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DEVELOPMENT AND TESTING OF GLASS FIBRE REINFORCED COMPOSITES

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Abstract— **A material may even be a artefact created of 2 or additional constituent materials with considerably completely different physical or chemical properties that, once combined, manufacture a artefact with characteristics. The individual parts stay separate and distinct at intervals the finished structure, differentiating composites from mixtures and solid solutions.**

The reinforcing constituent is embedded during a matrix to make the composite. Composite structures are quite common in nature where fibers and matrices are combined. For example, a tree is composed from cellulose fibers in a matrix of lignin which is a natural resin. The strength of wood is higher along the grain which defines the general direction of cellulose fibers and it is weaker across the grain. Splitting a piece of wood along the grain is much easier because one just has to fracture the lignin matrix which is much weaker than the cellulose fibers.

In this project a sample composite material is signed and developed by glass fibers reinforced in epoxy matrix. The samples are prepared by different orientation of fibres in matrix with different thickness. These sample composites are subjected to testing in order to determine their tensile strength, impact strength and Young's modulus of elasticity and then comparisons are made and the best one may be picked up. It has been expected that these composites possess high strength and ductility. Therefore, these composite materials are useful in many structural applications.

Keywords--- **Reinforced composites, Lignin, Epoxy solution**.

I. IINTRODUCTION

A technical development has centered around two main areas historically, first are the development of more powerful and efficient energy sources and second is to obtain maximum possible motive power from the available energy. Second development is heavily dependent on the properties of engineering materials. In aircraft and aerospace industries, a union of opposites i.e., lightweight together with high stiffness is demanded. In pressure vessels technology, corrosion resistance and high strength are the prerequisites for efficient operation. Composite materials provide an efficient solution to such problems whenever a designer faces such situations. The flexibility that can be achieved with composite materials is immense. Variety of properties can be altered merely by changing the composition thus making the composites reliable and versatile substitutes for the conventional structural materials.

II. MATERIALS AND METHODS

✓ REINFORCEMENT FORMS:

(i) Chopped Strands
Continuous strands of fiber are chopped into smaller lengths varying from 14 inch to 1 inch by means of choppers. These strands are dispersed in the matrix phase of the composite.

(ii) Chopped Strand Mat
Chopped strands about 50mm in length are randomly laid down as a continuous, thin, flat blanket form and the strands are bonded with compatible adhesive binders. The mat is available in various "densities" and enables the designer to achieve the desired thickness in the end product.

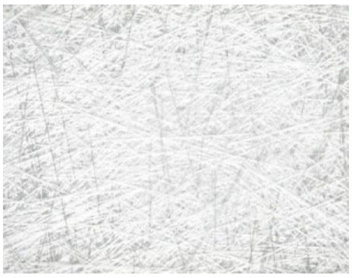

Fig 1: Chopped strand mat

Fig 2: Chopped strands

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(iii) Roving

They constitute a group of continuous strands of fiber gathered together and wound on a cylindrical cheese. This type is employed in hot press molding technique for making performs and in the manufacture of pre-peg mat.

(iv) Woven Roving

Continuous roving is woven into fabric, which is employed for the manufacture of flat laminates. Higher quality of fiber can be incorporated into the composite when woven roving is used and consequently a higher specific strength result. In our work glass fiber reinforced plastic (GFRP) specimens have been made using simple casting technique. We have chosen glass as the reinforcement material because of its inherent advantages such as

- ★ Easy availability
- ★ High stiffness
- ★ The flexibility with which the fibers may be placed
- ★ Economic viability

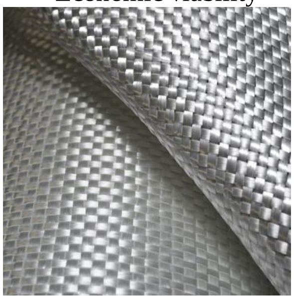

Fig 3: Woven roving Fig 4: Roving's

2nd level discrete wavelet transform is applied on the sub images to generate the approximate and detail coefficients.

