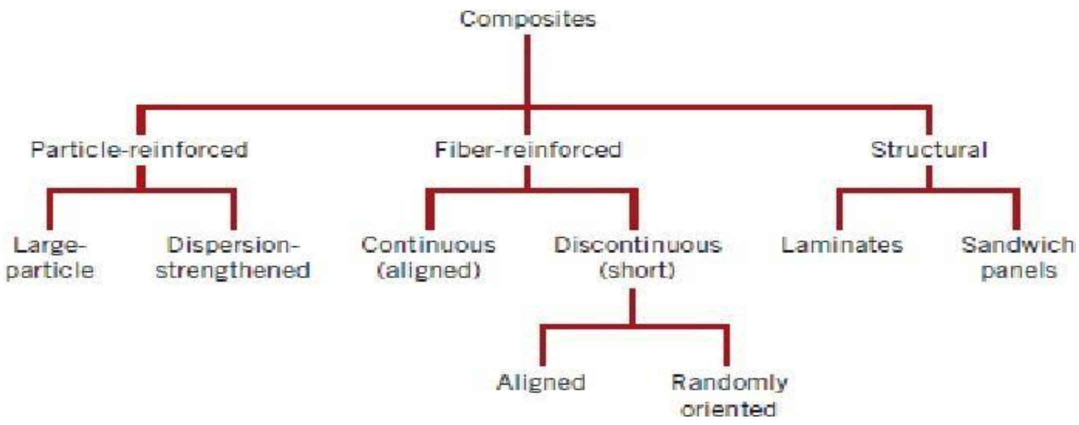

Fig : 1.1 – classification of composites

Types of composite materials

These three types of matrixes produce three common types of composites:

Polymer matrix composites (PMCs):

Polymer matrix composites are comprised of a variety of short or continuous fibers bound together by an organic polymer matrix. The advantage of PMCs is their light weight coupled with high stiffness and strength along the direction of the reinforcement. This combination is the basis of their usefulness in aircraft, automobiles, and other moving structures. Other desirable properties include superior corrosion and fatigue resistance compared to metals. Because the matrix decomposes at high temperatures, however, current PMCs are limited to service temperatures below about 600° F (316° C). PMCs are oriented generally fibers, whiskers, particulates, fabric.

Metal-matrix composites (MMCs):

In metal matrix composites use silicon carbide fibers embedded in a matrix made from an alloy of aluminium and magnesium, but other matrix materials such as titanium, copper, and irons are increasingly being used. Typical applications of MMCs include bicycles, golf clubs, and missile guidance systems. A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal necessarily, the other material may be a different metal or another material, such as a ceramic or organic. When at least three materials are present, it is called a hybrid composite.

Ceramic-matrix composites (CMCs)

The ceramic matrix makes them particularly suitable for use in lightweight, high-temperature components, such as parts for airplane jet engines. Ceramicmatrix composites (CMC) are produced from ceramic fibers embedded in a ceramicmatrix. Various ceramic materials, oxide or non-oxide, are used for the fibers and the matrix. Also, a large variety of fiber structures is available. So, properties of CMC can be adapted to special construction tasks. They are especially valuable for components with demanding thermal and mechanical requirements.

Different forms of composites

Unidirectional Lamina: It is basic form of continuous fiber composites. A lamina is also called by ply or layer. Fibers are in same direction. Orthotropic in nature with different properties in principal material directions

Woven fabrics: Examples of woven fabric are clothes, baskets, hats, etc. Flexible fibers such as glass, carbon, aramid can be woven in to cloth fabric, can be impregnated with a matrix material.

Introduction of Hybrid Composite Material

Incorporation of two or more fibers within a single matrix is known as hybridization and the resulting material referred to as hybrid composite materials. Glass fibers are the most commonly used reinforcement, carbon and boron fibers are highly expensive and their use only in aero space applications. Different types of hybrid constructions are available as mixed fiber tows, mixed fiber ply, individual fiber ply, sandwich and Reinforced with rods or webs.

By using hybrid composite materials reduce cost, high specific modulus, strength, and corrosion resistance. In many cases hybrid composite materials shows excellent thermal stability. It is generally accepted that the properties of hybrid composites are controlled by factors such as nature of the matrix length and relative composition of the reinforcements, fiber interfaces.

The use of two or more fibers allows the combination of desired properties from the fibers. For example, combination of aramid and carbon fibers gives excellent tensile properties of aramid and compressive properties of carbon fibers. Further, the aramid fibers are less expensive as compared to carbon fibers.

Introduction of Glass Fiber

Glass fibers are the most common of all reinforcing fibers for Polymeric Matrix Composites (PMC). The principle advantages of glass fibers are low cost, high tensile strength, high chemical resistance, and excellent insulating properties. The disadvantages are relatively low tensile modulus and high density (among the commercial fibers), sensitivity to abrasion during handling (i.e frequently decreases its tensile strength), relatively low fatigue resistance, and high hardness (which causes excessive wear on moulding dies and cutting tools). The fibers have low modulus but significantly higher stiffness. Individual filaments are small in diameters, isotropic and very flexible as the diameter is small. The glass fibers come in variety of forms based on silica which is combined with other elements to create specialty glass.

Types of glass fibers and their key features are as follows:

E glass - high strength and high resistivity.

S glass - high strength, modulus and stability under extreme temperature and corrosive environment.

R glass -enhanced mechanical properties.

C glass - resists corrosion in an acid environment.

D glass - good dielectric properties.

Continuous fibers:

If the fibers used in a composite are very long and unbroken or cut then it forms a continuous fiber composite. A composite, thus formed using continuous fiber is called as fibrous composite. The fibrous composite is the most widely used form of composite.

Short/chopped fibres:

The fibers are chopped into small pieces when used in fabricating a composite. A composite with short fibers as reinforcements is called as short fiber composite.

Applications of glass fiber:

Storage tanks, house hold, piping system, traffic lights, Helicopter rotor blades, surf boards, rowing shells

Applications of Fiber Reinforced Plastics

Many fiber-reinforced composite materials offer a combination of strength and modulus that are either comparable to or better than many traditional metallic materials. Because of their low specific gravity, the strength-weight ratio, and modulus-weight ratios, these composite materials are markedly superior to those of metallic materials. In addition, fatigue strength weight ratio as well as fatigue damage tolerance of many composite laminates is excellent. For these reasons fiber-reinforced composites have emerged as a major class of structural material and are either used or being considered as Substitutions for metals in many weight-critical components in aerospace,automotive and other industries.

Traditional structural materials, such as steel and aluminium alloys, are considered isotropic since they exhibit nearly equal properties irrespective of direction of measurement. In general the properties of fiber-reinforced composite depend strongly on direction of measurement. For example the tensile strength and modulus of unidirectional oriented fiber-reinforced laminate are higher when these properties are measured in the longitudinal direction of fibers. At any other angle of measurement, these properties are lower. The minimum value is observed at 90° to the longitudinal direction, similar angular dependence is observed for other physical and mechanical properties, such as coefficient of thermal expansion, thermal conductivity and impact strength.

In addition to directional dependence of properties, there are a number of other differences between structural metals and fiber-reinforced composite. For example, metals in general exhibit yielding and plastic deformation. Most fiber reinforced composites are elastic in their tensile stress-strain characteristics. However, the heterogeneous nature of these materials provides mechanisms for higher energy absorption on a microscopic scale comparable to yielding process.

Coefficient of thermal expansion of many fiber-reinforced composites is much lower than those metals. As a result composite structures may exhibit a better dimensional stability over a wide temperature range. Another unique characteristic of many fiber-reinforced composites is their higher internal damping. This leads to better vibration energy absorption within the material, resulting in reduced transmission f noise and vibrations to neighbouring structures.

Many common materials including iron, copper, nickel, carbon and boron have directionally dependent properties, with the directional dependence being due to the strengths of the inter atomic and intermolecular bonds. The bonds are stronger in some directions than in others, and the material unit is very stiff and exhibits considerable strength in direction of the stronger bond. Unfortunately the favourable properties found in one direction usually come at the expense of the properties in other direction,In directions perpendicular to the stiff and strong direction, the material is much softer and weaker. Other properties like electrical conductivity and heat conduction can also be directionally dependent.

