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Characterization of E-Glass Fiber Reinforced Composite Material by using Sisal Fiber

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Abstract: Composites are an important class of materials available to mankind. Studies of these composites play a very important role in material science, metallurgy, chemistry, solid mechanics and several engineering applications. The E-glass fiber reinforced polymer composite are more widely used in the automotive industry and other industrial applications, due to their advantages, like low cost, noise control, low weight and ease of processing. Presently very limited work has been done on the mechanical properties of chopped strand mat of E-glass fiber reinforced composites. The present work describes the development and mechanical characterization of new polymer composites consisting of glass fiber reinforcement, epoxy resin and sisal fiber. The newly developed composites are characterized for their mechanical properties. Experiments like tensile test, compression test, hardness test and impact test were conducted to find the significant influence of sisal fiber on mechanical characteristics of GFRP (Glass Fiber Reinforced Polymer) composites.

Keywords: E-glass fiber, epoxy resin, sisal fiber, mechanical properties, Glass Fiber Reinforced Polymer.

I. INTRODUCTION

A. Introduction to composite material

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical and mechanical properties. The reinforcing phase of the composites provides the strength and stiffness, to make them harder, stronger and stiffer than the matrix. The reinforcement is usually in the form of a fiber or a particulate.

The length-to-diameter ratio is known as the aspect ratio, and can vary greatly for fibers because the length of the fiber is much greater than its diameter. Continuous fibers have high aspect ratios, while discontinuous fibers have low aspect ratios, and the orientation of continuous fiber composites normally is perfect, while discontinuous fibers generally have a random orientation. Continuous fiber composites are often made into laminates by stacking single sheets of fibers in different orientations to obtain the desired strength and stiffness properties with fiber volume as high as 60 to 70%. In general, the smaller the diameter of the fiber, the higher its strength, but the cost increases when the diameter becomes smaller. In addition, smaller diameter fibers have greater flexibility, and are more amenable to fabrication processes such as weaving or forming, across the radius. The continuous phase is the matrix, which is a polymer, metal or ceramic. Polymers have low strength and stiffness, metals have intermediate strength and stiffness but high ductility, and ceramics have high strength and stiffness but are brittle. Discontinuous fiber composites are normally random in alignment which drastically reduces their strength and modulus. However, these composites are generally much less costlier than continuous fiber composites. Therefore, continuous fiber composites are used where higher strength and stiffness are required even at a higher cost, and discontinuous fiber composites are used where cost is the main driver and strength and stiffness are less important.

B. Introduction to glass Fiber



Fig 1: Glass Fiber

Glass fiber also called fiberglass. It is the material made from extremely fine fibers of glass. Fiberglass is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favourable when compared to metals, and it can be easily formed using moulding processes [1]. Glass is the oldest, and most familiar, performance fiber. Fibers have been manufactured from glass since 1930s.

C. Types of glass fibers

A-Type glass fiber: Alkali glass made with soda lime silicate. Used where electrical resistivity of E-glass is not needed. A-glass or soda lime glass is the predominate glass used for containers and windowpane.

AR- type glass fiber: Alkali Resistant glass made with zirconium silicates. Used in Portland cement substrates.

C – Type glass fiber: Corrosive resistant glass made with calcium borosilicate. Used in acid corrosive environments.

D – Type glass fiber: Low dielectric constant glass made with borosilicate. Used in electrical applications.

E- type glass fiber: Alkali free, highly electrically resistive glass made with alumina-calcium borosilicate. E-glass is known in the industry as a general-purpose fiber for its strength and electrical resistance. It is the most commonly used fiber in the fiber reinforced polymer composite industry.

ECR –type glass fiber: An E-glass with higher acid corrosion resistance made with calcium aluminosilicates. Used where strength, electrical conductivity and acid corrosion resistance is needed.

R – Type glass fiber: A reinforcement glass made with calcium aluminosilicates used where higher strength and acid corrosion resistance is needed.

S –Type glass fiber: High strength glass made with magnesium aluminosilicates. Used where high strength, high stiffness, extreme temperature resistance, and corrosive resistance is needed.

TABLE: 1.

PROPERTIES OF DIFFERENT GLASS FIBERS.

SNo	TYPES OF GLASS FIBERS	Density g/cm ³	Tensile strength MPa	Young's modulus GPa	% of elongation
1	A type glass fiber	2.44	3300	72	4.8
2	AR type glass fiber	2.7	1700	72	2.3
3	C type glass fiber	2.56	3300	69	4.8
4	C type glass fiber	2.11	2500	55	4.5
5	E type glass fiber	2.54	3400	72	4.7
6	ECR type glass fiber	2.72	3400	80	4.3
7	R type glass fiber	2.52	4400	86	5.1
8	S type glass fiber	2.523	4600	89	5.3

D. Introduction to e-glass fiber

Fiber glass has a white colour and is available as a dry fiber fabric as shown in Fig.1. Four major types of Glass Fiber used for composites: E-glass: have good strength & electrical resistivity. S-glass: have 40% higher strength, better retention of properties at elevated temperatures. C-glass: have corrosion resistant. Quartz: have low dielectric properties, good for antennae. There are two different types of forms that glass fibers can be placed in the composite material.

