Development of Radiator Fan using Composite Material for Automotive Application

Vinayak Ramchandra Naik

Abstract : In order to address failure issues related to fan blades, use of alternative materials is becoming popular. This not only saves natures resource of metal but also offers better performance with reduction in weight. In the present work, alternative radiator fan is developed to substitute metallic original one for light public transport vehicle. The paper deals with the methodology of development and also the experimentation carried out in this regard.

Keywords : Composite, Radiator, Rotor, Fan Blade.

I. INTRODUCTION

Radiator fan drags air and push it backward to cool the radiator by convective heat transfer which leads to effective engine cooling. The cooling fan is a part of the cooling system and it is designed to keep a temperature in the engine within permissible limits.

Composite material consists of two distinct phases. This material exhibit better properties with respect to each individual materials of which it consist of[1].

When compared to alloys, composite constituting element get advantage of their individual properties, separately exhibited, offering better performance, even though they are not homogenous and isotropic[2].

Currently different grades of aluminum and steel are widely used for radiator fan. Aluminum has various advantages over steel, like corrosion resistance and cost, however it has less strength as compared to steel. Composites can be used conveniently to replace existing materials for radiator fans. They offer advantage of reduced weight, light construction and custom build strength.

In the present paper, use of glass fiber epoxy material for the development of radiator cooling fan is discussed. With the advantages of composites as discussed earlier, in this paper development of radiator fan for automotive application is elaborated to suit the engine of light public transport vehicle. Fiberglass is a material made from extremely fine fibers of glass. The role of these fibers is to act as a reinforcement agent. Fiberglass is widely used in electronic, marine and automotive industries[3]. High strength is obtained from glass fiber.

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Problems Identified with Conventional Radiator Blade Fan

Even though catastrophic failure of the radiator fan blades have been recorded common causes of their failure are as follows[4]:

A] Problems related to radiator fan blade due to heat treatment.

B] Variation of pressure along the length of blade.

C] Sundry causes other than above.

A) Problems related to Heat Treatment of the Radiator Fan Blade

Fig. (1) : Blade Failure Due to Improper Heat Treatment

In case of cast blades, proper heat treatment must be carried out. For cast blades, post casting heat treatment is necessary. Normally process like precipitation hardening is effective for improved strength.

With poor or improper heat treatment porosity, pinholes are observed in various important sections at the blades, as shown in Fig. (1).

Cracks blemishes have been exhibited in and around such critical section of fan blades. One can observe that the cracked faces show clear cut separated dull, and bright appearing zones.

B) Variation of pressure along the length of blade –

When radiator fan rotate cutting air, it exhibit variation in pressure with repeat to cross section of the blade. Such pressure variation generates lift and drag forces. Such forces are dependent on the design of fan blade, and conditions under which the fan operates. If this lift force is not minimum, for radiator fans it leads to blade breakage. Fig. (2) indicates failure at such fan blade due to pressure variation along length of blade.

Fig. (2) : Blade Damage Due to Pressure Variations

C) Other Sundry Causes

Fan of any engine radiator is exposed to harsh working environment due to dust, heat and also calcium carbonate, silica sand, dust and carbon particles, oil, locomotives brake shoe dust, etc. Exposures to such elements lead to progressive failure of blades. Failures may occur due to cracks generated due to hard hitting of hoses, tool impacts and machinery items like clamps, pipes during engine maintenance or also due to overheating of the fan blades.

II. LITERATURE REVIEW

Literature review is a brief account of research and experimental work carried out by researcher related to radiator fan blades.

N. Saravanakumaret al (2017), investigated an axial flow fan modeled using UG. Present model had 12 no of blades. Material optimization is also carried for all the blades and the conventional material used for the blade was steel and the study was conducted for carbon steel of three different grades.

Gourav Guptaet al (2016), studied and noted that use of composites in various fields for structure subjected to loading condition of compression. Properties of these materials enable them to be used in aero space, sports and automotive.

Manish Dadhich et al (May 2015), have undergone experiment on centrifugal fans with high speed rotating turbo machines vulnerable to vibration resulting in the failure of the system eventually. During every startup and shut down of the centrifugal fan, the blades are subjected to centrifugal, bending and vibratory loads. This repeated start-up and shutdown can reduce the life of the fan blades. A fatigue and modal analysis of the fan is, therefore, very important in the design and development of fans, to prevent failure. The finite element analysis of a centrifugal fan impeller, for a high turned design, is carried out using ANSYS from fatigue analysis, one can determine whether the fan is safe to run in the operating conditions and further the design can be improved. Modal analysis of the fan is very important in the design and development of fan, to prevent failure.