Fibers have significant length, so they can be easily aligned in one direction to provide selective reinforcement within another material. A fiber contains many units in its length, and thus it has a greater chance of having an imperfection as a result fiber is weaker than a whisker. The strength property of fibers is a random variable. Testing 10,000 fibers would result in 10,000 different strength values. Obviously one can use such {aw strength data to form a probability distribution of the strength. The average strength and the scatter of the strength become important quantities in describing the properties of fiber.

The major structural applications of fiber-reinforced composites ate spacecraft, automotive components, sporting goods, marine engineering, military and commercial aircrafts.

Reinforced composite have been also found very well in chemical industry due to their corrosive resistance, low maintenance cost, chemical resistance and cheaper than conventional non corrosive materials like stainless steel.

Over the last few years, fiber-reinforced polymer composites have experienced a substantial usage in the sporting goods industry. The sporting goods like Tennis rockets, Racket balls, Golf club shafts, Fishing rods, Bicycle frames, Snow and water skis, Ski poles, pole vault poles, Hockey sticks, sail boats and kayaks, Oars, Paddles, Canoe hulls,surfboards, arrows, archery bows, javelins, helmets etc., are made of fiber-reinforced polymer composites

CHAPTER-2

LITERTAURE REVIEW

CHAPTER - 2

LITERATURE REVIEW

Introduction

A brief study on papers related to composite materials, fillers, mechanical properties, Tribological characteristics and Taguchi method. Many authors gave different ideas related to their works on glass fiber reinforced composite materials. The different papers reviewed are listed below:

Basavarajappa et al [1] have done their project using the optimization technique Taguchi and perform to acquire data in a controlled way. An orthogonal array and analysis of variance (ANOVA) was employed to investigate the influence of process parameters on the wear in composite materials. Based on Taguchi approach, the experimentation provides an orderly way to collect, analyses, and interpret data. Incorporation of the silicon carbide particles in the polymer matrix as a secondary Reinforcement increases the wear resistance of composite material. Applied load is the wear factor that has the highest physical as well as statistical influence on the wear of composite material.

Suresha et al [2] carried out experimentation to study the influence of two inorganic fillers of SiC particles and graphite on wear of the glass fabric reinforced epoxy composites. They reported that the increase of load and sliding velocity results higher wear loss. The coefficients of frictional values are increasing with increase of load and sliding velocities. By investigation, the Graphite filled glass fiber composite has lower coefficient of friction. Silicon carbide and Graphite filled composites exhibits maximum wear resistance. Inclusion of Graphite and silicon carbide filler particles in Glass fiber composite reduces friction and gives better wear resistance properties.

Manikandan1 et al [3] Conducted experimentation to study the influence of fly ash fillers on mechanical and tribological properties of woven jute fiber reinforced polymer hybrid composite. Composites were prepared using hand layup method with weight percentage of fly ash as filler material. Inclusion of Filler percentage increases hardness and wear resistance properties but decreases the tensile strength of composite material decreases.

BharatAdmile et al [4] Performed experimentation on metal matrix composites which plays a vital role intribological industries because of their inherent properties like high strength to weight ratio, low wear rate. Matrix material LM25 which is commercially available has advantage of lighter weight & major silicon content of alloy may helps to improve castability. ANOVA was used to determine the design parameters significantly influencing the wear rate (response). By the analysis applied load was most significant parameter having the highest statistical influence on the dry sliding wear of composites compared to sliding velocity and sliding distance.

SudeepDeshpande et al [5] investigated about sliding wear characteristics of epoxy composites. They reported that the addition of bone powder in hybrid fiber reinforced epoxy composites decreases the wear rate of composite. They are also studied about S/N ratio.

Sandhyarani Biswas et al [6] determined the physical and mechanical properties of bamboo fiber reinforced epoxy Composites. Composites were fabricated using short bamboo fiber at different weight percentages and observed that few properties increases significantly with respect to fiber loading, properties like void fraction increases with the increase in fiber loading. To reduce the void fraction, improve hardness and other mechanical properties and so silicon carbide filler is added in bamboo fiber reinforced epoxy composites resulting increases hardness, tensile strength and flexural strength.
Mukul Kant Paliwal et al [7] Carried out studies on Composites materials which are extensively used in almost all aspects of their most attractive properties are the high strength-to-weight ratio. Composite materials also have some problems such as fiber fracture, matrix cracking and delaminating. Matrix cracks and fiber fractures play an important role in laminates under tensile load. Materials added to the matrix help improving operating properties of a composite. To investigate the tensile strength of glass fiber and epoxy resin based composite with CaCO3 as filler. E-glass/epoxy composites were manufactured to fabricate the specimens, by using Hand lay-up technique.

Hemanth et al [8] Studied on glass fibers which plays an important role in thermoplastic based composites, as they shows good balance between properties and costs. Polymer based composites is very common in situations where combinations of good properties are required. Such properties are not obtained with a single polymer.

Strengthening of polymers along with fibers and fillers in varies proportions exhibit immense possibilities of producing materials with variable properties. By investigation hybrid composites are lower tensile strength and strain with increase in filler content, Polyoxymethylene composites better tensile, flexural, modulus properties. Composites filled with short glass/carbon fiber, silicon carbide and Aluminium oxide composites, exhibited improved flexure strength and modulus.

Sakthivel et al [9] Carried out studies on the natural fiber which has advantages like low density, appropriate stiffness, mechanical properties with high disposability and renewability. Banana fibers are one of the natural fiber it is recycling and biodegradable. Banana fibers are good reinforcement in polypropylene resin. The properties of the composites are strongly influenced by the fiber length. The hybrids composite has move out of and have the potential reinforcement material for composites and thus gain attraction by many researchers. Natural fiber and glass fiber hybrid composites were fabricated by using epoxy resin combination of hand lay-up method and cold press method. Banana fibers are Chemical treatment like NAOH will increases the flexural strength of the fiber and removes the moisture content of the fiber.

Ganesha et al [10] describes the development and mechanical characterization of new polymer Composites consisting of glass fiber reinforcement, epoxy resin and filler materials as cerium oxide. In Composite materials different variety of filler inclusions added organic and inorganic. The matrix material a medium viscosity epoxy resin (LAPOX L-12) and polyamine hardener (K-6) curing at room temperature, these matrix provide good resistance and adhesive properties to alkalis. By the investigation tensile strength and flexural strength of composite material is enhance with inclusion of cerium oxide.

Chandru et al [11] Performed studies on polymer composites. In their study, vinyl Ester is a resin produced by the esterification (The process of converting an acid into an alkyl) of an epoxy resin with an unsaturated mono carboxylic acid. It can be used as an alternative to polyester and epoxy materials in matrix or composite materials, where its characteristics, strengths, and bulk cost intermediate between polyester and epoxy. Vinyl ester has lower resin than polyester and epoxy. The vinyl ester resin used as general purpose resin. The resin combines, the strength properties of epoxy resins and ease of processing of unsaturated polyester resins. It is outstanding long-term performance at elevated temperatures and under stress conditions. But in general epoxy resin gives better results and easily available then vinyl ester.

Mohan et al [12] Carried out studies on Polymer matrix composites are plays important role in Tribological applications due to possibility of tailoring their properties with special fillers improve their performance. The addition of ceramics such (silicon carbide, aluminium oxide, titanium oxide etc.) as within the matrix then increases the friction coefficient and reduces the wear loss. Glass fibers enhance the toughness of the matrix silicon carbide shows high hardness, thermal stability and low chemical reactivity, leading to superior friction properties over normal glass fiber reinforced composite. The enhancement on the wear resistance of silicon carbide filled glass-epoxy composite is associated with less fiber matrix loss.

Summary of work

From the literature survey, many authors have identified the mechanical,tribological properties of glass fiber reinforced composites by altering the filler materials. Therefore, in this work alternative filler materials are selected to improve mechanical strength of the composite by incorporation of SiO_2 , $TiO_2$and Al_2O_3 powder particles as filler materials. The behaviour of the composite is examined for mechanical properties of the material. The better configuration of materials can be used for aerospace and automobile industries.

Chapter-3

FABRICATION OF GLASS FIBER REINFORCED POLYMER COMPOSITES

CHAPTER – 3

FABRICATION OF GLASS FIBER REINFORCED POLYMER COMPOSITES

INTRODUCTION

The materials that are used in fabrication of the GFRP composite and the process that was followed are discussed in this chapter.