Unidirectional

Unidirectional tapes have been the standard within the aerospace industry for many years, and the fiber is typically impregnated with thermosetting resins. Tape products have high strength in the fiber direction and virtually no strength across the fibers. The fibers are held in place by the resin. Tapes have a higher strength than woven fabrics.

Bi-directional

Most fabric constructions offer more flexibility for layup of complex shapes than straight unidirectional tapes offer. Fabrics offer the option for resin impregnation either by solution or the hot melt process. Generally, fabrics used for structural applications use like fibers or strands of the same weight or yield in both the warp (longitudinal) and fill (transverse) directions. For aerospace structures, tightly woven fabrics are usually the choice to save weight, minimizing resin void size, and maintaining Fiber orientation during the fabrication process.



Fig 2:E-Glass Fiber Matt.

In this research work, materials tested consist of E-glass fiber reinforced composites with Epoxy resin as matrix reinforced composites. The E-glass fiber matt used is, supplied by GO GREEN PRODUCTS, CHENNAI.

E. Introduction to Epoxy Resin

Resin is a generic term used to designate the polymer. The resin, its chemical composition, and physical properties fundamentally affect the processing, material. Thermosetting resins are the most diverse and widely used of all man-made materials. They are easily poured or formed into any shape, are compatible with most other materials, and cure readily (by heat or catalyst) into an insoluble solid. Thermo setting resins are also excellent adhesives and bonding agents. Epoxy resin is mostly used.

Epoxy resins are much more expensive than polyester resins because of the high cost of the precursor chemicals most notably epichlorohydrin. However, the increased complexity of the 'epoxy' polymer chain and the potential for a greater degree of control of the cross linking process gives a much improved matrix in terms of strength and ductility. Most epoxies require the resin and hardener to be mixed in equal proportions and for full strength require heating to complete the curing process. This can be advantageous as the resin can be applied directly to the fibers and curing need only take place at the time of manufacture. And known as pre-preg or pre impregnated fiber.

Epoxy polymers are made by reacting epichlorohydrin with bisphenol-A in an alkaline solution which absorbs the HCl released during the condensation polymerisation reaction. Each chain has a molecular weight between 900 and 3000 with an epoxide grouping at each end of the chain but none within the polymer chain.

The epoxy is cured by adding a hardener in equal amounts and being heated to about 120°C. The hardeners are usually short chain diamines such as ethylene diamine. Heat is usually required since the cross linking involves the condensation of water which must be removed in the vapour phase.

F. Hardener

A substance or mixture added to plastic composition to promote or control the curing action by taking part in it. Also, a substance added to control the degree of hardness of the cured film.



Fig 3:Epoxy resin and Hardener

G. Introduction to natural fiber(sisal fiber)

In the last two decades, there has been a dramatic increase in the use of natural fiber composites, and there is tremendous potential for future growth in this area both in terms of their industrial applications and research aspects. The reason for this is mainly to resist deforestation, and there is demand of new materials due to the growth in the world's population. The natural fiber composites are environment friendly and biodegradable materials (somehow these composites are called "Green Composites"). Recent studies in natural fiber composites offer significant improvement in materials from renewable sources, with enhanced support for global sustainability.

Natural fibers are renewable, economical, completely or partially recyclable, biodegradable, and environment friendly materials. This is a new generation of reinforcements and supplements for polymer based materials. Fibers from plants such as cotton, hemp,

jute, sisal, pineapple, ramie, bamboo, banana, etc., as well as wood and seeds of flax are used as the reinforcement in polymer matrix composites. Their availability, low density and price as well as satisfactory mechanical properties, make them attractive alternative reinforcements to glass, carbon and other manmade fibers.