Property	**E-glass**	**Aramid**	**SM carbon**
Relative cost of yarn	1	5	10
Density [g/cm³]	2.5	1.4	1.8
Modulus of elasticity [GPa]	70	100	210
Tensile strength [MPa]	2400	3000	4000
Strain at break point	4.5%	2%	1.2%
Impact strength	Better	Best	Fair
Fatigue resistance	Good	Better	Best

Table 1: Properties of Fibers

✓ ORTHOTROPIC BEHAVIOR OF COMPOSITES

Two or three mutually orthogonal two-fold axes of rotational symmetry is seen in an orthotropic material so as that its mechanical properties are generally, different along each axis. Thus, orthotropic materials are anisotropic; their properties depend upon the direction during which they are measured. In contrast, an isotropic material has an equivalent property in every direction.

One of the common examples of an orthotropic material with two axis of symmetry would be a polymer reinforced by graphite fibers or parallel glass. Strength and stiffness of such a material will usually be greater during a direction parallel to the fibers than within the transverse direction. A familiar example of an orthotropic material with three mutually perpendicular axes is wood, during which the properties (such as strength and stiffness) along its grain and in each of the two perpendicular directions are different. Hankinson's equation provides a way to quantify the difference in strength in several directions. Another example could also be a metal which has been rolled to form a sheet for which the properties within the rolling direction and each of the two transverse directions are going to be different due to the anisotropic structure that develops during rolling.

It is important that a cloth which is anisotropic on one length scale could also be isotropic on another (usually larger) length scale. For an instance, most metals are polycrystalline with very small grains. Each of these individual grains could also be anisotropic, but if the fabric as an entire comprises many randomly oriented grains, then its measured mechanical properties are going to be the mean of the properties over all the possible orientations of the individual grains.

From the standpoint of mechanics, fiber composites are among the class of materials called orthotropic materials, whose behavior lies between that of isotropic and that of anisotropic materials. Differences between these materials can be best explained through their response to tensile and shear loads. A uniaxial tensile load on the specimen of isotropic material will produce an elongation in the load direction and a shortening in the perpendicular direction. There will however be no change in the angles between two adjacent sides.

III. EXPERIMENT

✓ *MANUFACTURING PROCESS OF THE COMPOSITE LAMINATE*

A process in which an item is fabricated or made from the raw or semi-finished materials instead of being assembled from the readymade components of parts is a manufacturing process.

FRP products can be fabricated in the following basic process. They are

- ★ Sheet molding compound (SMC)
- ★ Filament winding

- Injection molding
- Hand lay-up
- Spray-up processes for Dough molding compound (DMC)
- Intermediate cure
- FRP continuous paneling process
- FRP form structure
- Vacuum bagmolding
- Pressure bagmolding

However, only some of the above processes are being employed now.

MATERIALS REQUIRED:

Different materials and components required for this process of manufacturing glass epoxy composite are as mentioned below.

SL. No	Materials	Quantity
1.	Fiber Glass	1047.6g
2.	Epoxy resin LY-556	429.04g
3.	Hardener HY-556	100g
4.	Teflon sheets (1x 1) m	1
5.	Measuring jar	2
6.	Stirring rod	1
7.	Gloves	8
8.	Portable Weighing Machine	1
9.	Weights	
10.	Scissors	1

Table 2: Required materials for manufacturing.

GLASS FIBRE:

In this process we have used E-Glass fiber (54% SiO_2, 15% Al_2O_3, and 12% CaO) of Woven Roving reinforcement type.

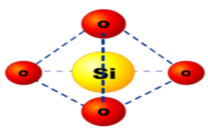

Fig 5: Molecular Structure of Glass

MATERIAL PROPERTIES OF GLASS FIBRE:

SL. No.	Parameter	Value
1.	Density	360 GSM
2.	Rockwell hardness	110 M scale
3.	Bond strength	>1000 kg
4.	Flexural strength	>345 MPa
5.	Tensile strength	>310 MPa
6.	Impact strength	>44 Nm/m
7.	Compressive strength	>415 MPa
8.	Dielectric strength	20 kV/mm
9.	Permittivity	4.8
10.	Dissipation factor	0.017
11.	Young's modulus	3.5x10^6 psi
12.	Poisson's ratio	0.136