Materials Required for Fabrication of GFRP Composites

- Glass Fiber
- Epoxy Resin
- Araldite
- Silicon Dioxide
- Aluminium oxide
- Titanium oxide

Introduction of Epoxy Resin

Epoxy resins are polymeric or semi-polymeric materials, and as such rarely exist as pure substances, since variable chain length results from the polymerization reaction used to produce them. High purity grades can be produced for certain applications, e.g. using a distillation purification process. One downside of high purity liquid grades is their tendency to form crystalline solids due to their highly regular structure, which require melting to enable processing.

The applications for epoxy-based materials are extensive and include coatings, adhesives and composite materials such as those using carbon fiber and fiber glass reinforcements (although polyester, vinyl ester, and other thermosetting resins are also used for glass-reinforced plastic). The chemistryof epoxies and the range of commercially available variations allow cure polymersto be produced with a very broad range of properties. In general, epoxies are knownfor their excellent adhesion, chemical and heat resistance, good-to-excellent mechanical properties and very good electrical insulating properties. Many properties of epoxies can be modified (for example silver-filled epoxies withgood electrical conductivity are available, although epoxies are typically electrically insulating). Variations offering high thermal insulation, or thermal conductivity combined with high electrical resistance for electronics applications, are available.

Hardener

Hardener is high viscous liquid material, mixed with resin in suitable proportion during the process of preparation of composites which helps in the solidification of the wet, smooth composite. It is used to harden the smooth composite hence it is called as hardener.

Araldite adhesive sets by the interaction of an epoxy resin with a hardener. Mixing an epoxy resin and hardener together starts a chemical reaction that produces heat - an exothermic reaction. It is claimed that after curing the bond is impervious to boiling water and to all common organic solvents.

Catalyst

Catalysis is the increase in the rate of a chemical reaction due to the participation of an additional substance called a catalyst. With a catalyst, reactions occur faster and require less activation energy. Because catalysts are not consumed in the catalyzed reaction, they can continue to catalyze the reaction of further quantities of reactant. Often only tiny amounts are required.

Catalysts are substances that increase the rate of a reaction by providing a low energy "shortcut" from reactants to products. In some cases, reactions occur so slowly that without a catalyst, they are of little value. Nearly all reactions that occur in living cells require catalysts called enzymes- without them, life would be impossible. There are two important classes of catalysts: homogenous catalysts like enzymes and aqueous ions that are uniformly mixed with the reactants and heterogeneous catalysts that provide a surface that holds and reconfigures the reactants in a way that is favourable for reaction.

SILICON DIOXIDE

Silicon Dioxide is a natural compound of oxygen and silicon, found mostly in the sand. It is also known as Silica, composed of silicon and oxygen, having chemical formula SiO2, or silicon dioxide. There are various forms of Silica, and all silica forms are identical in chemical composition but contain different atom arrangements. Silica has three primary crystalline varieties, quartz, tridymite, and cristobalite. Silicon dioxide is transparent to grey, crystalline, odourless, or an amorphous solid. They have melting and boiling points as 1713º C and 2950º C, respectively. The density is about 2.648 g/cm3. It is insoluble in both acid and water and soluble in hydrofluoric acid. Its molecular weight is about 60.08 g/mol. Silicon dioxide is not a very reactive compound because the polarity of the molecule is zero. The 'Si' forms two double bonds with the oxygen. Therefore, it's a very stable molecule. Moreover, it has high dielectric strength, so that it is used as an insulator and semiconductor.

There is various Silicon dioxide used in electronic, chemical, and pharmaceutical industries. In the chemical industry, it is used in the production of adhesives and sealants, adsorbents, ceramic, porcelain, corrosion inhibitors, anti-adhesives, dyes, and paint additives. In addition, silicon dioxide production occurs in agricultural chemicals. Coming to pharmaceutical industries, it helps as an additive of food and medicines to absorb water.

ALUMINIUM OXIDE

Aluminium oxide has a chemical formula Al2O3. Aluminum oxide is a chemical substance made up of atoms of aluminum and oxygen. It is amphoteric in nature, and is used in various chemical, industrial and commercial applications. Aluminium oxide may be found in nature as corundum, rubies, sapphires, and emeralds. It's an alkaline earth compound that interacts with both acids and bases. It appears white and exists as a solid. It has no odour and is insoluble in water. This molecule is most commonly found in crystalline form, which is known as -aluminium oxide or corundum. Because of its hardness, it is usually utilized as an abrasive and in cutting tools. Although aluminum oxide is an electrical insulator, it exhibits thermal conductivity in ceramic material. it has a relatively high melting point (2345K) and boiling point (3250K) and has a density of 3.987g/cm^3. It is most commonly utilized as a ceramic material. It is used as a plastic filler and Aluminosilicate glass is a common glass that contains aluminium oxide. Aluminosilicate glass comprises 5–10% of Aluminium oxide.

It is utilized as a catalyst in various industrial processes. For example, the Aluminium oxide is used as a catalyst in the Claus process, which converts hydrogen sulfide waste into elemental sulfur. Aluminium oxide can be used to eliminate water from gas streams. Aluminium oxide flakes are used in paints to add a reflecting or decorative look.

TITANIUM OXIDE

Titanium oxide (TiO_2) is available in the form of nanocrystals or nanodots having a high surface area. They exhibit magnetic properties. Titanium oxide is also known as flamenco, rutile, titanium dioxide . Titanium is strong, hard, silvery–whitish, lustrous, corrosion-resistant, and a lightweight transition metal. Chemically, it shows many similarities with zirconium. In the aqueous phase, it shows similarities with chromium and vanadium. At high temperatures, it forms a protective oxide coating which gives it a corrosion-resistant nature, but at normal temperature, it resists tarnish. It is insoluble in water but can dissolve in concentrated acids. On heating, titanium is malleable and ductile. On combining with halogens, or heating to obtain dioxide, metal burns in the air. The melting point of titanium is 1668°C and its boiling point is 3287°C. It has a density of 4.5 grams per cubic centimeter and exists as a solid phase at room temperature.

Titanium oxide nanoparticles are known for their ability to inhibit bacterial growth and prevent further formation of cell structures. Titanium oxide sub micron powder is mostly utilized as a white pigment due to its high diffraction index, strong light scattering, incident-light reflection capability, and a high UV resistance. These properties make TiO2 the standard pigment found in white dispersion paints with high hiding power. Titanium oxide (titania) have generated great interest due to its chemical stability and low toxicity. Due to these properties, titania is suitable for use in medical implants. A special engineered titanium oxide with controlled porosity and composition is ideal for protein adsorption and improves tissue attachment of implants. Titanium oxide is used in paint pigments, plastics, and enamels. Titanium is used in biological implants, in joints such as ball and socket joint replacement, hips, pins for bone settings.

Introduction to Fabrication Processes

Wet/Hand Lay-Up

The fibers are first put in place in the mould. The fibers can be in the form of woven, knitted, stitched or bonded fabrics. Then the resin is impregnated. The impregnation of resin is done by using rollers, brushes or a nip-roller type impregnator. The impregnation helps in forcing the resin inside the fabric. The laminates fabricated by this process are then cured under standard atmospheric conditions. The materials that can be used have, in general, no restrictions. One can use combination of resins like epoxy, polyester, vinyl ester, phenolic and any fiber material. Fig 3.1 shows the simple hand layup technique.

Advantages of Hand Lay up

- The process results in low cost tooling with the use of room-temperature cure resins.
- The process is simple to use.
- Any combination of fibers and matrix materials are used.
- Higher fiber contents and longer fiber as compared to other processes.

Disadvantages

- Since the process is worked by hands, there are safety and hazard considerations.
- The resin needs to be less viscous so that it can be easily worked by hands.
- The quality of the final product is highly skill dependent of the labour.
- Uniform distribution of resin inside the fabric isnot possible. It leads to voids in the laminates.
- Possibility of diluting the contents.