1. **Sisal fiber** Sisal fiber is obtained from the leaves of the plant *Agave Sisalana*, which is grouped under the broad heading of “hard fibers”, among which sisal is placed second to manila in durability and strength. In ancient days, these fibers were prepared by hand, and used for making ropes, carpets and clothing. It is one of the most extensively cultivated hard fibers in the world, and accounts for half the total production of textile fibers. The reason for this is the ease of cultivation of sisal plants, which have short renewing times, and are fairly easy to grow in all kinds of environments. A good sisal plant yields about 200 leaves and each leaf contains around 1000 fibers. The seasonal sisal plants are presented in below



Fig 4: Sisal Fiber Plants

Physically, each fiber cell is made up of the primary and secondary cell wall and the lumen. The cell wall consists of several layers of febrile, and the primary wall has a reticulated fibrillae structure. In the outer secondary wall, which is located inside the primary wall, the fibrillae are arranged in spirals with a spiral angle of 40° in relation to the longitudinal axis of the cell. The fibrillae in the inner secondary wall of the sisal fibers have a sharper slope of 18 to 25° . The thin, innermost, tertiary wall has a parallel fibrillae structure and encloses the lumen.

The sisal leaf contains three types of fibers, such as mechanical fibers, ribbon fibers and xylem fibers. The mechanical fibers are extracted mostly from the periphery of the leaf. They are the most commercially useful sisal fiber. Ribbon fibers occur in association with the conducting tissues in the median line of the leaf. The ribbon fibers are the longest fibers when compared to the mechanical fibers they can be easily split longitudinally during processing. Xylem fibers have an irregular shape and occur opposite to the ribbon fibers. The SEM micrographs of the sisal fibers are presented in which shows the surface features of the sisal fiber. In the case of micro-fibrillated sisal fibers, the surface micro-fibrils and aggregates were well developed, providing a larger contact area and introducing micro or nano-sized reinforcement to the fiber surface as shown.



Fig 5: Extraction of sisal from sisal plants Fig 6: Sisal fiber

H. Need for the present study

Now-a-days, natural fiber reinforced composite materials are replacing the conventional, synthetic and manmade fiber reinforced composites, due to their easy availability, biodegradability, eco-friendliness, in-homogeneity, non-ductility, renewable nature and user-friendly characteristics.

Glass fiber reinforced composites have excellent mechanical properties, but the process of disposal is very difficult due to severe environmental concerns, and the process of recycling these composites has been a serious problem.

Though glass and other synthetic fiber reinforced composites possess high strength, the field of their application is restricted, because of their higher cost of production and low biodegradability.

The usage of natural fiber based composite materials is growing during recent years, due to their specific properties, positive environmental impact, economical production and processing, and their safe handling and working conditions.

To take advantage of sisal fiber added with glass fiber co-jointly to the matrix, so that an optimal, superior but economical composite can be obtained.

II. BASIC DESIGN PROCEDURE

The following are the materials used to prepare e glass fiber composite material specimen with addition of natural fiber(sisal fiber)

A. Materials used

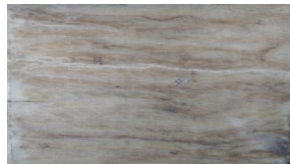
- 1) E-Glass fiber
- 2) Sisal fiber (Natural fiber)
- 3) Epoxy and hardener

B. Preparation of specimen

The following Specimen consists of three layers in which E-glass fiber mat is placed top and bottom of the specimen. Middle layer is filled with sisal fiber. The layers of fibers are fabricated by adding required amount of Epoxy resin. Initially sisal fiber is soaked in water and dried in sunlight to remove moisture. Epoxy and hardener are mixed in the ratio of 10:1. After mixing the epoxy resin is used to prepare specimen. Before going to making of specimen the glass fiber matt is cut into required dimensions. The following are the dimensions of glass fiber and sisal to prepare required specimen.


- 1) *Specimen -1:* The glass fiber had been cut into required size. Initially E-glass fiber is placed on an Aluminium foil and resin is coated on E-glass fiber using roller brush. Chopped sisal fiber is placed on a glass fiber and resin is coated on sisal fiber. Another glass fiber layer is placed on the sisal fiber. After these three layers aluminium foil is placed on the specimen. Weight is placed on the specimen and allowed to cure for three hours for the purpose of uniform shape.

TABLE 2
DETAILS OF SPECIMEN -1.

Dimensions	Fabrication details	Photo of specimen-1
Width=300mm Length=300mm Chopped sisal fiberlength=300mm	Glass fiber to natural fiber = 1:1 E-glass fiber = 70gms Sisal fiber= 70gms Epoxy and hardener = 220gms	
After fabrication the final weight of the specimen =260gms		


- 2) *Specimen-2*

TABLE 3
DETAILS OF SPECIMEN -2

Dimensions	Fabrication details	Photo of specimen-2
Width=50mm Length=300mm Chopped sisal fiber length=300mm	Glass fiber to natural fiber = 1:1 E-glass fiber= 17 gms Sisal fiber = 17 gms Epoxy and hardener = 55 gms	
After fabrication the final weight of the specimen =50 gms		


