

Experimental Test on Gfrp-Epoxy Composite Laminate for Mechanical, Chemical & Thermal Properties

Jatoth Prudhvi Raj Naik ¹, B.Mahasenadhipathi Rao² & B.Shiva Sambhi Reddy ³

¹ [M.Tech (CAD/CAM) final year student, Department of mechanical engineering, Sree nidhi institute of science & technology (Autonomous), Hyderabad, Andhra Pradesh, India.]

²[Assistant professor, Department of mechanical engineering, Sree nidhi institute of science & Technology (Autonomous), Hyderabad]

³ [Supervisor, managing director, Paru engineers Pvt ltd, phase-1, Cherlapally, Hyderabad, Andhra Pradesh, India.]

Abstract: GFRP (glass fibre reinforced plastic) composite materials are used in many engineering applications because of its high strength to weight ratio. The purpose of this experiment is to investigate mechanical, chemical and thermal properties of GFRP rotor blades which are used in cooling towers. These blades are manufactured by pressure bag moulding process by using suitable mould. Before installation (Delivery), the blade must be tested for mechanical, chemical, thermal and other properties. For this testing, GFRP laminate is made by hand layup technique. Epoxy resin is used as matrix in manufacturing of the gfrp laminate.

Key words: GFRP composite laminate, hand layup technique, mechanical properties, chemical resistance, thermal properties.

I. Introduction

Axial flow fans are large capacity air moving devices suitable for induced draught cooling towers. The conventional cast aluminium blades have a complex design with high power consumption and lower performance efficiency. This paper describes the successful development of a FRP fan with hollow blades. The main purpose of fan is to move air and to work. This air is supposed to be evenly distributed over the entire exit area of the fan. The energy is imparted to the air by a power driven impeller in order to work, the fan must overcome the resistance measured as pressure drops across the fan such as velocity pressure drop and static pressure drop.

The criterion for material selection for the fan blade was:

- a) Corrosion resistance
- b) Structural integrity
- c) Efficiency
- d) High strength-to-weight ratio
- e) Improved aero dynamic characteristics

The most common material for fan blade- Aluminium was not selected because of the following FRP's advantages over aluminium blades:

- A substantial reduction in weight could be achieved due to hollow construction of the FRP blade.
- The total FRP blade is varying from 7.5° to 24° throughout the length of the blade

These GFRP blades are made by hand layup process by designing suitable moulds. After manufacturing, these blades must be tested for different properties like mechanical, chemical, thermal and etc. we cannot conduct any experimentation directly on blades because it may damage the blade. For testing purpose GFRP laminate should be prepared same as the thickness of the blade. [2]



Figure 1: GFRP fans for cooling towers

II. Literature Review

The word composite in the term composite material signifies that two or more materials are combined on a macroscopic scale to form a useful third material. The key is the macroscopic examination of a material where in the components can be identified by the naked eye. Different materials can be combined on a microscopic scale, such as in alloying of metals, but the resulting material is, for all practical purposes macroscopically homogeneous, i.e., the components cannot be distinguished by the naked eye and essentially act together. The advantage of composite material is that, if will designed, they usually exhibit the best qualities of their components or constituents and often some qualities that neither constituent possesses. Some of the properties that can be improved by forming a composite material are: [1]

- ✓ Strength
- ✓ Stiffness
- ✓ Corrosion resistance
- ✓ Wear resistance
- ✓ Acoustical insulation
- ✓ Weight
- ✓ Temperature-dependent behaviour
- ✓ Thermal insulation
- ✓ Thermal conductivity

Classification of FRP composite materials

Classification of FRP composite materials into four broad categories has been done according to the matrix used. They are

- ✓ Polymer matrix composites
- ✓ Metal matrix composites
- ✓ Ceramic matrix composites and
- ✓ Carbon /Carbon composites.

Polymer matrix composites are made of thermoplastic or thermo set resins reinforced with fibres such as glass, carbon etc.

Metal matrix composites consist of a matrix of metals or alloys reinforced with metal fibres such as boron or carbon.

Ceramic matrix composites consist of ceramic matrices reinforced with ceramic fibres such as silicon carbide, alumina or silicon nitride. They are mainly effective for high temperature applications.

Carbon/carbon composites consist of graphite carbon matrix reinforced with graphite fibres.

III. Hand Layup Process For Glass Fibre

PREPARATION OF THE MOLD: Remove dust and dirt from mold. If mold is of plaster, wood, or new fiberglass, apply soft wax and buff with soft towel. Spray or brush with PVA, parting compound and allow drying. If mold material is glass, metal, ceramic, or well-cured fiberglass, apply three coats of hard wax, carnauba type, buffing between each coat.