Comfortson S et al. (2014), investigated the effect of glassfiber reinforced composite blade in ceiling fans it reduce the weight of the blade, thereby considerably reducing the power consumption. In this work the fabrication of composite fan blade made up of glass fiber reinforced polymer is carried out and the performance of this fan is compared with the conventional fans. Usage of glass fiber reinforced polymer blades in ceiling fans reduces the weight of the blade thereby reducing the power consumption .Air flow velocity through the blade increases by employing glass fiber blades. Cost of the ceiling fan blade reduce by imparting fiber glass polymer in place of existing blades.

Hemant Kumawat et al.(2014), had done investigation on Modeling and Simulation of Axial Fan Using CFD. Axial fan performance was simulated with CFD. Various parameters for their effectiveness were studied which were number of blade, blade velocity, pressure distribution along blade and temperature. Optimized model was developed using CFD.

Sudhir S Mathapatiet al. (2014), had discussed E-glass fiber reinforced composite with variation in volume fraction of glass fiber content like 1%, 2% and 3% with Bisphenol A as matrix material. Tensile and compression tests were conducted on the prepared composite. As a final point of view, the experimental results were compared with the FEA results by using analysis software like ANSYS. The results obtained experimentally were compared with the simulation in ANSYS software. The experimental values and ANSYS values match reasonably validating the experimental results. The E-glass fiber reinforced epoxy has high ultimate tensile strength and high improvement in the ultimate tensile strength at 3% volume fraction of the glass fiber. Elongation increases with the increasing volume fraction of Glass fiber.

G.Chandrashekar and Baswaraj S Hasu (2013), had done investigation on 'Composite material analysis of axial flow fans' The axial flow fans are conventionally designed with impellers made of aluminum or mild steel. The grey area noted was inconsistency in proper aerofoil selection & dimensional stability of the metallic impellers. This leads to high power consumption & high noise levels with lesser efficiency. In this paper, an axial flow fan is designed and is modeled in 3D modeling software.

Pawan S. Amrutkar and Sangram R. Patil (2013), studied and worked on "Automotive Radiator Performance" automotive engine cooling system takes care of excess heat produced during engine operation. It regulates engine surface temperature for engine optimum efficiency. Recent advancement in engine for power has forced engine cooling system design to develop new strategies to improve its performance efficiency. Also it has forced to reduce fuel consumption along with controlling engine emission to mitigate environmental pollution norms. This paper deals with the parameters which influence radiator performance along with reviews some of the conventional and modern approaches to enhance radiator performance.

Jatoth Prudhvi Raj Naik et al. (2013), present paper discussed about cooling tower blades for their mechanical, chemical and temperature effect during working condition. In the research work, original aluminum blades were replaced by GFRP blades to test the performance.

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M. Nagakiran and S. Srinivasulu, et al (Oct 2013), In present work, fan of axial flow was used for variation in number of blades from 8 to 12. The material of construction was changed to aluminum alloy 204, mild steel and Eglass. The performance of such variation was studies.

S. Prabhakaran and M. Senthilkumar (2012), In this paper, the authors have noted that Ceiling fan is one of the appliance that consumes electric power. The power consumption can be reduced by reducing the weight of the blade. The best way to reduce the power consumption without sacrificing safety is to employ fiber reinforced composite materials in the fan blades. The objective was to compare the power consumption, cost and weight of composite fan blade with that of aluminum fan blade.

Guru Raja M Net al (2012), Authors give brief account of latest applications and future scope of hybrid composites. This paper deals with hybrid composite material technology, in terms of materials and properties, it also outlines some of the important trends and speculations, with emphasis on various applications including some details of smart hybrid composites. The authors have identified application of hybrid composite in automotive, aerospace, marine, wind power areas.

Mahajan Vandana, et al (2011), this work deals with axial flow fan CFD based investigation reported, in order to study the effect of a change in speed of fan on air velocity, pressure, and mass flow rate. It has been observed that there is a significant change in mass flow rate, velocity of rotor and guide or stator vanes as the speed of the fan is varied.

Mohd. Yusof Sulaimanet al (2009), have undergone experiment on Computational Fluid Dynamics (CFD) modeling simulation of air flow distribution from an automotive radiator fan. The result shows the error of average outlet air velocity was 12.6 % due to dissimilarity in the tip shape of the blade.

