Preparation and Anlysis of Mechanical Properties in Sisal Fiber/Glass Epoxy Composites Using Weibull Modulus

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ABSTRACT

Compressive properties are commonly weak parts in structural application of fiber composites. Matrix modification may provide an effective way to improve compressive performance of the composites. In this work, the compressive property of epoxies (usually as matrices of fiber composites) modified by different types of nanoparticles was firstly investigated for the following study on the compressive property of carbon fiber reinforced epoxy composites. fiber/epoxy composites were fabricated with the matrices modified with eglass epoxy and sisal fibre. Testing results showed that the effect of different particle contents on the compressive property of fiber/epoxy composites was more obvious than that in their idle state. Both the compressive and flexural results showed that fibre composition have evident strengthening effects on the compression and flexural responses of static laminates fabricated from fibres.

KEYWORDS:Sisalfibre,glassepoxy,weibullmodulus.

1. INTRODUCTION

Natural Fiber-reinforced (FRP) composites have been the primary choice for structural applications for the past four decades. These FRP's undergo multiple damage mechanisms during service. Matrix cracking is one of the prominent damage modes along with fiber breakage, longitudinal splitting, debonding and delamination. Matrix cracking is the first damage observed and generally leads to loss of stiffness, local stress redistribution and most importantly, path for moisture or other fluid ingression leading to further reduction in composite strength or loss of its integrity. Recently, there have been attempts to include matrix cracking and other damage-based models in the structural design.

Experimental investigation of matrix cracking and its effects on composite materials have been extensively reported and reviews on such findings are available in the literature. In the context of cross-ply laminates, the 'thickness effect 'characterizes the effect of thickness of $90\circ$ ply on the crack density evolution. Concurrently, the 'neighbouring ply effect 'characterizes the effect of varying thickness of the $0 \circ$ neighbouring ply on $90\circ$ ply. The thickness effect is studies with varied thickness of the coil spring fiber/glass epoxy fibers.

1.2 Classification of Composites

Composite materials can be classified in different ways. Classification based on the geometry of the reinforcement

which is responsible for the mechanical properties and high performance of the composites. A typical classification is presented in FIG 1. The two broad classes of composites are:
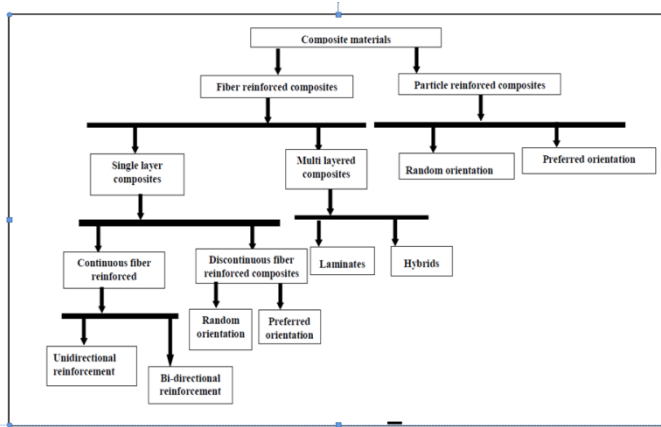
(i) Fibrous composites
(ii) Particulate composites

Figure 1. Classification of Composites

1.3 Particulate Composites

As the name itself indicates, the reinforcement is of particle nature (platelets are also included in this class). It may be spherical, cubic, tetragonal, platelet, or of other regular or irregular shape, but it is approximately equiaxed. In general, particles are not very effective in improving fracture resistance but they enhance the stiffness of the composite to a limited extent. Particle fillers are widely used to improve the properties of matrix materials such as to modify the thermal and electrical conductivities, improve performance at elevated temperatures, reduce friction, increase wear and abrasion resistance, improve machinability, increase surface hardness and reduce shrinkage.

1.3 (a) Fibrous composites

A fibre is characterized by its length being much greater compared to its cross-sectional dimensions. The dimensions of the reinforcement determine its capability of contributing its properties to the composite. Fibres are very effective in improving the fracture resistance of the matrix since a reinforcement having a long dimension discourages the growth of incipient cracks normal to the reinforcement that might otherwise lead to failure,

particularly with brittle matrices. Man-made filaments or fibres of non-polymeric materials exhibit much higher strength along their length since large flaws, which may be present in the bulk material, are minimized because of the small cross-sectional dimensions of the fibre. In the case of polymeric materials, orientation of the molecular structure is responsible for high strength and stiffness. Fibres, because of their small cross-sectional dimensions, are not directly usable in engineering applications. They are, therefore, embedded in matrix materials to form fibrous composites. The matrix serves to bind the fibres together, transfer loads to the fibres, and protect them against environmental attack and damage due to handling. In discontinuous fibre reinforced composites, the load transfer function of the matrix is more critical than in continuous fibre composites.

1.4 COMPONENTS OF A COMPOSITE MATERIAL

In its most basic form, a composite material is one, which is composed of at least two elements working together to produce material properties that are different to the properties of those elements on their own. In practice, most composites consist of a bulk material (the 'matrix'), and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix.

1.5 Role of matrix in a composite

Many materials when they are in a fibrous form exhibit very good strength but to achieve these properties the fibres should be bonded by a suitable matrix. The matrix isolates the fibres from one another in order to prevent abrasion and formation of new surface flaws and acts as a bridge to hold the fibres in place. A good matrix should possess ability to deform easily under applied load, transfer the load onto the fibres and evenly distributive stress concentration. A study of the nature of bonding forces in laminates indicates that upon initial loading there is a tendency for the adhesive bond between the reinforcement and the matrix to be broken. The frictional forces between them account for the high strength properties of the laminates.

Materials used as matrices in composites

In practice, most composites consist of a bulk material

(the matrix) and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix.

1.6 Bulk-Phases

1.6 (a) Metal Matrices

Metal matrix composites possess some attractive properties, when compared with organic matrices. These include (i) strength retention at higher temperatures, (ii) higher transverse strength, (iii) better electrical conductivity, (iv) superior thermal conductivity, (v) higher erosion resistance etc. However, the major disadvantage of metal matrix composites is their higher densities and consequently lower specific mechanical properties compared to polymer matrix composites. Another notable difficulty is the high-energy requirement for fabrication of such composites. In the aerospace industry interest has been concentrated primarily on fibre reinforced aluminium and titanium. Boron and to a lesser extent silicon carbide (SiC), have been investigated as the reinforcing fibres. Aluminium alloys reinforced with boron have been extensively produced by a variety of methods. Titanium reinforced with SiC, boron (coated with SiC) and even with beryllium, used for compressor blades. Good elastic modulus properties can be achieved by the unidirectional incorporation of fibres or whiskers in the metal matrix even though the bonding between them may be poor. But, strong metallic matrices rather than weak metal or polymer matrices are essential for good transverse modulus and shear strength. Carbon/graphite fibres have been used with metal matrices on a laboratory / experimental scale only, because most basic fabrication techniques involve high temperatures which have detrimental effects on the fibre. However, research on these linesis continuing in view of the potential of the composites.

