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Manufacturing And Testing of Gfrp-Epoxy Composite Desert Cooler Fan Blade

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Abstract: *The Desert Cooler Fans Are Broadly Used For Providing The Airflow For Heat & Mass Transfer Operations In Different Industrial Equipment And Processes. These Include Cooling Towers For Air-Conditioning & Ventilation, Air Heat Exchangers For Various Chemical Processes. All The Foremost Industries Such As Power Generation Units, Petroleum Refining & Petrochemicals, Cement, Chemicals & Pharmaceuticals, Fertilizer Production Units, Mining Activities, Textile Mills Etc. Use Large Number Of Cooler Fans For The Abovementioned Operations. The Desert Cooler Fans Are Usually Designed With Impellers Made Of Aluminium Or Mild Steel. This Leads To High Power Consumption & High Noise Levels With Lesser Efficiency. The Leading Fan Manufacturers In And Around The World Have Been Looking At Frp Fans For Higher Efficiency. 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. The Purpose Of This Experiment Is To Replace The Conventional Aluminum Material With Gfrp And To Investigate The Mechanical Properties And Airflow Of The Rotor Blade Before Installation.*
Keywords: *GFRP composite laminate, hand layup technique, composite blade, epoxy resin.*

I. Introduction And Literature Review

Generally, desert cooler fans are large capacity air moving devices and the conventional cast aluminium blades have a complex design with high power consumption and lower performance efficiency. Because of its high strength to weight ratio GFRP (glass fibre reinforced plastic) composite materials are used in many engineering applications. Keeping in view the international trends and energy savings potential, the project on 'Development of Energy Efficient FRP Axial-flow Fans' was launched by the Advanced Composites Mission of TIFAC, Department of Science & Technology in partnership with M/s.Parag Fans & Cooling Systems Ltd., Dewas (MP). The technology support in terms of aerodynamic design of axial flow fan impellers, composite structural design, raw materials, fabrication process and performance evaluation was provided by the Department of Aerospace Engineering, Indian Institute of Technology (IIT), BOMBAY. Although there are many varieties of resins and fibres are available, taking into account the manufacturing easiness and the mechanical aspects epoxy resin and E- glass fibre is employed in the fabrication work. The term "epoxy" refers to a chemical group consisting of an oxygen atom bonded to two carbon atoms. The simplest epoxy is a three-member ring structure known by the term "alpha-epoxy" or "1,2-epoxy". Epoxy resin is almost fully transparent when cured. E- Glass fibre has good tensile and compressive strength, stiffness and good electrical properties. It is comparatively low cost, but the impact resistance is relatively poor. E-glass is the most common form of reinforcing fibre used in polymer matrix composites. Chandrasekhar designed an axial flow fan and modelled and observed that the present used axial flow fan has 10 blades, so changed to 12 and 8 to observe the results. By observing the analysis results, for all materials, the analyzed stress values were less than their respective yield stress values, so using all the three materials is safe under given load conditions and observed that the strength of the composite material Carbon Epoxy is more than that of other 2 materials Mild Steel and Aluminium Alloy. By observing the analysis results, the displacement and stress values are less when 8 blades are used [3]. Comfortson fabricated the composite fan blade made up of glass fibre reinforced polymer and the performance of the fan is compared with the conventional fans. Compared to existing fan blade, it is observed that the composite blade saves 26% of power, and reduces the cost by 28%. The weight is reduced by 27% thus reducing the power consumption. And confirmed that the flow velocity through the composite blade is 15% more than that of the conventional fan [4]. Prudhvi Raj investigated mechanical, chemical and thermal properties of GFRP rotor blades which are used in cooling towers, and observed that GFRP possess very good insulating properties and very less reactive to the chemicals [5].

II. Methodology

2.1 Materials used

For blades the material required is as follows:

Glass: 185g, Roving: 357g, CSM: 156g, Resin: 900g, Hardener: 90g from this the total weight of the fan is obtained as 1.170kg

2.2 Advantages

The Fibre Reinforced Plastics (FRP) fans have the following advantages

1) Higher efficiency suitable for any specific application.
2) Reduced overall weight of the fan, thereby extending the life of mechanical drive systems such as motors, gearboxes, bearings etc.
3) Low power consumption resulting in appreciable energy savings as compared to existing metallic fans.
4) Lower flow noise and mechanical noise levels compared to the conventional metallic fans.
5) Longer life of fans due to improved mechanical strength.
6) Excellent corrosion & erosion resistance and fire retardance.

The criterion for material selection for the blade is:

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

2.3 Manufacturing Method

Hand lay-up is a simple method for composite production. A mould is used for hand lay-up parts. Existing fan blade is used as the mould. The following are steps to be followed in this technique to obtain the fan blade.

1. **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 mould where damage will not show on part) then proceed with next step.
2. **Lay-Up Skin Coat:** Work with roller adding more resin where necessary until all white areas in mat fibres 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.

Fig.1 mould used for fabrication of fan with hand lay-up technique

3. **Laying Fibreglass Reinforcement:** 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.

4. **Trim:** On a small lay-up, the fibreglass laminate which hangs over the edge of the mould 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.

Fig.2 Performing trimming operation on the fan

5. **Cure:** Cure may take from two hours to overnight, depending upon turnover desired, temperature and nature of the part. If laid up in a female mould, longer cure will affect shrinkage and easier parting. In the case of the male mould, the part comes off more easily before it shrinks appreciably. In any case, when the part is removed it should be supported in its desired shape until fully cured.
6. **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.
7. **Finish:** Trim edges and back of part may need to be fine-sanded and coated with surfacing resin or gel coat.