Table 3: Properties of glass fiber

EPOXY RESIN:

LY556 is the resin used in this process of manufacturing glass epoxy composites. $((CH)_3C(C_6H_4OH)_2)$

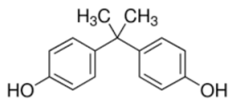

Fig 6: Molecular Structure of Epoxyresin

MATERIAL PROPERTIES OF EPOXY RESIN:

SL. No	Parameter	Value
1.	Density	1.175 gm/cc
2.	Rockwell hardness	80 M scale
3.	Elastic modulus	2415 MPa
4.	Flexural strength	>120 MPa
5.	Tensile strength	>90 MPa
6.	Impact strength	>20 Nm/m
7.	Compressive strength	>173 MPa
8.	Dielectric strength	300 V/mil
9.	Thermal conductivity	$0.188\ w/m^{-0}c$
10.	Dissipation factor	0.017
11.	Elongation at break	3-9 %
12.	Poisson's ratio	0.145

Table 4: Properties of Epoxy resin

DETERMINATION OF REQUIRED EPOXY RESIN AND GLASS FIBER:

Generally, to measure the required amount of materials for manufacturing the composite laminate, we need an electronic weighing machine that measures the quantity exactly in grams. In this project, we are using two different ratios of glass fiber to epoxy resin.

PREPARATION OF MOULD:

To make the test specimen, composite laminates are prepared on a wooden mould of dimensions 20*30 cm*cm as shown in the figure.

Fig 7: wooden mold to prepare composite material

CUTTING OF GLASS FIBRE:

Glass fiber must be cut into several layers each of dimension 250x250mm, so that it will fit into the mold exactly. A normal blade can be used to cut the glass fiber and it's weight can be measured by the electronic weighing machine.

Fig 8: Cutting of glass fiber

PROCESSOR IN MANUFACTURING:

Apply a Teflon sheet to the wooden mold initially and coat it with the wax gel to avoid sticking of polymer to the surface. To get a good surface finish of the product, thin Teflon sheets are used at the top and bottom of the mold plate.

Allow it to dry for a few minutes and once it is dried properly, PVA coating is applied which acts as a mold release. This PVA coating should be applied only in the area where Teflon is applied, this coating should be applied until it forms a thin film on Teflon. This whole setup is allowed to dry completely. Then, the liquid form thermosetting polymer is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and is poured onto the mold. Spread the polymer uniformly with the help of brush. Mix resin and hardener in the ratio of 10:1 i.e. if the resin is taken in 100g then the hardener should be taken in 10g.

Resin and hardener must be mixed just before the preparation of the laminates since this mixture hardens after 15-20 minutes and will be of no use in such a case. The reinforcement which is cut earlier is placed in the woven mats in layers where the resin and hardener are already applied. Repeat this process for each layer of polymer and mat, till the required layers are stacked. Repeat the above process again and continue until the required thickness is obtained. Allow it to settle for half an hour and then the weights are applied on the mold. A wooden plank of dimensions 30x30cm is placed such that uniform pressure is applied.

This is a stage at which the best physical properties of any molding are developed. Allow laminate to cure for 12-16hrs once it is settled. After the curing is done, the specimen is taken out of the mold and cut into the required length as per the dimensions (200 x 25 x 8mm).

Fig 9: Applying Teflon sheet

Fig 10: applying PVA coating on mold

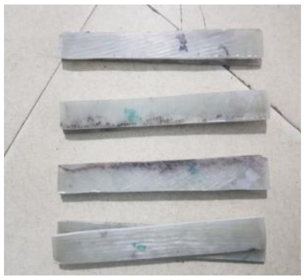

Fig 13: Glass epoxy laminate specimen of varying orientations

Fig 11: mixing resin and hardener

Fig 12: settling of laminate

TESTING OF SPECIMEN

- Specimens used for testing should be cut into required dimensions for two different tests.
- The tests performed on the specimens are Tensile and Compressive tests.
- Both the tests were performed on Universal Testing Machine (UTM).
- For Tensile test, the specimen should be in the dimension of 200x25x5mm.
- For Compressive test, the specimen should be in dimension of 200x25x5 mm.