1.6 (b) Polymer Matrices

In composite materials, the constituent which is continuous and present in greater quantity is called matrix. The main functions of the matrix are to hold or bind the fibre together, distribute the load evenly between the fibres and protect the fibre from the mechanical and environmental damage. It has advantages like low cost, good chemical and corrosion resistance, low specific gravity, high specific properties, easy processability, manufacturing flexibility and chemical stability . There are two major classes of polymers used as matrix materials such as thermoplastic and thermoset.

Thermoplastic are in general, ductile and tougher than thermoset materials. They are reversible and can be reshaped by application of heat and pressure. Thermoplastic molecules do not cross-link and therefore they are flexible and reformable. The most common materials used in thermoplastic composites are nylons, acrylic, polyethylene, polystyrene etc.

Thermo sets are materials that undergo a curing process through part fabrication and once cured cannot be re-melted or reformed. Thermoset matrix possesses distinct advantages over the thermoplastics such as higher operating temperature, creep resistance and good affinity to heterogeneous materials. Compared to thermoplastic composites, the initial low viscosity of thermoset polymers enables the higher concentration of both fillers and fibres to be incorporated in it while still holding good dispersion of filler and fibre wet-out . The most common resin materials used in thermoset composites are epoxy, phenolics, vinyl ester, polyester and polyaimides.

1.6 (c) Ceramic Matrices

Ceramic fibres, such as alumina and SiC (Silicon Carbide) are advantageous in very high temperature applications, and also where environment attack is an issue. Since ceramics have poor properties in tension and shear, most applications as reinforcement are in the particulate form (e.g. zinc and calcium phosphate). Ceramic Matrix Composites (CMCs) used in very high temperature environments, these materials use a ceramic as the matrix and reinforce it with short fibres, or whiskers such as those made from silicon carbide and boron nitride.

1.7 Reinforcement

The role of the reinforcement in a composite material is fundamentally one ofincreasing the mechanical properties of the neat resin system. All of the different fibres used in composites have different properties and so affect the properties of the composite in different ways. For most of the applications, the fibres need to be arranged into some form of sheet, known as a fabric, to make handling possible. Different ways for assembling fibres into sheets and the variety of fibre orientations possible to achieve different characteristics.

1.8 Interface

It has characteristics that are not depicted by any of the component in isolation. The interface is a bounding surface or zone where a discontinuity occurs, whether physical, mechanical, chemical etc. The matrix material must "wet" the fibre. Coupling agents are frequently used to improve wettability. Well "wetted" fibres increase the interface surfaces area. To obtain desirable properties in a composite, the applied load should be effectively transferred from the matrix to the fibres via the interface. This means that the interface must be large and exhibit strong adhesion between fibres and matrix. Failure at the interface

(called de-bonding) may or may not be desirable.

1.9 TYPES OF COMPOSITE MATERIALS

The composite materials are broadly classified into the following categories as

1.9.1 Fibre-reinforced composites

Reinforced-composites are popularly being used in many industrial applications

because of their inherent high specific strength and stiffness. Due to their excellent structural performance, the composites are gaining potential also in tribological applications. Fibre reinforced composites materials consists of fibre of high strength and modulus in or bonded to a matrix with distinct interfaces (boundary) between them . In this form both fibres and matrix retain their physical and chemical identities. Yet they produce a combination of properties that cannot be achieved with

either of the constituents acting alone. In general, fibres are the principal load carrying candidates, while the surrounding matrix keeps them in the desired location and orientation . A Fibrous composite can be classified into two broad groups: continuous (long) fibre composite and discontinuous (short) fibre composite.

1.9.2 Continuous or long fibre composite

Continuous or long fibre composite consists of a matrix reinforced by a dispersed phase in the form of continuous fibres. A continuous fibre is geometrically characterized as having a very high length-to- diameter ratio. They are generally stronger and stiffer than bulk material. Based on the manner in which fibres are packed within the matrix, it is again subdivided in to two categories: (a) unidirectional reinforcement and (b) bidirectional reinforcement. In unidirectional reinforcement, the fibres are oriented in one direction onlywhere as in bidirectional reinforcement the fibres are oriented in two directions either at right angle to one another (cross-ply), or at some desired angle (angle-ply). When fibres are large and continuous, they impart certain degree of anisotropy to the properties of the composites particularly when they are oriented. Multi-axially oriented continuous fibrecomposites are also display near isotropic properties.

1.10 What is a Composite laminate?

In materials science, a composite laminate is an assembly of layers of fibrous composite materials which can be joined to provide required engineering properties, including in-plane stiffness, bending stiffness, strength, and coefficient of thermal expansion.

The individual layers consist of high-modulus, high-strength fibers in a polymeric, metallic, or ceramic matrix material. Typical fibers used include cellulose, graphite, glass, boron, and silicon carbide, and some matrix materials are epoxies, polyimides, aluminium, titanium, and alumina.

Layers of different materials may be used as shown in the figure 1, resulting in a hybrid laminate. The individual layers generally are orthotropic (that is, with principal properties in orthogonal directions) or transversely isotropic (with isotropic properties in the

transverse plane) with the laminate then exhibiting anisotropic (with variable direction of principal properties), orthotropic, or quasi-isotropic properties. Quasi-isotropic laminates exhibit isotropic (that is, independent of direction) inplane response but are not restricted to isotropic out-of-plane (bending) response. Depending upon the stacking sequence of the individual layers, the laminate may exhibit coupling between inplane and out-of-plane response. An example of bending-stretching coupling is the presence of curvature developing as a result of in-plane loading.
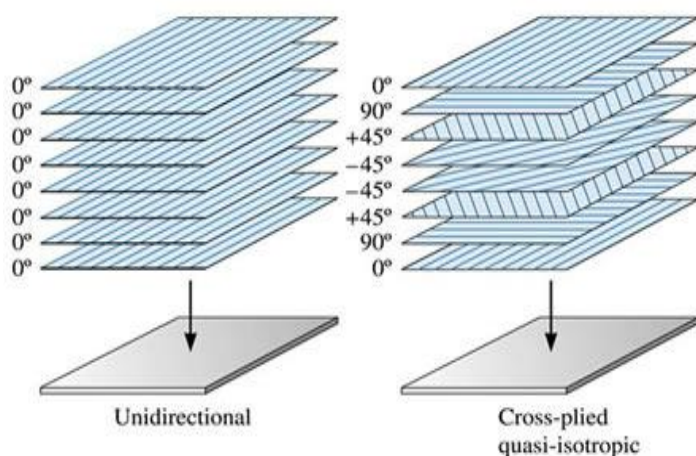