APPLYING THE GEL-COAT: If gel-coat is to be brushed on, allow first coat to cure and then apply the second coat to make sure that there should be no light spots. If gel-coat is to be sprayed on with a gel-coat gun, spray up to a thickness of .015” to 020”. When gel-coat has cured long enough that your fingernail cannot easily scrape it free (test at edge of mold where damage will not show on part) then proceed with next step.

LAY-UP SKIN COAT: Cut ¾ or 1 oz. mat to cover part. Brush catalyzed resin over gel-coat then applies the mat. Work with roller adding more resin where necessary until all white areas in mat fibers have disappeared and all air bubbles have escaped. Resin-rich areas weaken the part. Where rollers will not reach, brushes must be used. When this step is complete, clean all tools in acetone. Allow skin coat to cure before next step.

LAYING FIBERGLASS REINFORCEMENT: For a 12 ft. boat, two layers of 1½ oz. or 2 oz. mat may be adequate, depending upon design. For a 14 ft. boat, an additional layer of woven roving will add considerable strength. Apply each layer as in step 3, but it will not be necessary to wait for curing between these layers. Be sure to shake all acetone out of brushes and rollers before applying resin. Acetone drips can result in uncured spots in the lay-up.

TRIM: On a small lay-up, the fiberglass laminate which hangs over the edge of the mold can be trimmed off easily with a razor knife if you catch the “trim stage,” of the period after the lay-up has gelled but before it has hardened. On a larger lay-up, it can be trimmed with a saber saw and coarse sand paper.

CURE: Cure may take from two hours to overnight, depending upon turnover desired, temperature, canalization, and nature of the part. If laid up in a female mold, longer cure will affect shrinkage and easier parting. In the case of the male mold, the part comes off more easily before it shrinks appreciably. If the part is

subject to warping, a longer cure may be necessary. In any case, when the part is removed it should be supported in its desired shape until fully cured.

REMOVE PART FROM MOLD: First, examine the trim edge all the way around the mold and make sure there is no resin bridging the line between the mold and the part. Sand this edge where necessary. Then wooden wedges, such as “tongue sticks,” can be pushed into the edges to start the separation. Continue separation by pulling and flexing. In some cases it is necessary to drill a small hole in the mold and apply air or water pressure.

FINISH: Trim edges and back of part may need to be fine-sanded and coated with surfacing resin or gel coat.

IV. Gfrp Composite Laminate Preparation

Composite laminates are assemblies 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.[3]

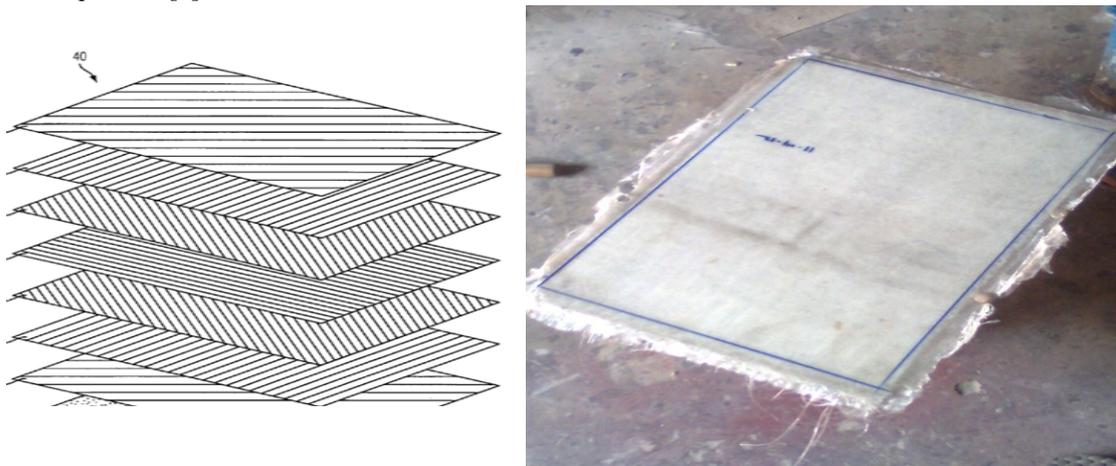


Figure 2: Construction of a laminate

V. Specifications of Materials Used In the Gfrp Laminate

TYPE OF FIBRE: Glass fibre (chopped strand mat-300 g/s-m, woven roving-400 g/s-m, unidirectional fabric - 220 g/s-m, 10 mil glass cloth)

MATRIX: Epoxy resin (L12 grade epoxy resin & K6 grade hardener)

For the manufacture of FRP fan blades formerly aluminium materials were used. However, with development of the composites, aluminium has been replaced by frp (epoxy resins) where high strength is called, like in aerospace and rotor application.