- 3) *Specimen-3 (oval shape)*

TABLE 4
DETAILS OF SPECIMEN -3

Fabrication details	Photo of specimen-3
Glass fiber to natural fiber = 1:1 E-glass fiber = 20 gms Sisal fiber = 20 gms Epoxy and hardener = 220 gms	
After fabrication the final weight of the specimen = 75 gms	

4) Specimen-4 (Square plate)

TABLE 5
DETAILS OF SPECIMEN -4

Dimensions	Fabrication details	Photo of specimen-4
Width = 300 mm Length = 300mm Chopped sisal fiber length=300mm	Glass fiber to natural fiber = 1:1 E-glass fiber = 70 gms Sisal fiber = 70 gms Epoxy and hardener = 220 gms	
After fabrication the final weight of the specimen = 260 gms		

III. RESULTS AND DISCUSSIONS

After fabrication of composite specimens the specimens are tested to know the mechanical characterization by conducting various tests. The tests conducted are: Tensile test, Compression test, Rockwell hardness test, Impact test

A. Tensile Test

Tensile strength is the capacity of material or structure to withstand loads tending to elongate, as opposed to compressive strength, which withstands loads tending to reduce size. In other words, tensile strength resists tension (being pulled apart) [2]. strength is the measurement of the force required to pull something such as rope, wire, or a structural beam to the point where it breaks. The specimen-2 is tested in the universal testing machine (UTM) and the samples are left to break till the ultimate tensile strength occurs.

TABLE 6
TENSILE TEST ON UNIVERSAL TESTING MACHINE



Specimen before testing	Tensile test on Universal Testing Machine	Specimen after tensile test
		

The test process involves placing the test specimen in the testing machine and slowly extending it until it fractures. During this process, the elongation of the gauge section is recorded against the applied force. The data is manipulated so that it is not specific to the geometry of the test sample. The elongation measurement is used to calculate the relations between stress and strain, stress and displacement and load and displacement.

B. Compression Test

Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. In other words, compressive strength resists compression (being pushed together), whereas tensile strength resists tension (being pulled apart) [3]. Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures. Compressive strength is often measured on a universal testing machine The specimen-4 is used for compression test. Compression test is conducted in universal testing machine.

Table 7
Compression test on universal testing machine

Specimen before compression	Compression test on Universal Testing Machine	Specimen after compression test
		

C. Hardness Test

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied. Some materials (e.g. metals) are harder than others (e.g. plastics). Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behavior of solid materials under force is complex [4]. Common indentation hardness scales are Rockwell, Vickers, Shore, and Brinell. The Rockwell hardness test is carried out for the Glass fiber reinforced composite materials and the applied is 60kg for 6 mm penetrator for all specimens. These are the following results obtained by Rockwell hardness testing machine.

Table 8
Hardness test on rockwell tester

Point	Specimen-1	Specimen-2	Specimen-3	Specimen-4
1	B20	B45	B34	B45
2	B24	B33	B31	B32
3	B32	B28	B31.5	B30
4	B34	B32	B33	B26






Fig 7 Rockwell hardness testing machine

D. Impact Test

In mechanics, an impact is a high force or shock applied over a short time period when two or more bodies collide. Such a force or acceleration usually has a greater effect than a lower force applied over a proportionally longer period. The effect depends critically on the relative velocity of the bodies to one another.

Table 9 Impact test

Specimen before impact test	Impact Testing Machine	Specimen after impact test
		

Impact test is conducted on two specimens, one for charpy impact test and another for izod impact test. The results indicated that maximum charpy impact strength obtained is 516 Joules. The specimen size used for the charpy impact strength is 75x8x3 mm. For Izod impact test result indicate that maximum Izod impact strength obtained is 228 Joules. Specimen size for the Izod impact strength is 75x8x3 mm.

The following are the results obtained from impact test.

Table 10
Results of impact test & charpy test

For charpy impact	For izod impact
INITIAL READING=300div FINAL READING=42div FINAL IMPACT=300-42=258 div $258 \times 2 = 516 \text{ joules,}$ 1div=2joules NOTE:	INITIAL READING =168div FINAL READING =54div FINAL IMPACT =168-54=114 div $114 \times 2=228 \text{ joules,}$ 1div=2joules NOTE:

IV. CONCLUSIONS

In this work, the design and fabrication of e-glass fiber reinforced composite material is performed with addition of sisal fiber. And it is concluded that, the E-glass fiber reinforced composite material with adding of sisal fiber is more advantageous for aerospace and automobile applications. The following conclusions were made:

- The Hardness, tensile, compression, impact characteristics of E-Glass fiber reinforced sisal composite material gives better results compare than Ordinary E-Glass fiber composite material.
- By conducting different types of mechanical tests, better results are obtained compared than normal E-Glass fiber matrix composite material.
- The hardness, tension and compression values are better than normal E Glass fiber matrix material by adding natural fiber (Sisal fiber).

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