figure 2 showing laminates of Fiber Matrix

1.11 EPOXY:

Epoxy is either any of the basic components or the cured end products of **epoxy resins**, as well as a colloquial name for the epoxide functional group.[1] Epoxy resins, also known as **polyoxides**, are a class of reactive prepolymers and polymers which contain epoxide groups. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homopolymerisation, or with a wide range of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, alcohols and thiols (usually called mercaptans). These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Reaction of polyepoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with favorable mechanical properties and high thermal and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronics/electrical components/LEDs, high tension electrical insulators, paint brush manufacturing, fiber-reinforced plastic materials and structural adhesives.

OBJECTIVE

1) Epoxy Resin

2) Components

3) Characteristics of Epoxy

4) Method of Application

EPOXY RESIN

Epoxy resin is a durable, two-component pavement marking material consisting of a pigmented resin base and a hardener. Before installation, both components are mixed at a ratio of 2 parts resin: 1-part hardener, and applied by a specialized epoxy application truck. These criteria are based on the manufacturer's specifications. This material is sprayed and combined with drop-on reflective beads to provide nighttime retroreflectivity.

COMPONENTS

Pigments Epoxy resin pavement markings use pigments, similar to all other pavement marking materials. Pigments are ground and dispersed into the resin side of the system.

Mixture The epoxy resin is mixed with the hardener creating a binder system that is sprayed to form a durable pavement marking. To realize all the advantages of an epoxy system, it is critical that the components are properly mixed. Each component is stored in separate tanks on the epoxy application truck and heated to temperatures in accordance with manufacturer recommendations. Proportioning pumps draw the material at a 2:1 ratio. The material is then mixed by a static mixing tube and sprayed onto the road surface at approximately 1,200 psi.

Reflective Beads are uniformly applied across the entire width of the marking by a bead gun located immediately behind the epoxy spray gun. A double drop method is typically used for the application of the beads. Large and small beads are typically applied at a rate of 11 to 13 lbs./gal for each bead size for a total of 25 lbs./gal.

CHARACTERISTICS OF EPOXY

Epoxy striping material is classified as 100 percent solids, meaning the evaporation of solvents or water is not used to cure the material. Thus, without this evaporation process, a typical application rate of 20 mils wet yields 20 mils of dry material. Epoxy striping material is cured via a thermoset chemical reaction.

Advantages

- Good wet-night visibility
- Can be applied at lower temperature
- Makes a mechanical bond with the road surface
- Good bead retention
- Low profile resists snowplow damage
- Epoxy does not contribute volatile organic compounds

Disadvantages

- Slow cure (no-track time)
- Mix proportions are critical

METHOD OF APPLICATION

The mixed epoxy material is heated and sprayed onto the road surface. The equipment performing this operation is a specially designed epoxy truck that cannot be used to apply any other liquid binder material. Because of the composition of the material, environmental temperatures will increase or decrease the no-track times.

Shelf Life

Epoxy material has a shelf life of one year. The manufacture date should be stated in the shipping documents.

How to Mix the Material

The mix ratio for epoxy resin material is typically 2:1 (2 parts resin to 1-part hardener). It is very important that components are mixed thoroughly and at the correct ratio prior to being sprayed on the road surface. The mixing operation is a function of the epoxy installation truck. It shall be performed in accordance with manufacturer's recommendations.

Temperature

Epoxy shall not be applied unless the surface and ambient temperatures are a minimum of 35°F and rising. Remember that no-track times increase as the temperature decreases and vice versa. Always check temperature minimums (air and surface) for each agency when applying epoxy.

Pavement Surface Considerations

The road surface shall be free of curing compounds, laitance, oil, grease, salt, dust, or other debris. Epoxy materials shall not be applied if moisture is present on the road surface. Epoxy material can be applied behind the HMA paving operation as long as the mat has cooled enough to support the weight of the epoxy application truck. Epoxy materials can be applied over other epoxy materials. However, this shall only be done one time.

1.12 Natural Composites:

Natural composites. Natural composites exist in both animals and plants. Wood is a composite – it is made from long cellulose fibres (a polymer) held together by a much weaker substance called lignin. Cellulose is also found in cotton, but without the lignin to bind it together it is much weaker.

1.13 What is Fiber-reinforced composite?

A fibre-reinforced composite (FRC) is a composite building material that consists of three components:
(i) The fibres as the discontinuous or dispersed phase,
(ii) The matrix as the continuous phase, and
(iii) The fine interphase region, also known as the interface. This is a type of advanced composite group, which makes use of rice husk, rice hull, and plastic as ingredients. This technology involves a method of refining, blending, and compounding natural fibers from cellulosic waste streams to form a high-strength fiber composite material in a polymer matrix. The designated waste or base raw materials used in this instance are those of waste thermoplastics and various categories of cellulosic waste including rice husk and saw dust.

Carbon Glass fiber-reinforced plastic (GFRP) composites are one of lightweight materials and show a high tensile strength and tensile modulus when compared with other materials. Increasingly applied to primary structures in the aerospace fields, such as for the new commercial aircraft, Boeing 787. The properties of the axial direction of the fiber in CGEF Carbon-Glass Epoxy Fiber matrix are important in such applications from a viewpoint of determining the potential weight saving. It has been reported that the optimum interface of CF/epoxy exist to improve the tensile strength of unidirectional composites. To avoid interfacial debonding because it causes serious implications of delamination, splitting, or loss of impact resistance. A number of extent studies aimed at finding ways to accurately predict the tensile strength of unidirectional CGFRP composites. In the global load-sharing (GLS) model, it was assumed that the load shared by a broken fiber is distributed uniformly over all unbroken fibers in the same plane as the break. The local load-sharing assumes that the stress that is no

longer accommodated by a broken fiber is not equally shared among the remaining unbroken fibers, but rather more load is transferred to the glass fiber polymers.