Fig.3 finally obtained fan by hand lay-up technique

2.4 Experimental test set-up design details

Table1. Fan blade dimensions

Total diameter	600mm
Hub diameter	200mm
Thickness	10mm
Wing length	200mm
Wing width	30mm
Wing thickness	5mm

To fabricate the set-up it is required to have 665x220x8mm M.S Plate, 245x220x8mm M.S Plate and 50x1000x6mm Flat (M.S)

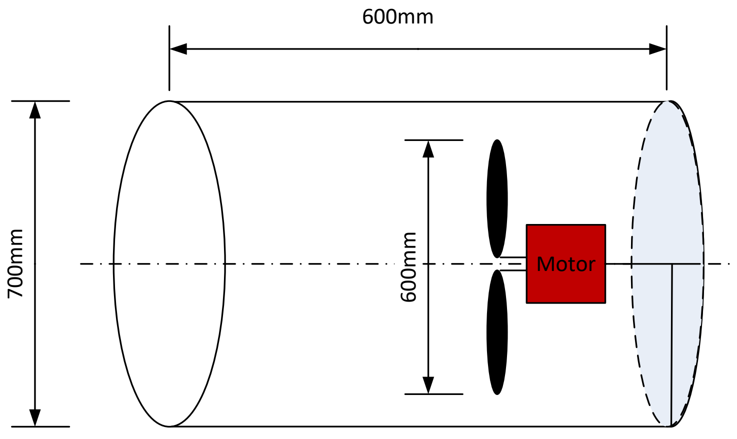

Fig.4 Experimental set-up design

Fig.5 Fabricated experimental set-up

III. Result and Discussions

Aluminium density 2.685 gr/cc
GFRP density 1.60 gr/cc
Mass of Aluminium fan blade 1963 grams.
Mass of GFRP fan blade obtained is 1170 grams.

3.1 Calculation of anemometer location

1) DF – inside diameter of fan ring= 700mm
2) DSD – Hub diameter= 200mm
3) Gross Area (AG)= 0.7854 $(DF)^2$
4) Net Free Area (NFA)= 0.7854 $(DF^2\text{-}DSD^2)$
5) Area/Band (A/B) = NFA/2xNo. Of Bands
6) Area within centre of Band4= (AG-A/B)= A_4

$R_4 = \sqrt{\frac{A4}{\pi}}$ ft. Radius to centre of Band4

7) Area within centre of Band3= $(A_4\text{-}2(A/B))= A_3$

$$R_3 = \sqrt{\frac{A3}{\pi}}$$

8) Area within centre of Band2= $(A_3\text{-}2(A/B))= A_2$

$$R_2 = \sqrt{\frac{A2}{\pi}}$$

9) Area within centre of Band1= (A_2-2(A/B))= A_1

$$R_1 = \sqrt{\frac{A1}{\pi}}$$

3.2 Calculation of distances from fan ring

$d_4 = D/2-R_4$, $d_3 = D/2-R_3$, $d_2 = D/2-R_2$, $d_1 = D/2-R_1$

AG = 0.7854 x $(700)^2$ = 384846mm^2

NFA = 0.7854 x (700^2-200^2) = 353430mm^2

A_4 = (384846-44178.75) = 340667.25mm^2

R_4 = 329.382mm^2

A_3 = (340667.25- (2x44178.75)) = 252309.75mm^2

R_3 = 283.466mm

A_2 = 252309.75 - 88357.5 = 163952.25mm^2

R_2 = 228.504mm

A_1 = 163952.25 – 88357.5 = 75594.75mm^2

R_1 = 155.16mm

Table2. Fan design calculations

BAND	Centre point Radius (mm)	Distances from fan ring (mm)
4	329.382mm	20.618mm
3	283.466mm	66.534mm
2	228.504mm	121.496mm
1	155.16mm	194.84mm

Table3. Air velocity calculations in all directions

Direction	Distance from Fan hub in inches	Air Velocity(m/s)	Avg. Air Velocity(m/s)
East	10	2.8	6.9583
	7	6.2	
	5	9.7	
West	10	2.0	
	7	10.4	
	5	10.8	
North	10	1.9	
	7	6.2	
	5	10.6	
South	10	1.9	
	7	9.7	
	5	11.3	

Air flow rate Q = A x V

Motor power =3H.P.

Avg. Velocity = 6.9583m/s

Area = 0.38465 m^2

Q = A x V = 0.38465 x 6.9583 x 3600

Area flow rate Q = 9622.693 m^3/hr

The air flow of conventional aluminium blade is 9510 m^3/hr according to same calculations.

The power consumption of fan was measured by ammeter. The power consumed by gfrp fan blade is 1.573 amp at load condition and 1.146 amps at no load conditions. The power consumed by conventional aluminium blade is 2.029 amps which is more than frp fan result.

IV. Conclusion

The purpose of this experiment is to replace the conventional aluminum material with GFRP and to investigate the airflow of the rotor blade before installation. So it is fabricated with GFRP and analysis is made for the air flow rate and it is noted down.

1. The airflow rates of the conventional blade and GFRP blade are 9510 and 9622 m^3/hr respectively. It is clear that the result of GFRP blade is more than Aluminium blade.
2. The weights of conventional blade and GFRP blade are 1.963 and 1.170 kgs. As the weight of GFRP blade is less, there will be less thrust and vibration on bearing while fan is rotating. Hence ,life of GFRP fan is more than existing conventional blades.

3. Due to less weight of GFRP blade, the power consumption is also less for GFRP blade than conventional blades. The power consumed by gfrp fan blade is 1.573 amp at load condition and 1.146 amps at no load conditions. The power consumed by conventional aluminium blade is 2.029 amps which is more than frp fan result. Hence, maintainance cost is also less for GFRP fan blade.

The results obtained for GFRP blade are better than existing conventional blades. So, GFRP blades are economically more efficient to use.

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