Design and Analysis of Glass Fiber Reinforced Plastic Composite Rotor Blade

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Abstract— GFRP (Glass Fiber 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 properties of GFRP rotor blades which are used in cooling towers. These blades are manufactured by pressure bag molding process by using suitable mould. Before installation (Delivery), the blade must be tested for mechanical properties. For this testing, GFRP laminate is made by hand layup technique. Epoxy resin is used as matrix in manufacturing of the GFRP laminate. Axial flow fans are large capacity air moving devices suitable for mine ventilations and air heat exchangers. The conventional cast aluminum blades have a complex design with a higher power consumption and lower performance efficiency. The aim of proposed work is to fabricate, design, and analyze the epoxy based glass fiber composite, compare these results with experimental and theoretical values.

Key words: GFRP Composite Laminate, Hand Layup Technique, Mesh Works, Hyper Works

I. INTRODUCTION

A. Preliminary Remarks

In recent times, composite materials are a subject being talked about a lot among engineers, technologists and scientists. The simple reason is that this class of materials have the capability to meet some of the demanding requirements of modern technology be it aircraft, missile, wind turbine blades, cooling tower blades, spacecraft, automobile or for that matter a bullock cart or common sauce pan used in kitchen.

Axial flow fans are large capacity air moving devices suitable for induced draught cooling towers. The conventional cast aluminum blades have a complex design with high power consumption and lower performance efficiency. This project describes the successful development of a Fiber reinforced plastic fan with hollow blades. 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.

B. Significance of Project

Some of the properties that can be improved by forming a composite material are:
- Strength
- Stiffness
- Corrosion resistance
- Wear resistance
- Acoustical insulation
- Weight
- Temperature-dependent behaviour
- Thermal insulation
- Thermal conductivity
- Composite rotor blades that can be withstand temperature up to 160 degree centigrade.

C. Aim and scope of work

The aim of proposed work is to fabricate, design, and analyze the epoxy based glass fiber composite, compare results with experimental and theoretical values.

D. Objective of work

The objective of this project was to investigate the mechanical properties of glass fiber reinforced plastic composite rotor blade.

Fig. 1: Energy efficient axial flow FRP fan

II. LITERATURE SURVEY

Due to the requirement of high performance of the material in aerospace and marine structures, the prospect of future research of composite material, such as Glass fiber reinforced plastic (GFRP) is very bright.

Experimental test on GFRP-Epoxy composite laminate for chemical & thermal properties were determined by Jatoth Prudhvi Raj Naik, B. Mahassenadhipathi Rao & B. Shiva Sambi Reddy in 2013.

Analysis of mechanical properties of chopped strand Mat E-Glass fiber epoxy resin nanoclay composites were experimentally determined by Dr. P. K. Palani, M. Nanda Kumar in 2013.

Design and Structural analysis of jute/E-glass woven fiber reinforced epoxy based hybrid composite leaf spring under static loading by Amrita Srivastava and Sanjay Choudhary in 2013.

Fiber reinforced polymer composites are very widely used because of their favourable properties such as high specific tensile and compressive strength, controllable electrical conductivity, low coefficient of thermal expansion, good fatigue resistance and suitability for the production of complex shape materials. These materials have become the alternative of conventional structural materials such as steel, wood or metals in many applications.

Typical areas of composite applications are car industry, aircraft fabrication, wind power plant, boats, ships, etc. During the human history, composites made occasionally large breakthroughs in construction and other
materials. Among the composites, Chopped strand mat E-glass/epoxy composite is emerging as a promising material for marine application due to their excellent superior strength, moisture resistance and electrical and fire insulation than that of other composites in making boat hulls, fiber glass boat.

Various other different methods of fabricating the polymer matrix composites are wet lay up (hand layup), resin transfer moulding, filament winding and compression moulding. Among the techniques mentioned above, Hand layup technique is used in this study since; it is effective, economic, good surface finish and easy fabrication.

III. HAND LAYUP PROCESS FOR GLASS FIBRE

A. 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.

B. 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.

C. 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.

D. Laying Fiber Glass 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.

E. 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.

F. 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.

G. 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.

H. Finish

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

I. Grinding

Grinding is an abrasive machining process that uses a grinding wheel as the cutting tool.

IV. GRP 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.

Fig. 2: Composite Laminate

Specifications of Materials Used In The GFRP Laminate:

A. Type of Fibre

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

B. 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.
V. EXPERIMENTATION AND RESULTS
This experimentation work is focused to know the mechanical properties of the GFRP composite laminate.

Tests carried out on GFRP laminate are:
1) Tensile test
2) Cross breaking strength test
3) Shear strength test

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

Fig. 3: Test specimens

A. Tensile Test Result
- Thickness of specimen (D) = 0.712 cm
- Width of specimen (B) = 2.009 cm
- Maximum load (W) = 3274.21Kgf
- Tensile strength = W/ (B*D)
- Tensile strength = 2289.004Kgf/cm²

Fig. 4: Tensile test and Failure of the specimen

B. Cross Breaking Strength Test Result
- Thickness of specimen (D) = 0.700 cm
- Width of specimen (B) = 1.517 cm
- Load at fracture (W) = 82.4 kgf
- Distance between supports (L) = 12 cm
- Cross breaking strength = (1.5*W*L/ B*D²)
- Cross breaking strength = 1995.34 kgf/cm²

Fig. 5: Cross breaking test and Failure of the specimen

C. Shear Strength Test Result
- Thickness of specimen (D) = 0.666 cm
- Width of specimen (B) = 0.668 cm
- Shear load (W) = 691.10 kgf
- Shear strength = W/(2* B*D*K), factor K=1.048
- Shear strength = 741.14 kgf/cm²

Fig. 6: Shear test and Failure of the specimen

VI. ANALYSIS RESULTS
Software Used: Mesh Works (Design, Boundary conditions), Hyper Works (Optistruct-Solving, Hyper view - Results)

A. Tensile Strength Test

Fig. 7: Specimen CAD model

B. Cross Breaking Strength Test

Fig. 8: Tensile Stress

B. Cross Breaking Strength Test

Fig. 9: Specimen CAD Model
The voids significantly affect the mechanical properties and the performance of the composites at the work place. Higher void content mean lower fatigue resistance, greater susceptibility to water penetration and weathering., However presence of voids is unavoidable in hand layup process.

In this work, GFRP composite rotor blade is fabricated, designed, and analyzed the epoxy based glass fiber composite, compared results with experimental and theoretical values.

REFERENCES


VII. CONCLUSIONS

In this work, GFRP laminate was prepared by hand layup process in order to evaluate mechanical properties. This GFRP laminate composition is used in manufacturing of wind turbine blades, cooling tower blades etc. instead of aluminum 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.

<table>
<thead>
<tr>
<th>Test</th>
<th>Theoretical Values (MPa)</th>
<th>Experimental Values (MPa)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
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<tr>
<td>Tensile Strength</td>
<td>196.13</td>
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<td>Cross Breaking Strength</td>
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<tr>
<td>Shear Strength</td>
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Table 1: Experimental vs Theoretical values