IV. RESULTS AND DISCUSSIONS

TENSILE TEST:

The tensile strength for the composite material with different blending compositions of epoxy resin and glass fibers of various orientations is presented in table 6.1.

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INPUT DATA		**OUPUT DATA**	
SPECIMEN SHAPE	FLAT	LOAD AT PEAK	3.671KN
SPECIMEN TYPE	COMPOSITE	ELONGATION AT PEAK	2.400 mm
SPECIMEN DESCRIPTION	GLASS FIBER (0*)	TENSILE STRENGTH	18.864 N/mm^2
WIDTH	28.53mm		
THICKNESS	6.59mm		
INTIAL G.L FOR % ELONGATED	00		
MAX LOAD	200KN		
MAX ELONGATION	200mm		
SPECIMEN CROSSSECTION AREA	194.603m^2		

Table 5: Tensile test

INPUT DATA		**OUPUT DATA**	
SPECIMEN SHAPE	FLAT	LOAD AT PEAK	45.671KN
SPECIMEN TYPE	COMPOSITE	ELONGATION AT PEAK	10.590 mm
SPECIMEN DESCRIPTION	GLASS FIBER (30*)	TENSILE STRENGTH	268.564 N/mm^2
WIDTH	28.39mm		
THICKNESS	5.99mm		
INTIAL G.L FOR % ELONGATED	50mm		
MAX LOAD	200KN		
MAX ELONGATION	200mm		
SPECIMEN CROSSSECTION AREA	170.056m^2		

Table 6: Compression test

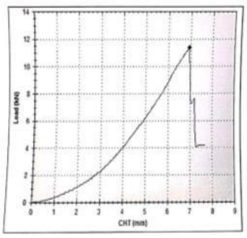

Fig 14: Fluctuations of load shown on line graph

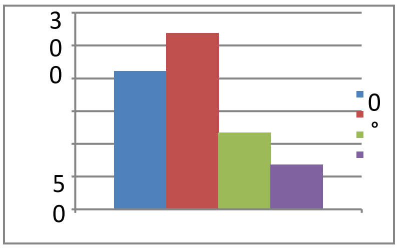

Fig 15: Graph for Tensile Test

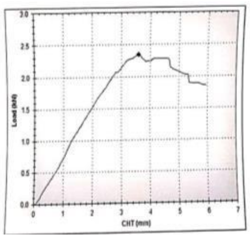

Fig 16: Fluctuations of load shown on line graph

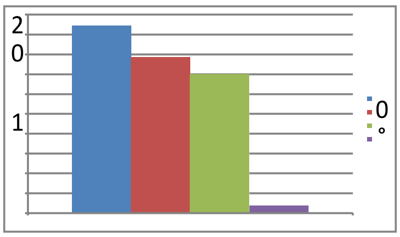

Fig 17: Graph for Compression Test

COMPRESSION TEST:

The Compression test at break for a composite with different blending compositions of epoxy resin and glass fibers are presented in table 6.2. Hardness was calculated using the equation.

V. CONCLUSIONS

From the Impact test, we conclude that

- ★ The composite material shows higher tensile strength in the orientation of 30º.
- ★ The composite material shows the lower tensile strength

in the orientation of 90º.

- The order of tensile strengths of the specimens is 30º > 0º > 45º > 90º.

From Hardness test, we conclude that

- The composite material shows higher compression strength in the orientation of 0º.
- The composite material possesses lower compression strength in the orientation of 90º.
- The order of compression strengths of the specimens is 0º > 30º > 45º > 90º.

- The tensile strength of specimens with an orientation of 30º is higher when compared to all other specimens with different orientations. Whereas the compression strength of the specimen with an orientation of 30º is only a percentage less than the 0º orientation.
- From this, we can conclude that the composite material with orientation of 30º is best among all the considered orientations.

FUTURE *SCOPE*

From our experiments, we conclude that composite materials have good mechanical properties and are light in weight. It is better to replace the conventional materials with composite materials.

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