Fiber reinforced plastics have been widely used for manufacturing aircraft and spacecraft structural parts because of their particular mechanical and physical properties such as high specific strength and high specific stiffness. Another relevant application for fiber reinforced polymeric composites (especially glass fiber reinforced plastics) is in the electronic industry, in which they are employed for producing printed wiring boards. Composite materials are constituted of two phases: the matrix, which is continuous and surrounds the other phase, often called as reinforcing phase. Epoxy resins are widely used as matrix in many fiber reinforced composites; they are a class of thermoset materials of particular interest to structural engineers owing to the fact that they provide a unique balance of chemical and mechanical properties combined with wide processing versatility. Within reinforcing materials, glass fibers are the most frequently used in structural constructions because of their specific strength properties. The present study focuses on mechanical property of CGFRP laminated composites.

1.14 What is Glass Epoxy Fiber?

Fiberglass (US) or fibreglass (UK) is a common type of fiber-reinforced plastic using glass fiber. The fibers may be randomly arranged, flattened into a sheet (called a chopped strand mat), or woven into a fabric. The plastic matrix may be a thermoset polymer matrix—most often based on thermosetting polymers such as epoxy, polyester resin, or vinylester—or a thermoplastic. Cheaper and more flexible than carbon fiber, it is stronger than many metals by weight, and can be molded into complex shapes. Applications include aircraft, boats, automobiles, bath tubs and enclosures, swimming pools, hot tubs, septic tanks, water tanks, roofing, pipes, cladding, casts, surfboards, and external door skins.

Other common names for fiberglass are **glass-reinforced plastic** (**GRP**), **glass-fiber reinforced plastic** (**GFRP**). Because glass fiber itself is sometimes referred to as "fiberglass", the composite is also called "fiberglass reinforced plastic". This article will adopt the convention that "fiberglass" refers to the complete glass fiber reinforced composite material, rather than only to the glass fiber within it.

1.15 PREPARATION OF GLASS EPOXY FIBER:

The process of manufacturing fiberglass is called pultrusion. The manufacturing process for glass fibers suitable for reinforcement uses large furnaces to gradually melt the silica sand, limestone, kaolin clay, fluorspar, colemanite, dolomite and other minerals until a liquid forms. It is then extruded through bushings, which are bundles of very small orifices (typically 5–25 micrometres in diameter for E-Glass, 9 micrometres for S-Glass). These filaments are then *sized* (coated) with a chemical solution. The individual filaments are now bundled in large numbers to provide a roving. The diameter of the filaments, and the number of filaments in the roving, determine its *weight*, typically expressed in one of two measurement systems:
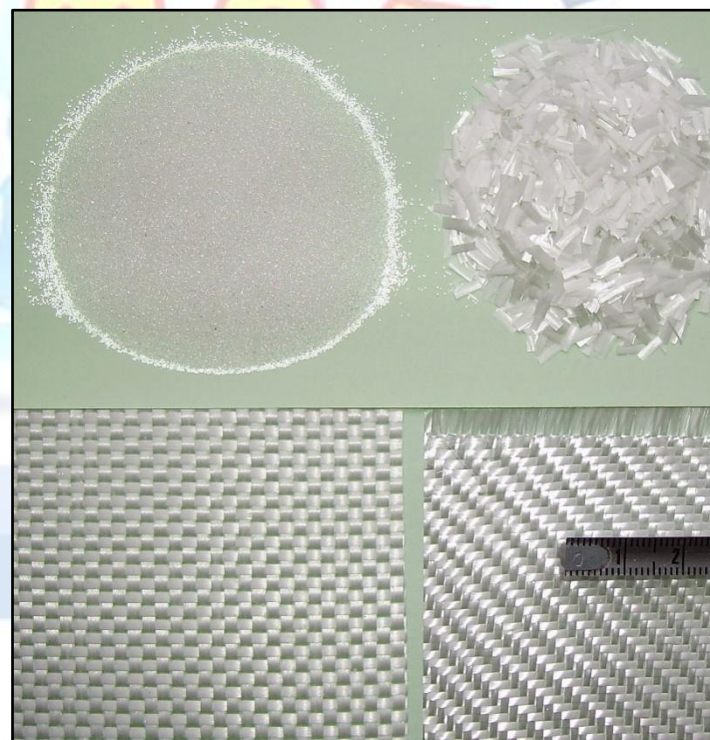

Figure 3: Glass reinforcements used for fiberglass woven.

1.16 TYPES OF GLASS FIBERS:

Composition: the most common types of glass fiber used in fiberglass is E-glass, which is alumino-borosilicate glass with less than 1% w/w alkali oxides, mainly used for glass-reinforced plastics. Other types of glass used are A-glass (Alkali-lime glass with little or no boron oxide), E-CR-glass (Electrical/Chemical Resistance; alumino-lime

silicate with less than 1% w/w alkali oxides, with high acid resistance), C-glass (alkali-lime glass with high boron oxide content, used for glass staple fibers and insulation), D-glass (borosilicate glass, named for its low Dielectric constant), R-glass (alumino silicate glass without MgO and CaO with high mechanical requirements as Reinforcement), and S-glass (alumino silicate glass without CaO but with high MgO content with high tensile strength).Naming and use: pure silica (silicon dioxide), when cooled as fused quartz into a glass with no true melting point, can be used as a glass fiber for fiberglass, but has the drawback that it must be worked at very high temperatures. In order to lower the necessary work temperature, other materials are introduced as "fluxing agents" (i.e., components to lower the melting point). Ordinary A-glass ("A" for "alkali-lime") or soda lime glass, crushed and ready to be remelted, as so-called cullet glass, was the first type of glass used for fiberglass. E-glass ("E" because of initial Electrical application), is alkali free, and was the first glass formulation used for continuous filament formation. It now makes up most of the fiberglass production in the world, and also is the single largest consumer of boron minerals globally. It is susceptible to chloride ion attack and is a poor choice for marine applications. S-glass ("S" for "stiff") is used when tensile strength (high modulus) is important, and is thus an important building and aircraft epoxy composite (it is called R-glass, "R" for "reinforcement" in Europe). C-glass ("C" for "chemical resistance") and T-glass ("T" is for "thermal insulator"—a North American variant of C-glass) are resistant to chemical attack; both are often found in insulation-grades of blown fiberglass.

1.17 PROPERTIES OF GLASS FIBER

• An individual structural glass fiber is both stiff and strong in tension and compression—that is, along its axis.

• Although it might be assumed that the fiber is weak in compression, it is actually only the long aspect ratio of the fiber which makes it seem so; i.e., because a typical fiber is long and narrow, it buckles easily. On the other hand, the glass fiber is weak in shear—that is, across its axis. Therefore, if a collection of fibers can be arranged permanently in a preferred direction within a material, and if they can be prevented from buckling in compression, the material will be preferentially strong in that direction.