Epoxy resins are more expensive than polyester but have superior mechanical properties, higher dynamic strength and fatigue resistance. The epoxy resin laminate have low water absorption with high tensile and shear strengths. Epoxy resins are the ultimate choice of the FRP fan blades and are more advantageous in hollow construction.

VI. Experimentation and Results

This experimentation work is focused to know the mechanical, thermal and chemical properties of the GFRP composite laminate.

Tests carried out on GFRP laminate are:

1. Tensile test
2. Cross breaking strength
3. Chemical resistance
4. Impact (Charpy & Izod)
5. Thermal contact conductance

TENSILE TEST

Tensile test specimen and cross breaking strength specimen are sliced from the GFRP Laminate and test carried out as per IS 1998-1962 standard. [6]

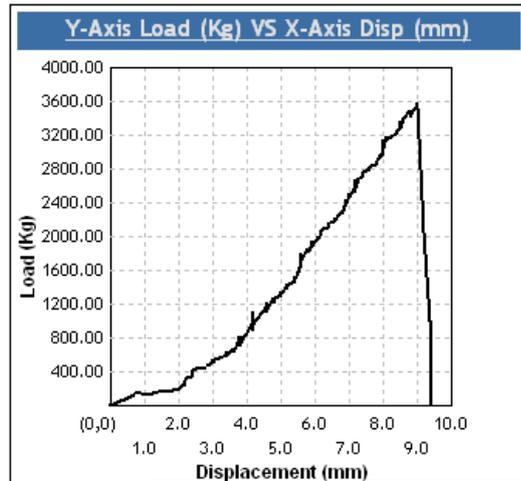
Result:

Thickness of specimen D = 0.746 cm
 Width of specimen B = 2.268 cm
 Maximum load W = 3584 Kgf
 Tensile strength = W / (B*D)
Tensile strength = 2118.29 Kgf/cm²

CROSS BREAKING STRENGTH

Result:

Load at fracture W = 85.62 Kgf
 Distance between supports L = 12 cm
 Width of specimen B = 1.668 cm
 Thickness of specimen D = 0.727 cm
 Cross breaking strength = (1.5*W*L / B*D²)
Cross breaking strength = 1748.33 Kgf/cm²



Load Vs Displacement Graph

Chemical Resistance Testing and Results

ASTM D543 - 95, Standard Test Methods for Evaluating Resistance of Plastics to Chemical Reagents, outlines test procedures for determining resistance of the laminate to various chemical reagents by means of reporting weight, dimensions, appearance, and strength properties, after a set duration period of immersion.

The test method consisted of soaking test laminate coupons cut from the long length laminate in the following chemical reagents for a seven day period. For a 100ml of solution, the % of chemicals taken were 1% Nitric Acid, 1% Ferric Chloride, 5% Ammonium Hydroxide, 5% Sodium Hydroxide, 20% Sulphuric Acid. The cut samples were placed in 5 different solutions as mentioned. [4]

The initial weights of the specimens must be recorded before placing the specimen into the chemical reagents. After seven days the pieces are taken out from the beakers and rubbed with the soft cloth in order to make the pieces dry. The final weights also recorded. The difference of the two weights can be calculated to know the performance of the material. The test equipment is as shown below.

Formula for calculating % of weight loss or gain

$$\%w = \frac{W_f - W_i}{W_i}$$

Where W_f = Final weight of the specimen ; W_i = Initial weight of the specimen

After the immersion of the samples in chemical reagents for seven days period, it was observed that there was slight change in the weights of the specimens compared to their initial weights.

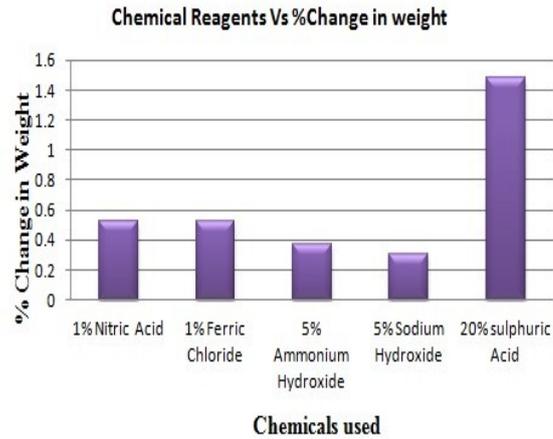


Figure 3: Chemical Resistance Experimental setup

VI. Results:

Table no 1 Chemical Resistance Values

Chemical used (%)	Initial weight	Observed weight	% Change in weight
1% Nitric Acid	5.462	5.491	0.53
1% Ferric Chloride	4.400	4.423	0.52
5% Ammonium Hydroxide	4.836	4.854	0.37
5% Sodium Hydroxide	5.232	5.248	0.30
20% Sulphuric Acid	5.924	6.012	1.48