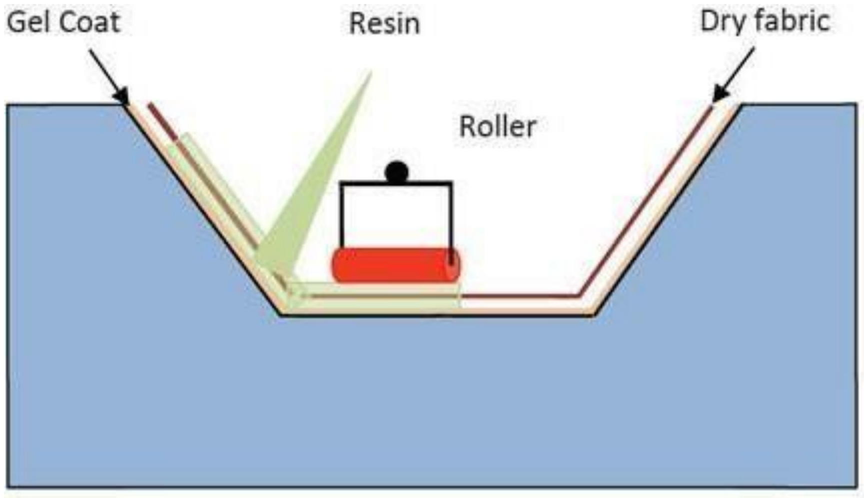

Fig 3.1 Hand Lay-up Technique

Pultrusion

It is a continuous process in which composites in the form of fibers and fabrics are pulled through a bath of liquid resin. Then the fibers wetted with resin are pulled through a heated die. The die plays important roles like completing the impregnation and controlling the resin. Further, the material is cured to its final shape. The die shape used in this process is nothing the replica of the final product. Finally, the finished product is cut to length. The resins like epoxy, polyester, vinyl ester and phenolic can be used with any fibers.

Vacuum Bagging

This is basically an extension of the wet lay-up process described above where pressure is applied to the laminate once laid-up in order to improve its consolidation. This is achieved by sealing a plastic film over the wet laid-up laminate and onto the tool. The air under the bag is extracted by a vacuum pump and thus up to one atmosphere of pressure can be applied to the laminate to consolidate it.

Centrifugal Casting

In this process the chopped fibers and the resin is sent under pressure to the cylindrical moulding. The moulding is rotating. Due to centrifugal action, the mixture of resin and chopped fibers get deposited on wall of the moulding. Thus, the mixture gets the final form of the product.

Filament Winding

This process is an automated process. This process is used in the fabrication of components or structures made with flexible fibers. This process is primarily used for hollow, generally circular or oval sectioned components. Fiber tows are passed through a resin bath before being wound onto a mandrel in a variety of orientations, controlled by the fiber feeding mechanism, and rate of rotation of the mandrel. The wound component is then cured in an oven or autoclave. It can use resins like epoxy, polyester, vinyl ester and phenolic along with any fiber. The fiber can be directly from creel, non-woven or stitched into a fabric form.

Applications of composite materials

- **Aerospace:** Aircraft, spacecraft, satellites, space telescopes, space shuttle,space station, missiles, and booster's rockets, helicopters (due to high specific strength and stiffness) fatigue life, dimensional stability.
- **Missile:** Rocket motor cases, Nozzles, aerodynamic fairings etc.
- **Launch vehicle:** Inter stage structure, High temperature nozzles, and control surfaces etc.
- **Composite railway carriers:** Bodies of railway bogeys, seats, doors, gear case, pantographs etc.
- **Sports equipments:** Tennis rockets, golf clubs, base-ball bats, helmets etc.
- **Automotive:** Drive shafts, fan blades, clutch plates, gaskets, engine parts etc.
- **Industrial:** conveyer belts, hoses, tear and puncture resistant fabrics, ropes, cables etc.
- **Medical:** Wheel chairs, crutches, Hip joints, surgical equipments etc.
- **Electronic:** chips in electronic computing devices, electronic packaging materials etc.
- **Marine:** ship hulls, masts, hydrofoils, hovercrafts, propellers etc.
- **Military:** Helmets, bullet proof vests, impact resistant vehicles, portable bridges etc.

- **Miscellaneous:** Paints and coatings, adhesives, industrial tooling, petroleum and petrochemical etc.

Fabrication of Composites by Hand lay-up technique

This chapter describes about the method of fabrication and various tests that are to beconducted Hand lay-up technique is the simplest and oldest open molding method of composite fabrication process. In this work, SiO_2 ,TiO_2 and Al_2O_3 powder particles as filler materials different weight percentages given in Table 3.1 are mixed with epoxy resin, hardener and fiber reinforcements. The thickness of the composite sheet to be fabricated is controlled by the layers placed on the mould. After the preparation of composite sheets, the work pieces are cured for 24 to 48 hrs so that work pieces will get hard as shown in Fig 3.1. After this, the specimens were cut according to ASTM standards using cutting machine as shown in Fig3.2 and finished the composite materialwith Emory paper as shown in Fig 3.4. The designations of work pieces are shown inTable 3.1.

Table 3.1. **Material Selection**

Material	**Sample S1**	**Sample S2**	**Sample S3**	**Sample S4**	**Sample S5**
GlassFiber	42%	41.35%	40.77%	40.20%	39.50%
Epoxy Resin	57%	56.15%	55.33%	54.30%	53.50%
Hardner	1.0%	1.0%	0.9%	1%	1%
SiO_2	0%	0.5%	1.0%	1.5%	2.0%
TiO_2	0%	0.5%	1.0%	1.5%	2.0%
Al_2O_3	0%	0.5%	1.0%	1.5%	2.0%
Total	100%	100%	100%	100%	100%

Fig 3.2(a)

Fig 3.2(b)

Fig 3.2 Fabrication by hand lay-up method

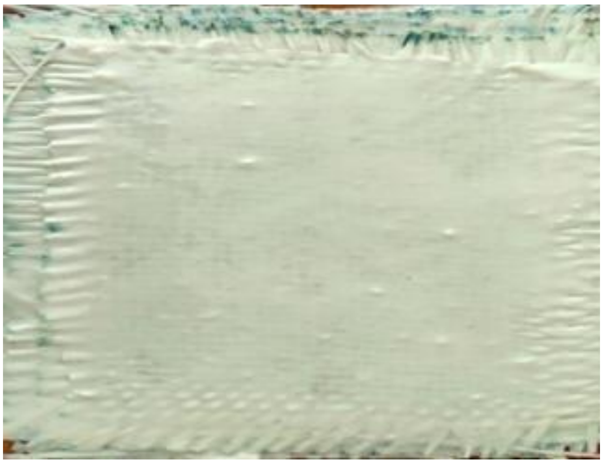

Fig 3.3 Solidified composite sheets after curing 48 hours at room temperature

Fig 3.4 Specimens after cutting

Chapter-4

TENSILE BEHAVIOUR OF GFRP COMPOSITES

CHAPTER 4
TENSILE BEHAVIOUR OF GFRP COMPOSITES

INTRODUCTION

In this chapter the tensile behaviour of different samples ofGFRP composites are presented. The Tensile test was carried out on computerised UTM, as per ASTM standards. The four specimens were subjected to tensile test and their values were reported.

Equipment for Tensile Testing

A computerised UTM is used to find the tensile properties of the composites. Universal Testing Machine which is available in electronic and computerized functioning. This machine is used to test the tensile and compressive properties of material. The reason Universal Testing machine is named so because it can perform all the tests right from compression, bending to tension and examine the material in all mechanical properties. Operation of the universal testing machine is by hydraulic transmission of load from the test specimen to a separately housed load indicator. The system is ideal since it replaces transmission of load: through levers andknife edges, which are prone to wear and damage due to shock on rupture of test pieces.Load is applied by a hydrostatically lubricated ram. Main cylinder pressure is transmitted to the cylinder of the pendulum dynamometer system housed in the controlpanel. The cylinder of the dynamometer is also of self - lubricating design. The load transmitted to the cylinder of the dynamometer is transferred through a leverage to the pendulum. Displacement of the pendulum actuates the rack and pinion mechanism which operates the load indicator pointer and the autographic recorder. The deflection of the pendulum represents the absolute load applied on the test specimen. Return movement of the pendulum is effectively damped to absorb energy in the event of sudden breakage of the specimen

Method of tensile testing

The Composite material used in the current study consists of glass fibre, epoxy resin as matrix and silicon carbide and rubber powder as filler materials in different weight percentages. Tensile test is the basic important test to evaluate the strength of any material. The machine is equipped with advanced load cell technology for faster testing and reduction of inertia errors. Tensile test is performed based on ASTMD638-02a standard of (Type1) shown in fig 4.2(C). The specimens before test and after test are indicated in fig 4.2(a) and fig 4.2(b).