• Furthermore, by laying multiple layers of fiber on top of one another, with each layer oriented in various preferred directions, the material's overall stiffness and strength can be efficiently controlled.

• In fiberglass, it is the plastic matrix which permanently constrains the structural glass fibers to directions chosen by the designer.

• With chopped strand mat, this directionality is essentially an entire two-dimensional plane; with woven fabrics or unidirectional layers, directionality of stiffness and strength can be more precisely controlled within the plane.

• A fiberglass component is typically of a thin "shell" construction, sometimes filled on the inside with structural foam, as in the case of surfboards.

• The component may be of nearly arbitrary shape, limited only by the complexity and tolerances of the mold used for manufacturing the shell.

• The mechanical functionality of materials is heavily relied on the combined performances of both the resin (AKA matrix) and fibers. For example, in severe temperature condition (over 180 °C) resin component of the composite may lose its functionality partially because of bond deterioration of resin and fiber.

• However, GFRPs can show still significant residual strength after experiencing high temperature (200 °C).

1.18 What is WEIBULL MODULUS:

• The **Weibull modulus** is a dimensionless parameter of the Weibull distribution which is used to describe variability in measured material strength of brittle materials.

• For ceramics and other brittle materials, the maximum stress that a sample can be measured to withstand before failure may vary from specimen to specimen, even under identical testing conditions. This is related to the distribution of physical flaws present in the surface or body of the brittle specimen, since brittle failure processes originate at these weak points. When flaws are consistent and evenly distributed, samples will behave more uniformly than when flaws are clustered inconsistently. This must be taken into account when describing the strength of the material, so strength is best represented as a distribution of values rather than as one specific value. The Weibull modulus is a shape parameter for the Weibull distribution model which, in this case,

maps the probability of failure of a component at varying stresses.

• Consider strength measurements made on many small samples of a brittle ceramic material. If the measurements show little <u>variation</u> from sample to sample, the calculated Weibull modulus will be high and a single strength value would serve as a good description of the sample-to-sample performance. It may be concluded that its physical flaws, whether inherent to the material itself or resulting from the manufacturing process, are distributed uniformly throughout the material. If the measurements show high variation, the calculated Weibull modulus will be low; this reveals that flaws are clustered inconsistently and the measured strength will be generally weak and variable. Products made from components of low Weibull modulus will exhibit low reliability and their strengths will be broadly distributed.

EXPERIMENTATION
2.1 MATERIALS SELECTION

Materials used for characterization are GFRP and CFRP composites which use E-glass fiber of woven roving mat (WRM) of 610 gsm and Sisal fiber of woven roving mat of 450 gsm as reinforcement with Araldite epoxy matrix and Hardener (Aradour), respectively. Fiber to resin ratio of 1:1 and resin to hardener ratio of 10:1, by weight, are maintained. Fig. 1 depicts the different stacking sequences [(0/90/30/-60), (0/90/45/-45) of glass /epoxy and sisal/epoxy composites which are prepared by using compression molding technique. Each laminate has four layers and each layer has 0.4 mm thickness.

Fig. 4

Fig. 5

2.2 MECHANICAL PROPERTIES:

Tests have been performed by using the Instron universal testing machine of capacity 30-40 kN at a strain rate of 0.0083 s^{-1}. Using the drop mass test setup, high strain rate studies are carried out. The gauge length of 10 mm is used for the high strain rate test. The drop mass setup is used to perform medium (above 10 s^{-1}) to high strain rate (below 1000 s^{-1}) studies which is shown in Fig. 6. This setup fills the gap between conventional servo-hydraulicmachine and Split-Hopkinson pressure bar. The high strain rate fixture indicates that when the mass is dropped on the fixture top disc (circular plate) which hit the specimen assembly through the sliding guide rods to induce the tensile failure. The Piezoelectric load sensor is used to obtain the dynamic load data with the help of LabVIEW.
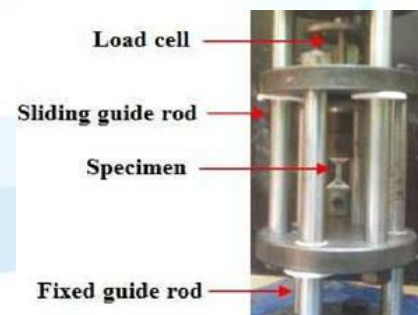

Fig. 6 Experimental Setup of Tensile fixture

2.3 HARDNESS:

Hardness tester as shown in the figure 7 below, may be defined as the resistance of material to plastic deformation. However, the term may also refer to stiffness or resistance. Hardness characteristics of glass epoxy composite materials are presented in the table 4. From these results it shows that fabricated material of

Sample 1 laminated with 0-90/30/60 shows the highest hardness number of 72 IRHD when compared with fabricated material of Sample 2 laminated with 0-90/45/45. The reason behind that is due to continuous laminates with equal matrix distribution and boding with the fabricated material of sample 1. It has a great bonding capacity between fibre and matrix. This may be due to improved capacity of bonding between the fibre and reinforcement. When increasing the filler material loading in matrix surface which reduces the indentation so values are low. 0-90/45/45 laminated matrix material shows low hardness number due to bond strength.
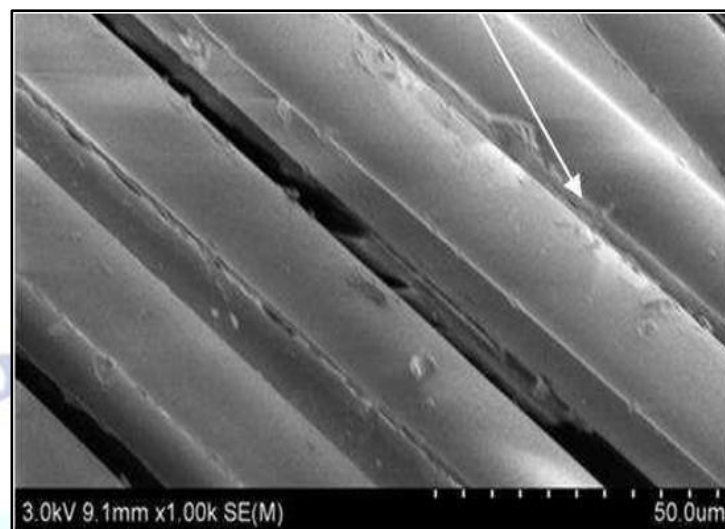