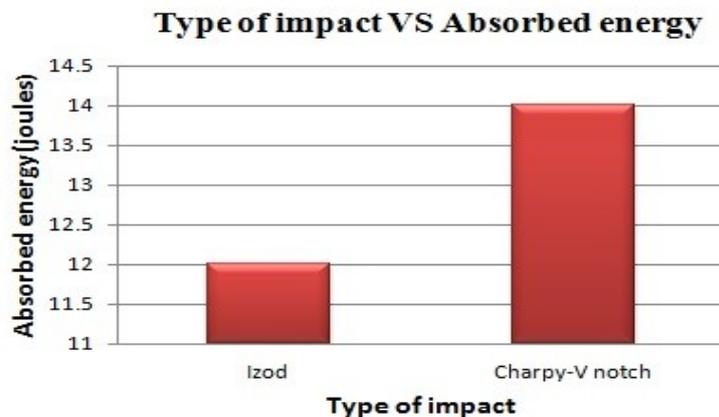


Impact Testing (Charpy & Izod):

The impact test is a standardized high strain rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material’s notch toughness and acts as a tool to study temperature-dependant ductile-brittle transition. This test is carried out as per ASTM D 256-04 at room temperature. Dimensions of Izod impact test specimen are 12.5x7.58x65 mm where as the dimensions for charpy-v notch test specimen is 12.5x7.58x55 mm. Depth of notch is 2.54mm and the included angle of the notch shall be 45°. [5]

Results:

Type of test	Location of sample	Absorbed energy(joules)
Charpy-V	Longitudinal direction	14
Izod-V	Longitudinal direction	12



Thermal Contact Conductance:

Thermal contact conductance is a measure of the ability of a material to transfer heat per unit time, given one unit area of the material and a temperature gradient through the thickness of the material. It is measured in watts per meter per degree Kelvin.

Diameter of specimen = 0.25m

Area = $4.908 \times 10^{-4} \text{ m}^2$

Thickness of specimen = $7.36 \times 10^{-3} \text{ m}$

Results:

Q = 17.86watts

$K = Q \cdot \Delta x / A \cdot \Delta T$

K = 3.52 W/m K

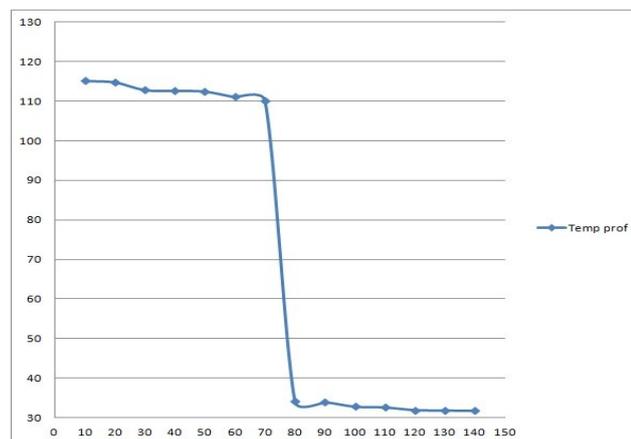
Thermal conductivity of GFRP laminates

Specimen K = 3.52 W/m K



Figure 4: Thermal conductivity setup

**Research & Development Centre, SNIST,
Hyderabad**



Graphical representation on Thermal contact conductance

VII. Conclusion

In this work, GFRP laminate was prepared by hand layup process in order to evaluate mechanical, chemical and thermal properties. This GFRP laminate composition is used in manufacturing of wind turbine blades, cooling tower blades etc. instead of aluminium blades in order to avoid pitting on the surfaces, scales formation and reduction of maintenance cost as well. This material possess very good insulating properties and very less reactive to the chemicals.

Acknowledgement

Authors sincere thanks to Principal and Technical team of R&D centre, Sree Nidhi institute of Science & Technology, Hyderabad and Managing Director of Paru Engineers Pvt ltd for extending all sort of help in bringing out this technical paper .

References

- [1] 'Mechanics of composite materials' Madhujit Mukhopadhyay, Universities Press (India) private limited
- [2] 'Manufacturing process of FRP fan blades' by RECONDO LIMITED, MUMBAI, INDIA
- [3] 'Laminated plastics' Duffin, D.J., Reinhold publishing corporation, New York
- [4] 'Chemical Resistance in accordance with ASTM D543'
- [5] 'ASTM D256-04 Standard Test Methods for Determining the Charpy Impact Resistance of Notched Specimens of Plastics
- [6] 'IS 1998-1962' Indian standard test method for tensile properties.