Fig 4.1 Tensile Testing Machine

Table 4.1 Technical specifications for computerized version universal testing machine

MODEL	**TUE-C-600**
Measuring capacity (KN)	600
Measuring Range (KN)	0-600
Least count (KN)	0.06
Resolution of piston movement(mm)	0.1

Overall dimensions approx(mm)	2200 × 800 × 2400
Weight approx..(kg)	3100
Distance between columns(mm)	600
Piston stroke(mm)	250
Power supply	3 phase 415v 50HZ AC
Total H.P	2.5
Pair of compression plate diameter(mm)	120
Tension test jaws for flat specimen thickness(mm)	0-30
Tension test jaws for Maximum width of flat specimen(mm)	70

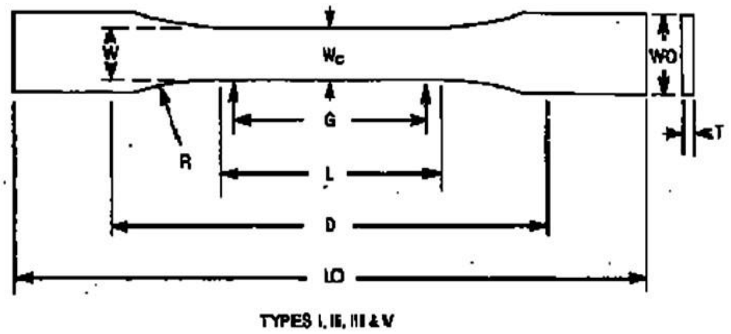

Fig 4.2 Tensile test specimen as per ASTM standard

The notations used in Fig 4.1 (c) are indicated with the dimensions Lo – Overall length 165(6.5) mm, D- Distance between grips 115(4.5) mm, L- Length of narrow section 57 (2.25) mm, G- Gauge length 50(2) mm, R- Radius of fillet 76(3.0) mm, Wo-Width overall 19 (0.75) mm, Wc- Width of narrow section 13(0.50) mm, T – Thickness of the specimen 10 (0.50) mm.

Initially, the specimens are fixed between two clamping jaws firmly and loaded gradually with incremental load until failure takes place. The values of deformation against each load value are noted and tabulated. The breaking load for each specimen is noted and ultimate tensile strength values of all the samples with varying surface treatments are calculated.

Fig 4.3 Specimens after testing

Analysis of tensile test result:

Type of composite	Maximum load (KN)	Load at break (KN)	Ultimate tensile strength (Mpa)
S1(0%)	15.81	7.63	152.019
S2(0.5%)	21.85	5.46	210.14
S3(1.0%)	24.42	8.98	254.278
S4(1.5%)	12.45	2.88	118.41
S5(2.0%)	20.52	6.9	197.308

Table4.2. Ultimate tensile strength values of all specimens

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TENSILE TEST REPORT

Machine Model	: TUE-C-600	Test File Name	: 44_2022.Utm
Machine Serial No	: -----	Date & Time	: 18/03/2022
Customer Name	: Fine Spavy Assco. & Engg. Pvt Ltd	Customer Address	: C-45/2, M.I.D.C. Miraj 416410 Sangli Maharashtra
Order No.	:	Test Type	: Tensile
Lot No.	:	Heat No.	:

Input Data

Specimen Shape	: Flat	
SpecimenType	: Glassfibre+ epoxy+Tio2+Sio2+Al2o3	
Specimen Description	: 0%	
Specimen Width	: 13	mm
Specimen Thickness	: 8	mm
Initial G.L. For % elong	: 115	mm
Pre Load Value	: 0	kN
Max. Load	: 600	kN
Max. Elongation	: 250	mm
Specimen Cross Section Area	: 104.000	mm2

Output Data

Load At Yield	: 5.28	kN
Elongation At Yield	: 0.000	mm
Yield Stress	: 50.769	N/mm2
Load at Peak	: 7.470	kN
Elongation at Peak	: 0.00	mm
Tensile Strength	: 71.827	N/mm2
Load At Break	: 6.060	kN
Elongation At Break	: 21.180	mm
Breaking Strength	: 58.269	N/mm2

Stress Vs. Strain

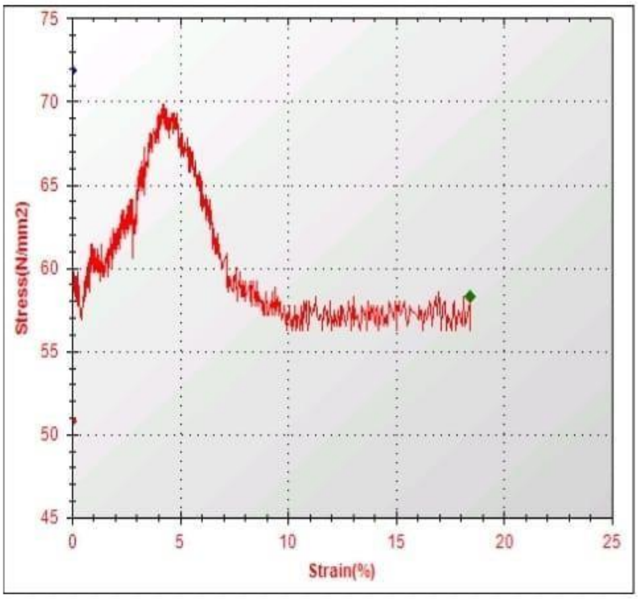

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Fig 4.5 Tensile Stress vs strain for sample S1

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TENSILE TEST REPORT

Machine Model	: TUE-C-600	Test File Name	: 45_2022.Utm
Machine Serial No	: -----	Date & Time	: 18/03/2022
Customer Name	: Fine Spavy Assco. & Engg. Pvt Ltd	Customer Address	: C-45/2, M.I.D.C. Miraj 416410 Sangli Maharashtra
Order No.	:	Test Type	: Tensile
Lot No.	:	Heat No.	:

Input Data

Specimen Shape	: Flat	
SpecimenType	: Glassfibre+epoxy+Tio2+Sio2+Al2o3	
Specimen Description	: 0.5%	
Specimen Width	: 13	mm
Specimen Thickness	: 8	mm
Initial G.L. For % elong	: 115	mm
Pre Load Value	: 0	kN
Max. Load	: 600	kN
Max. Elongation	: 250	mm
Specimen Cross Section Area	: 104.000	mm2

Output Data

Load At Yield	: 15.84	kN
Elongation At Yield	: 8.120	mm
Yield Stress	: 152.308	N/mm2
Load at Peak	: 19.800	kN
Elongation at Peak	: 9.660	mm
Tensile Strength	: 190.385	N/mm2
Load At Break	: 4.410	kN
Elongation At Break	: 9.740	mm
Breaking Strength	: 42.404	N/mm2

Stress Vs. Strain

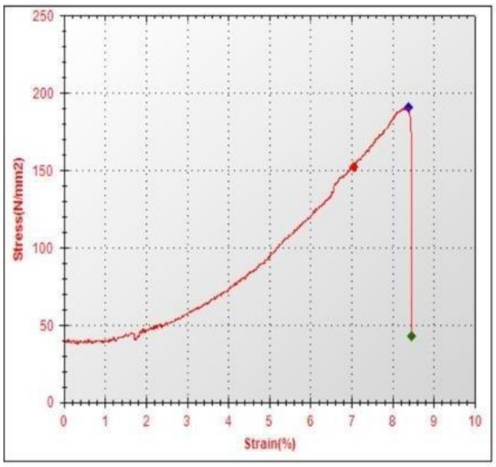

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Fig 4.5 Tensile Stress vs strain for sample S2

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TENSILE TEST REPORT

Machine Model	: TUE-C-600	Test File Name	: 46_2022.Utm
Machine Serial No	: -----	Date & Time	: 18/03/2022
Customer Name	: Fine Spavy Assco. & Engg. Pvt Ltd	Customer Address	: C-45/2, M.I.D.C. Miraj 416410 Sangli Maharashtra
Order No.	:	Test Type	: Tensile
Lot No.	:	Heat No.	:

Input Data

Specimen Shape	: Flat	
SpecimenType	: Glassfibre+epoxy+Tio2+Sio2+Al2o3	
Specimen Description	: 1%	
Specimen Width	: 13	mm
Specimen Thickness	: 8	mm
Initial G.L. For % elong	: 115	mm
Pre Load Value	: 0	kN
Max. Load	: 600	kN
Max. Elongation	: 250	mm
Specimen Cross Section Area	: 104.000	mm2