Figure 8(a) Showing adhesive bonding of fiber

Evidence of micrograph from figure8(a) shows the adhesive bondage of epoxy resin between the fibers after the laminates are solidified viewed at 50 microns.
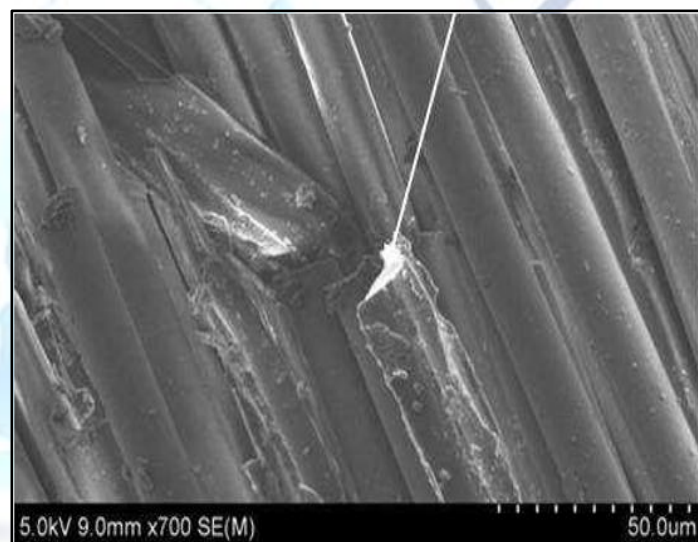

Figure 8(b) Showing Breakage of fiber

From the fig 8(b), it is evident that the breakage of bonded fiber is observed after adhesiveness during the solidification. The local load-sharing assumes that the stress that is no longer accommodated by a broken fiber is not equally shared among the remaining unbroken fibers, but rather more load is transferred to the glass fiber polymers.
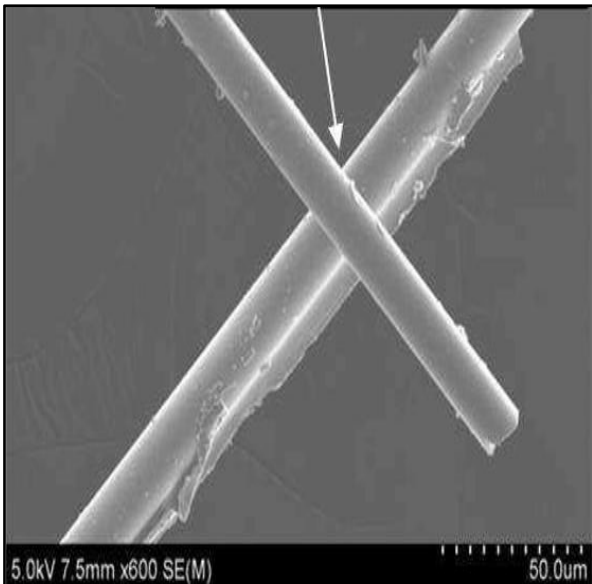

Figure7: SHORE-D TESTER for measuring hardness.

2.4 SEM ANALYSIS:

SEM analysis is performed to get some information about strength of interaction between glass and sisal fibers, and epoxy resin which provides the evidence of the brittle failure in dynamic loading such as matrix damage, fiber pull-out and fiber breakage are found in (0/90/30/-60), (0/90/45-45) and (30/-60/60/-30) glass/epoxy laminates, respectively whereas in sisal/epoxy composites of same lay-ups fiber-matrix interface cracking, bunch fiber pull-out and river markings in the matrix are observed in SEM micrographs which are as shown in the figures below 8(a),8(b), 8(c) and 8(d).

Figure8(c) Showing adhesive bonding of fiber

Figure 8(c) shows the laminates of 90^0 and 45^0 matrix at 50 microns, shows the bonding of fibers does not displace its original position.
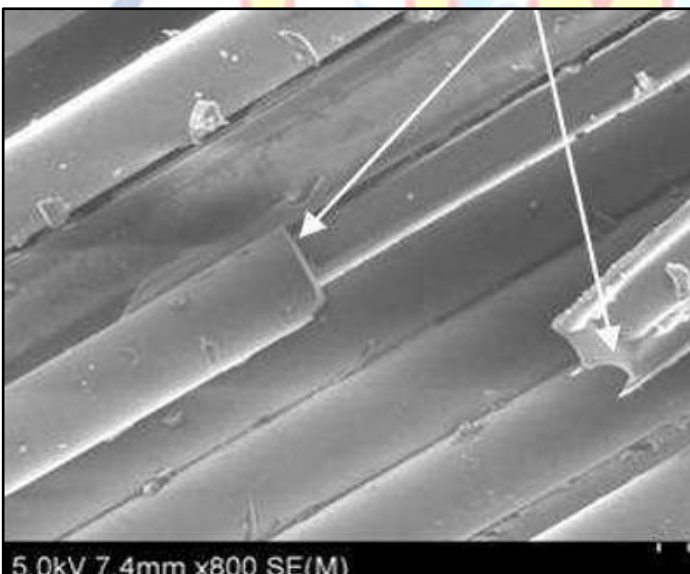

Figure 8(d) Showing adhesive bonding of fibre

Figure 8(d) which also shows the fibre breakage during the laminate preparation left over after solidification.

4.5 Solubility Measurements:

Solubility measurements were A digital calliper (accuracy = 0.002 mm) was used to measure diameter and thickness. The diameter of each specimen was measured at two points at right angles to one another, and the mean diameter was calculated. The thickness of each specimen was measured at the centre of the specimen and at four equally spaced points on the circumference, and the mean thickness was calculated. The volume (V) of each specimen was calculated in mm^3 using the formula $V=\pi \times r^2 \times h$,

where r is the mean sample radius (diameter/2) and h is the mean sample thickness.

Figure 8(e)

Figure 8 (f)

Figure 8(g)

RESULT AND DISCUSSION

5.1 STRAIN TEST:

The strain tests are performed from different height as explained and the values are as showin in the table 1 showing the variance of increased height with increased strain rate in sample-1 and sample-2.

TABLE 1:

Height (m)	Strain rate (s^{-1})
Quasi-static	0.0083
0.25	221
0.5	313
0.75	384
1	443
1.25	495
1.5	542

From the table 1, it shows that the increase in the load height, increase in the strain rate is observed in the specimen with both samples as showing in the figure 1 varying the tensile.
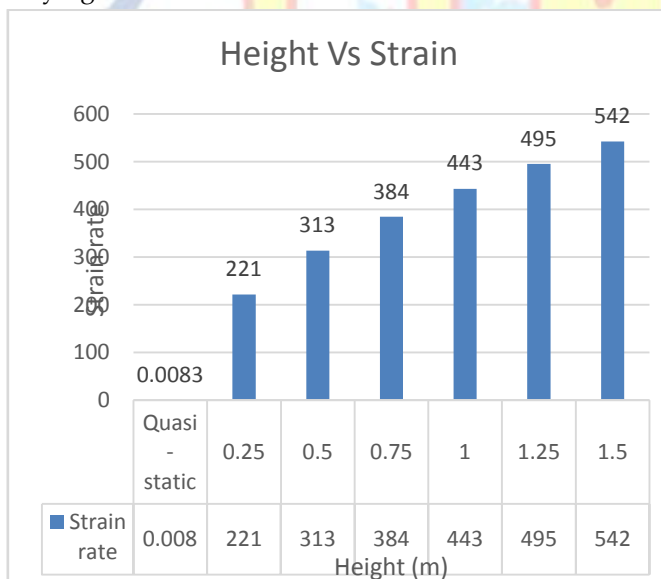

Figure 9: Height vs Strain rate

From the figure 1 the strain rate increases with increase in height of the load released as detailed in experimentation.

5.2 TENSILE STRENGTH FOR 0/90/30/60 LAMINATE MATRIX:

Table 2:

Laminates	Trails	Tensile strength (MPa)
0/90/30/-60	1	213.6
		219.15
		224.4
		Avg 219
	2	262.68
		269.16
		273.98
		Avg 268.6
	3	266.41
		286.22
		304.7
		Avg 285.78
	4	305.61
		323.88
		336.75
		Avg 322 ± 15.65
	5	350.69
		358.55
		364.59
		Avg 357.94 ± 7
	6	355.48
		378.78
		402.17
		Avg 378.81 ± 23.34

From the table 2, the average tensile load taken from 6 samples, the average tensile strength obtained is 305.33 MPa for the laminate matrix of 0/90/30-60 samples of Glass epoxy and banana fabric mat.

5.3 TENSILE STRENGTH FOR 0/90/45/-45 LAMINATE MATRIX:

TABLE 3:

Laminates	Trails	Tensile strength (MPa)
0/90/45/-45	1	165.16
		174.54
		181.67
		Avg 173.5
	2	191.14
		208.76
		225.86
		Avg 208.58
	3	228.86
		252.23
		267.45
		Avg 249.51
	4	278.5
		288.52
		295.96

	Avg 287.66
	283.74
5	292
	300.88
	Avg 292.2 ± 8.57
	296.26
6	302.85
	308
	Avg 302.37 ± 5.88

From the table 3, the average tensile load taken from 6 samples, the average tensile strength obtained is 252.3 Mpa for the laminate matrix of 0/90/45-45 samples of sisal/ Glass epoxy and banana fabric mat. From the table-2 and table-3 it proves that the tensile strength of laminate 0-90/30/60 is higher than 0-90/45/45 as shown in the figure 11.

Height (m)	Strain Rate (s⁻¹)	Tensile (Mpa) of 0/90/30/-60 Laminate matrix
Quasi-static	0.0083	219
0.25	221	268.6
0.5	313	285.78
0.75	384	322
1	443	357.94
1.25	495	78.81

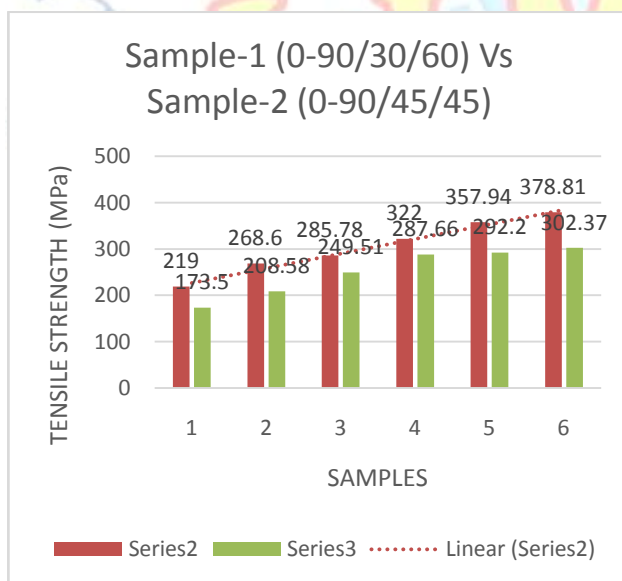Figure 11: Graph showing Strain Rate Vs Tensile Strength of Laminate (1)

Figure 10 : Tensile strength of Sample 1 Vs Sample 2

From the figure 11, it shows that the graph is increasingly high in the case of sample 1 with laminates 0-90/30/60 than samples with 0-90/45/45.

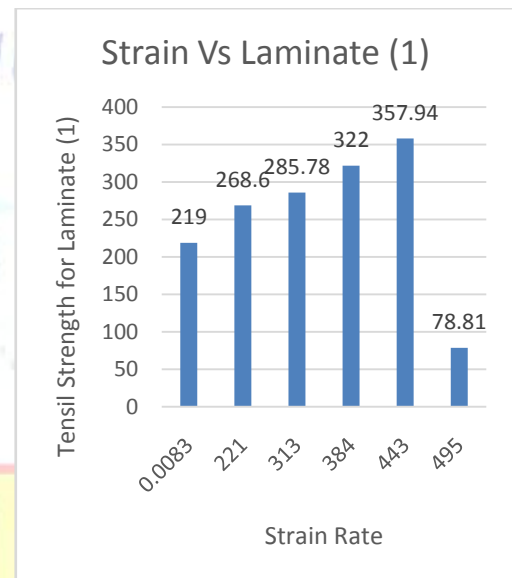### 5.4 Strain Rate Vs Tensile Strength of Laminate (1):
TABLE 4:

5.5 Strain Rate Vs Tensile Strength of Laminate (2):
TABLE 5:

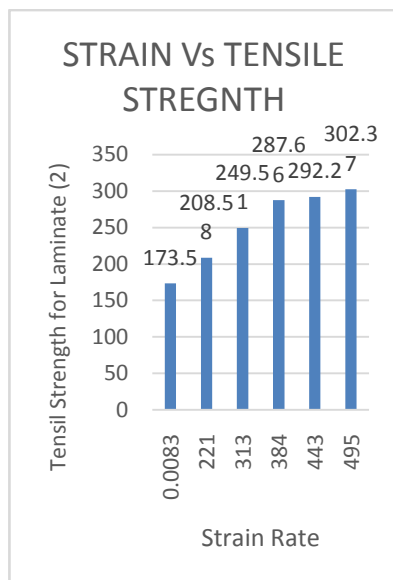| Height (m)	Strain Rate (s⁻¹)	Tensile (Mpa) of 0/90/45/-45 Laminate matrix
Quasi-static	0.0083	173.5
0.25	221	208.58
0.5	313	249.51
0.75	384	287.66
1	443	292.2
1.25	495	302.37

Figure 12: Graph showing Strain Rate Vs Tensile Strength of Laminate (1)

As strain rate increased the Tensile strength for Laminates also increases as obtained from the experimental results.