Output Data

Load At Yield	: 21.36	kN
Elongation At Yield	: 8.020	mm
Yield Stress	: 205.385	N/mm2
Load at Peak	: 26.730	kN
Elongation at Peak	: 10.030	mm
Tensile Strength	: 257.019	N/mm2
Load At Break	: 11.820	kN
Elongation At Break	: 10.520	mm
Breaking Strength	: 113.654	N/mm2

Stress Vs. Strain

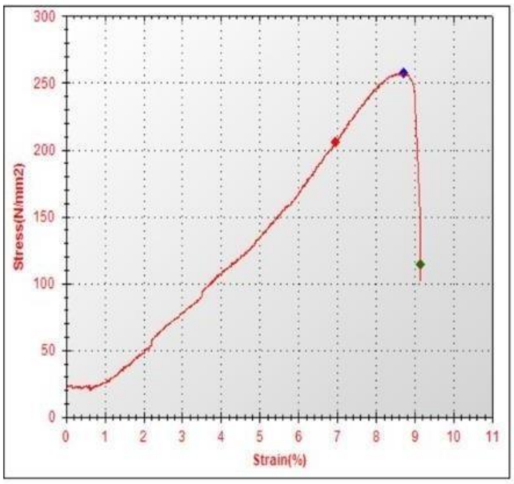

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Fig.4.6 Stress vs strain for sample S3

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TENSILE TEST REPORT

Machine Model	: TUE-C-600	Test File Name	: 50_2022.Utm
Machine Serial No	: -----	Date & Time	: 18/03/2022
Customer Name	: Fine Spavy Assco. & Engg. Pvt Ltd	Customer Address	: C-45/2, M.I.D.C. Miraj 416410 Sangli Maharashtra
Order No.	:	Test Type	: Tensile
Lot No.	:	Heat No.	:

Input Data

Specimen Shape	: Flat	
SpecimenType	: Glassfibre+epoxy+Tio2+Sio2+Al2o3	
Specimen Description	: 1.5%	
Specimen Width	: 13	mm
Specimen Thickness	: 8	mm
Initial G.L. For % elong	: 115	mm
Pre Load Value	: 0	kN
Max. Load	: 600	kN
Max. Elongation	: 250	mm
Specimen Cross Section Area	: 104.000	mm2

Output Data

Load At Yield	: 11.13	kN
Elongation At Yield	: 8.790	mm
Yield Stress	: 107.019	N/mm2
Load at Peak	: 13.950	kN
Elongation at Peak	: 9.550	mm
Tensile Strength	: 134.135	N/mm2
Load At Break	: 2.880	kN
Elongation At Break	: 9.910	mm
Breaking Strength	: 27.692	N/mm2

Stress Vs. Strain

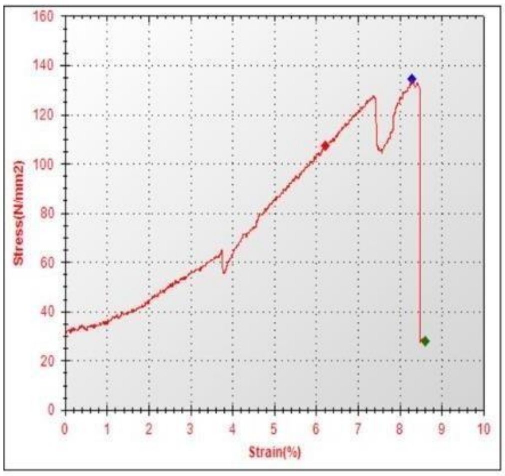

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Fig. 4.7 Stress vs strain for sample S4

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TENSILE TEST REPORT

Machine Model	: TUE-C-600	Test File Name	: 52_2022.Utm
Machine Serial No	: -----	Date & Time	: 18/03/2022
Customer Name	: Fine Spavy Assco. & Engg. Pvt Ltd	Customer Address	: C-45/2, M.I.D.C. Miraj 416410 Sangli Maharashtra
Order No.	:	Test Type	: Tensile
Lot No.	:	Heat No.	:

Input Data

Specimen Shape	: Flat	
SpecimenType	: Glassfibre+epoxy+Tio2+Sio2+Al2o3	
Specimen Description	: 2%	
Specimen Width	: 13	mm
Specimen Thickness	: 8	mm
Initial G.L. For % elong	: 115	mm
Pre Load Value	: 0	kN
Max. Load	: 600	kN
Max. Elongation	: 250	mm
Specimen Cross Section Area	: 104.000	mm2

Output Data

Load At Yield	: 18.54	kN
Elongation At Yield	: 7.510	mm
Yield Stress	: 178.269	N/mm2
Load at Peak	: 23.190	kN
Elongation at Peak	: 9.540	mm
Tensile Strength	: 222.981	N/mm2
Load At Break	: 6.900	kN
Elongation At Break	: 9.650	mm
Breaking Strength	: 66.346	N/mm2

Stress Vs. Strain

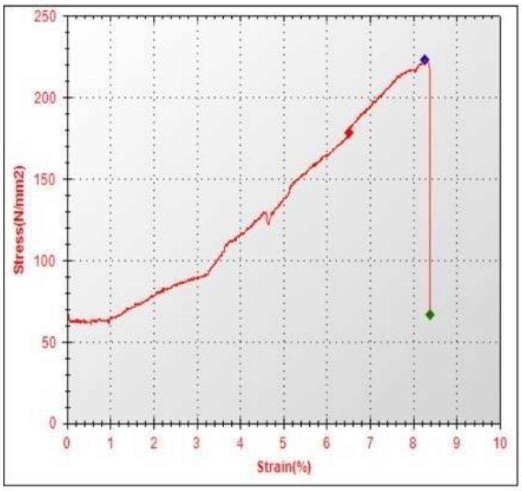

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Fig. 4.8 Stress vs strain for sample S5

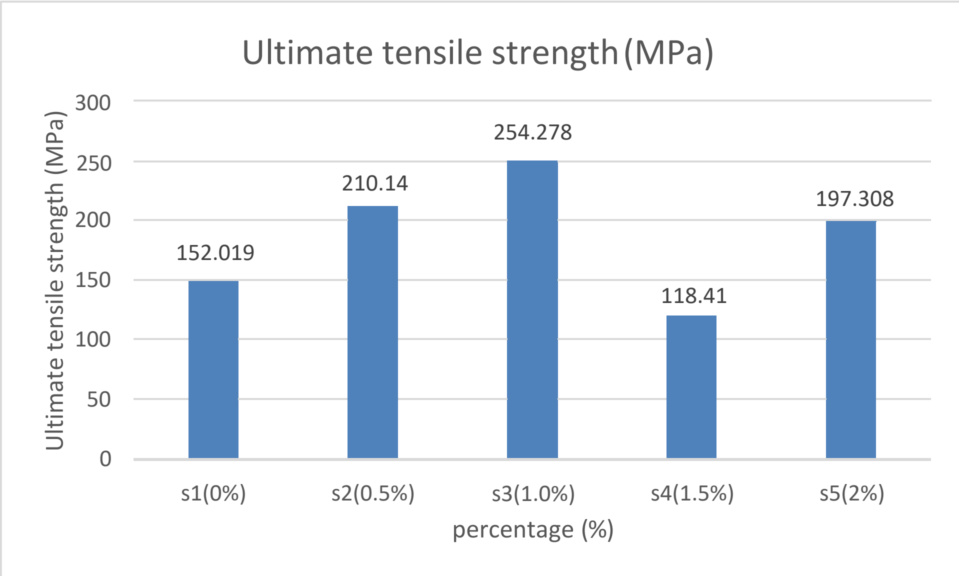

Fig.4.9 Variation tensile Strength for different weight percentages of fillers

This sample specimen S3 with selected ingredients can sustain more load and can extend its application in usage in glass fiber reinforced composites in aerospace and automobile industries, The main reason to have better tensile properties for the sample specimen S4 is the selection of ingredients. The load carried by the specimen is taken initially by the fiber and transmitted to the ingredients.