5.6 Strength of Laminate (1) Vs Strength of Laminate (2):

The tensile strength of laminate 0/90/30/-60 is higher than laminate 0/90/45/-45 which are shown from the figure 14
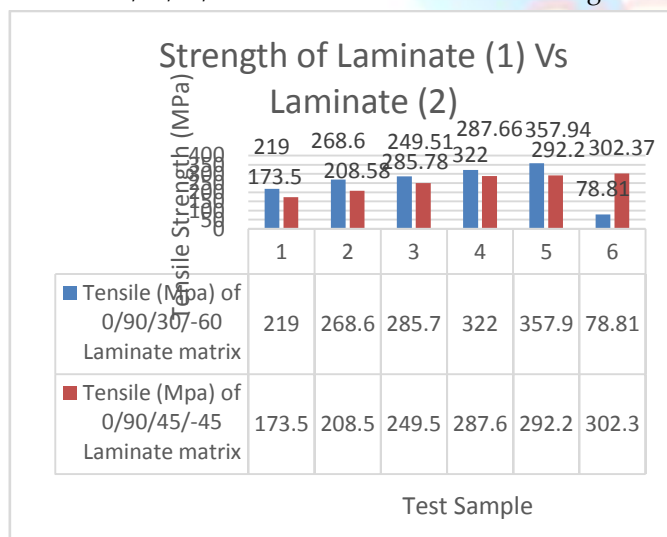

Figure 13: samples Vs tensile strength

5.7 HARDNESS of SAMPLE-1 and SAMPLE-2:

TABLE 6:

S. No	HARDNESS, SAMPLE 1 (0/90/30/60)	SHORE D HARDNESS, SAMPLE 2 (0/90/45/45)
1	60	51
2	68	55
3	72	50
4	66	59
5	55	61
6	51	60

From the table 6 it shows that the hardness of sample 1 having highest of 72 than the hardness of sample 2 having height of 61 as explained from the figure
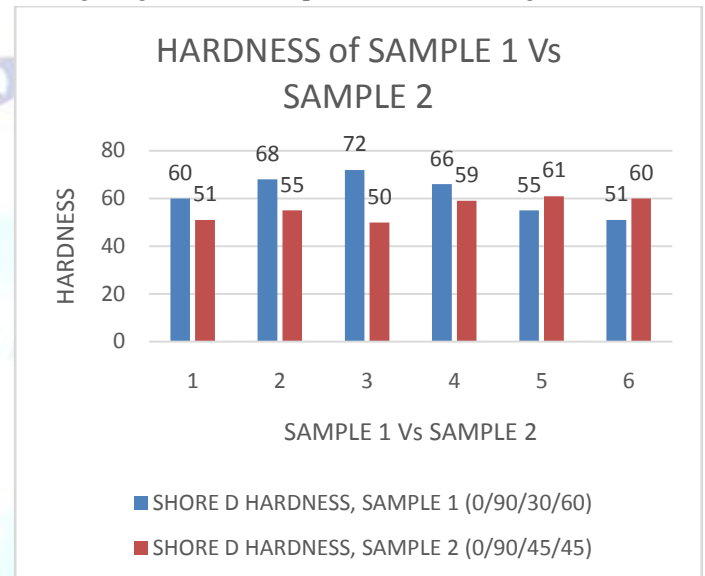

Figure14: Hardness of Laminate 0/90/30/60 Vs Laminate 0/90/45/45

The increase in the hardness for the laminates having glass epoxy with laminate of sample-1 having highest hardness than sample 2.

5.8 WEIBULL SHAPE PARAMETERS:

Laminates	Weibull Parameters						
	0.0083 s^{-1}	221 s^{-1}	313 s^{-1}	384 s^{-1}	443 s^{-1}	495 s^{-1}	542 s^{-1}
0/90/30/-60	39.01	46.33	14	20.28	48.9	15.44	8.48
	221.12	271.34	294.62	329.2	361.25	389.05	391.8
0/90/45/-45	19.56	11.45	12.74	32.6	38.19	48.9	64.97
	176.58	215.78	258.4	291.35	294.64	304.79	318.59

Table: Shape and scale parameters for different CGFC laminates and at different strain rates

From Tables 1, it is apparent that as the strain rate increases from quasi-static to 542 s^{-1}, the tensile strength increases for all the laminates of different orientations of glass/epoxy and sisal/epoxy composites. The fibre matrix interfacial bond strength increases with the increase of test speed. As a result, tensile strength is enhanced at higher strain rates as compared to lower strain rates. laminates the values are 65% and 48%, respectively. The strain rate sensitivity on the tensile strength is more for (0/90/45/-45) laminates than the other laminates. This trend is seen both in glass/epoxy and sisal/epoxy composites.

In contrast to (0/90) sisal/e-glass epoxy laminates, the significant strength variation is observed in the present study for sisal/e-glass epoxy composites from the tests carried out with samples.

5. CONCLUSION

In the present work, experiments are carried out for different strain rates ranging from 0.0083 s^{-1} to 542 s^{-1} and the results are used in two parameter Weibull distribution to determine the theoretical tensile strength values of glass/epoxy and sisal/epoxy composites of two different orientations (0/90/30/-60), (0/90/45/-45). Comparison of Strength of sisal GFRP laminates with the stacking sequences of (0/90/30/-60) and (0/90/45/-45) indicate that the obtained values of the tensile strength of sisal GFRP laminates are significantly higher with laminates of (0/90/30/-60) than (0/90/45/-45) sisal GFRP laminates, the scale parameter (characteristic strength) increases by 77%,and 80.5% respectively, whereas for CFRP laminates, the corresponding increase are 48.5% and 53%, respectively with the increase of strain rate from quasi-static to 542 s^{-1}. The strain rate sensitivity of all laminate orientations is higher for GFRP composites than CFRP composites. Both laminates of sisal GFRP composites of the (0/90/45/-45) laminates possess more strain rate sensitivity than (0/90/30/-60) laminates. The hardness of the laminates (0/90/30/-60) possess high hardness than the laminates (0/90/45/-45). The theoretical tensile and cumulative probability density values are obtained using Weibull parameters. These values show good agreement with experimental results.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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