Chapter-5

FLEXURAL BEHAVIOUR OF GFRP COMPOSITES

Chapter 5

FLEXURAL BEHAVIOUR OF GFRP COMPOSITES

INTRODUCTION

In this chapter the flexural behaviour of different samples of Glass fiber reinforced plastics with different compositions is presented.The flexural test wascarried out on computerised UTM ,as per the ASTM standards.The test specimens areprepared as per ASTM D790(125×3.2×12.7)mm.The four specimens were subjected toflexural test and their values were reported.

Equipment for Flexural testing

A 10 ton capacity computerised UTM was used for conducting flexural test. The instrument is equipped with integrated computer compatible software in order to display various graphical results. And a special three point loading attachment is provided for conducting flexural test.

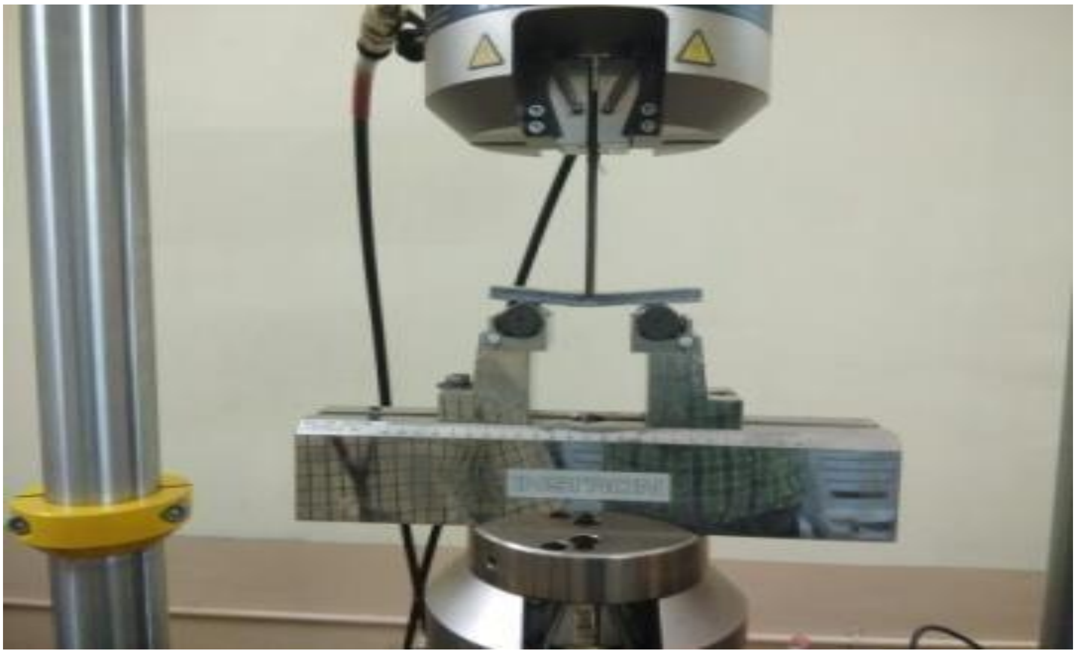

Fig5.1 Flexural test apparatus

Methods of Flexural testing

There are three basic methods which cover the determination of flexural properties of the polymer.

Method 1

It is basically a three point loading, utilizing centre loading on a simply supported beam. A bar of rectangular cross section rests on two supports and is loaded by means of a loading nose at the centre. The maximum axial fiber stress occurs on a line under the

Fig.5.2 Three Point Bending

Method 2

In this method a four point loading system is utilized .Two load points equally spaced from their adjacent supporting points, with a distance between loading points equal to one third of the support span. In this test, the bar lies on a two points each at an equivalent distance from the adjacent support points.

Either method can be used for conducting the experiment. Method 1 is usedfor materials that break at relatively at low loads. Method 2 is used particularly for those materials that undergo large deflections during testing. Standard test method, ASTM D790, for flexural properties of reinforced polymer composites has been used to test the Composites. Table 5.1 indicating the maximum bending load and maximum bending stress.

Flexural test is performed on all specimens by mounting a three point bending load fixture, shown in fig 5.1. The sample to be tested is placed on the two end supports and a concentrated load is applied at the centre of thespecimen. This test determines the maximum amount of load carried by the specimen under bending load.

Analysis of Flexural test results

Table 5.1. Flexural strength values for all samples

Type of composite	Load at max Flexure load (KN)	Flexural stress at max flexural load (Mpa)
S1(0%)	4.45	2175.293
S2(0.5%)	5.78	2722.555
S3(1.0%)	7.29	3559.57
S4(1.5%)	7.2	2636.719
S5(2.0%)	8.16	2988.281

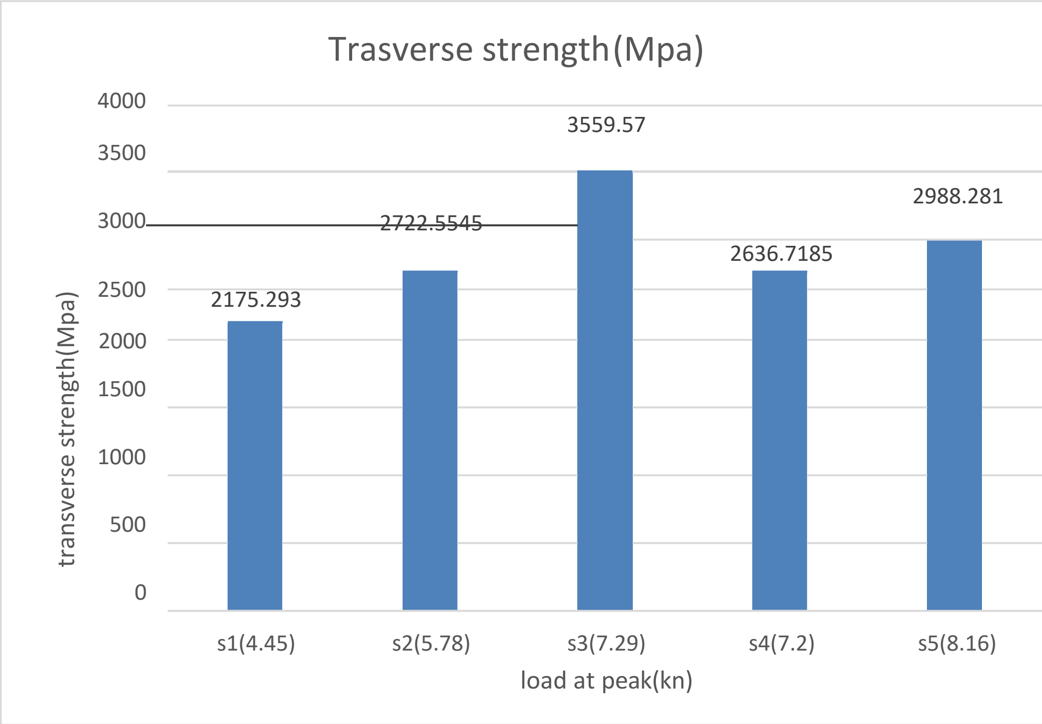

Fig. 5.3 Variation of Flexural Strength with varying percentages of fillers

From Fig5.4, it was observed that sample S3 along withtheremaining ingredients can sustain more bending load (i.e 7.29KN) and possess a high flexural strength value (i.e 3559.57 MPa) compared to the remaining formulations of the material. This sample specimen S3 with selected ingredients can sustain more bendingload and can extend its application in the fabrication of brake friction material. The main reason to have better flexural properties for the sample specimen S3 is the selection ofbetter ingredients The load carried by the specimen is initially transmitted to the fiber and then it is transmitted to the ingredients.

Chapter-6

IMPACT BEHAVIOUR OF GFRP COMPOSITES

Chapter 6

IMPACT BEHAVIOUR OF GFRP COMPOSITES

INTRODUCTION

In this chapter the impact behaviour of different samples of GFRP composites is presented. The Impact test was carried out on Izod Impact testing machine, as per the ASTM standards. The test specimens are prepared as per ASTM D256 (64X12X4) mm. The four specimens were subjected to Impact test and their values were reported.

The equipment and the method for impact testing are discussed in the sections 8.2 and 8.3 respectively. In section 8.4, the analysis on the results of the experimental investigations for the impact strength various samples of glass fibre reinforced polymer resin matrix composites of different weight ratios is presented.

Equipment for Impact Testing

An analog Izod impact tester is used to find the impact strength of glass fibre reinforced polymer resin matrix composite specimens. The equipment has four working ranges of impact strength and they are 0-2.71 J,0-5.42 J, 0-10.84 J and 0-21.68 J, with a minimum resolution on each scale of 0.02 J, 0.05 J, 0.1 J and 0.2 J respectively.

Fig 6.1 Impact Test Machine

Four scales and the corresponding four hammers are provided for all the above working ranges. The four hammers are designated as R1, R2, R3 and R4 respectively.

Method of impact testing

Impact test is conducted as per ASTM D256 standards specimen cut in to 64× 12.7 × 5 □□.The behaviour of material under dynamic loading may sometimes differ markedly from their behaviour under static or gradually increasing loads. The capacity of material to withstand such blows (impact or shock loads) without fracture is called impact strength. The material with high toughness will generally exhibit greater impact strength. Static tests are unsuitable for determining the impact strength. Dynamic tests have been developed to establish impact resistance by using a notched specimen. The impact testing machine is shown in Fig 8.1. The specimen is held in an anvil and is broken by a single blow of the pendulum, which falls from a fixed height (h1). After breaking the specimen the pendulum continues to swing on the other side through a height(h2), if the weight of the hammer is W, then the energy delivered to the specimen to break it is W(h1-h2). The pendulum type impact machine is provided with scales and pointer, and scales are usually calibrated to read energy required to break the specimen in KJ.

It is obvious that the initial energy, Wh1 must be greater than that required to break thespecimen. Correction for the energy losses due to machine friction and air resistance onthe pendulum may be made by repeating the experiment without placing a specimen onthe anvil and with indicator set at zero. The energy lost in friction, E_f may be computed.The actual energy absorbed is given by equation

$$E_a=E-E_f$$

The small amount of energy lost in friction may be neglected in commercial testing.

After calculating the energy required to break the specimen, the impact strength canbe found by the formula,

Impact strength = $\frac{\text{□□□□□□□ □□ □□□□□□□□□}}{\text{□□□□□□−□□□□□□□□ □□□□ □□ □□□□}h}$

.

Table 8.1 Technical specifications of impact tester

MODEL	AIT-300
Maximum Impact Energy of pendulum(joules)	300
Minimum Value of scale graduation(joules)	2
Weight of the machine(kg)	250
Distance between supports(mm)	40
Angle of test piece support	78° to80°
Angle of inclination of supports	0°
Radius of supports(mm)	1-1.5
Maximum width of striker(mm)	18
Angle of striking edge	$30^0 \pm 1^0$
Radius of curvature striking edge(mm)	2-2.5
Pendulum drop angle	140°
Effective weight of pendulum(kg)	22.35
Suitable for specimen size(mm)	10 × 10 × 55

Calculation and Analysis of Impact Strength

Impact strength = $\frac{\text{[illegible]}}{\text{[illegible]} - \text{[illegible]}\, h}$

Actual Energy observed in Fracture of bare material $E_a = E - E_f$

$E_a = 56 - 36 = 20$

Cross-section area at notch in Fracture of bare material A=8 ×8=64

Impact strength of Bare material = $\frac{7}{70}$ =0.1 J/mm^2

Impact strength of S1 material =0.169 J/mm^2

Impact strength of S2 material =0.173 J/mm^2

Impact strength of S3 material =0.203 J/mm^2

Impact strength of S4 material =0.159 J/mm^2

Impact strength of S5 material =0.150 J/mm^2

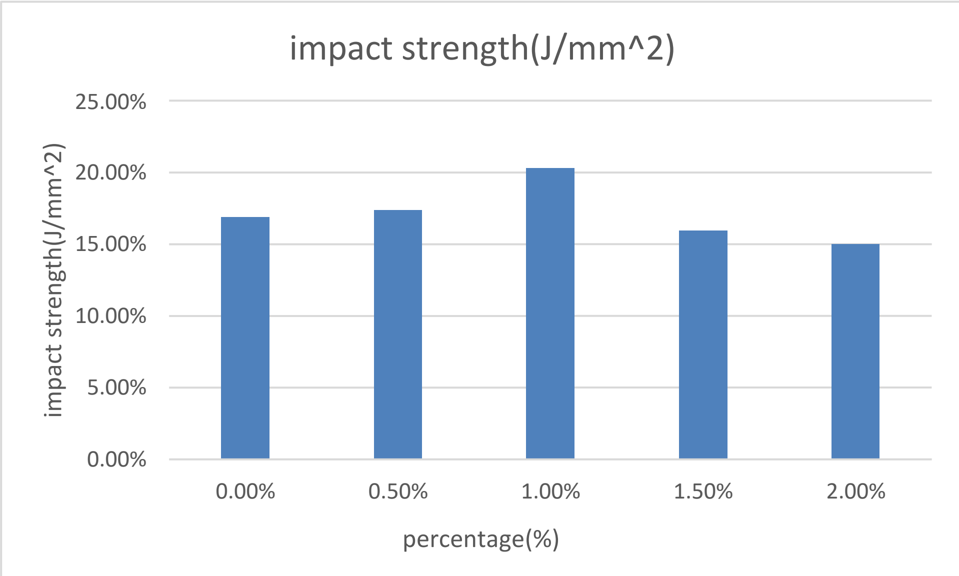

Fig.6.2 Variation of Impact Strength with varying percentage of fillers

From the above bar chart it is clearly understood that the impact strength of the sample S2 is more when compared to the other samples. Hence Impact strength of sample S2 ranges from 20% to 30% greater than the remaining composites of different compositions.

Chapter-7

CONCLUSION

Chapter-7

CONCLUSIONS

Glass fiber reinforced composite materials are fabricated by varying the content of filler materials such as Sio_2& $Al_2o_3$and Tio_2 Five different formulations of composite sheets are fabricated. Experimental investigation on tensile, flexural, and Impact behaviour of Glass fibre reinforced polymer composites with different weight percentages of filler materials have been carried out in the present research work. All the tests are conducted as per ASTM standards. Critical observations of the present study are highlighted in this chapter.

The Tensile test results :

Tensile test is utilized for assessing tensile properties of epoxy composites loaded up with Al_20_3, SiO_2 and TiO_2 metal powders. It is observed that with increase in metal powder percentages tensile strength of composites decreases. At 0% to 1% (weight percentage) tensile strength increases gradually and then decreases the tensile strength upto 1% to 2% (weight percentage), from the graph the maximum Tensile strength is 254.278Mpa

The flexural test results :

Flexural Bending test is utilized for assessing flexural properties of epoxy composites loaded up with Al_20_3, SiO_2 and TiO_2 metal powders. It is observed that with increase in metal powder percentages flexural strength of composites decreases. At 0% to 1% (weight percentage) flexural strength increases gradually and then decreases the flexural strength upto 1% to 2% (weight percentage), from the graph the maximum flexural strength is 3559.57 MPa.

The Impact Test Results:

Impact test is utilized for assessing the impact properties of epoxy composites loaded up with Al_20_3, SiO_2 and TiO_2 metal powders it is observed that with the increase in metal powders percentages impact strength of composites decreases at 0% to 1%(weight percentage) impact strength increases gradually and the decrease of impact strength upto 1% to 2%(weight percentages), from the graph the maximum impact strength is 0.203Mpa.

TABLE 7.1 Comparison of strengths for different filler percentages

Type of GFRP samples	Tensile Strength (Mpa)	Flexural Strength (Mpa)	Impact Strength (joules/□□^{2})
S1	152.019	2175.293	0.169
S2	210.14	2722.555	0.173
S3	254.278	3559.57	0.203
S4	118.41	2636.719	0.159
S5	197.308	2988.281	0.150

The mechanical properties is performed on all the samples of composite sheets. Based on mechanical property results, it was observed that sample sheet S3 with the selected ingredients possess higher ultimate tensile, and flexural strength value compared to remaining formulations of materials. It was also observed that, Impact test results reveal that, the sample specimen S3 possesses high impact energy compared to remaining formulations.

Therefore, based on the Mechanical tests it was observed that, sample specimen S3 possess better values compared to other material configurations. The mainreason to have better mechanical properties is the selection of ingredients like Silicon Oxide , Aluminium Oxide and Titanium Oxide and for improving mechanical properties of the composite. This material combination S3 can extend its usage in the field of aerospace and automobile industries.

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