A. Dubin & E. Homsi (2003), the authors have discussed the guideline in brief for the development of a plastic fan for metal fan. It was limited with respect to axial flow type fans. It is suggested that these rules to be defined in general sense as a starting point in the development process especially when initial geometric data was lacking. It was also essential to integrate a testing program throughout the different development stages, to evaluate the performance of the various basic design changes and their impact on achieving the desired outcome.

Ali Zareet, et al (2002), in this work, improvement in fan efficiency achieved by reducing material was recorded. Due to this, decreasing the airfoil chord length to the optimum value leads to a decline in a number of used materials in the blade design and manufacturing. Factor of safety changes by varying the chord length of the airfoil. However, this paper attempts to analyze the factor of safety in an axial fan blade with different chord lengths by use of finite element method. The load values are determined by the experimental test.

Avinash Gudimetla & S. Sambhu Prasad (2001), In this paper, reversed engineering approach was used for radiator blades. ANSYS was used to check the performance for structural and dynamic loads.

After rigorous literature reviews for typical application under consideration, following methodology as shown in Fig. (3) was proposed. Glass fibres were chosen as fibre material and epoxy resin as matrix material.

Fig. (3) indicates a flowchart that shows the steps to carry out the development work. The implementation work begins from develop the component for application. Then select the proper material. After that, fabricate the specimen by using proper manufacturing method and then test the specimen for tensile strength.

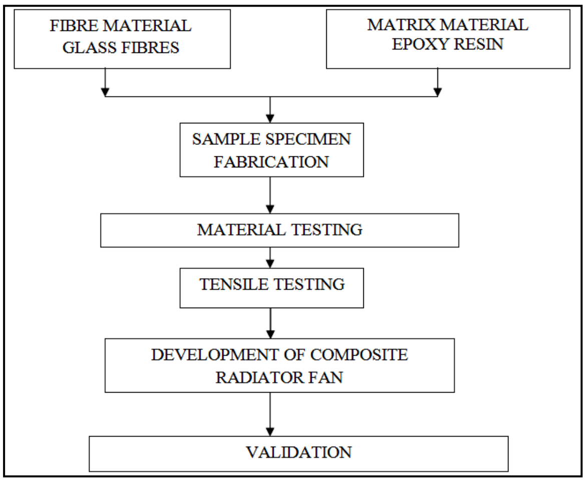

Fig. (3) : Methodology Flow Chart

Table A : Properties of Glass Fiber Epoxy Material

PROPERTIES	**VALUES**
Glass Transition Temperature Tg	120 – 130 0c
Tensile Strength	85 N/mm2
Tensile Modulus	10500 N/mm2
Elongation at Break	0.8 %
Flexural Strength	112 N/mm2
Flexural Modulus	10000 N/mm2
Compressive Strength	190 N/mm2

Table B : Material Comparison

Sr. No.	**Material**	**Young's Modulus (Gpa)**	**Bending Stress (Gpa)**	**Bending Strain (%)**	**Density (Mg/m^3)**	**Cost (Rs/Kg)**
1	E-Glass	72.4	2.4	2.6	2.54	61.6
2	S-Glass	85.5	4.5	2.0	2.49	1232-1848
3	Aramid	124	3.6	2.3	1.45	1232-1848
4	Boron	400	3.5	1.0	2.45	18480-24640
5	HS-Graphite	253	4.5	1.1	1.80	3696-6160
6	HM-Graphite	520	2.4	0.6	1.85	12320-36960

From Table B, it shows that S-glass fibres have better mechanical properties than other reinforcing materials.

But due to cost consideration E-glass fibres are used as reinforcement material. The material properties of E-Glass fibre epoxy are as shown in Table A.

D) Hand Layup Process for Glass Fiber reinforced plastic (Epoxy) as follows[5]:

Hand layup process was used for the development of fan blades. Various steps involved in the development are as specified, which consist of mold preparation, applying gel coat, laying up skin coat, trimming and curing. After that the part is removed from the mode. The edges and burr is finished and coated with resin.

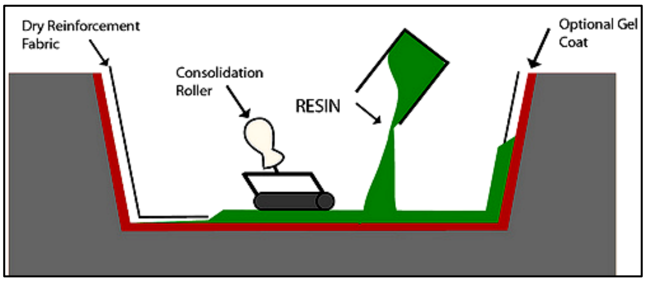

Fig. (4) : Hand Lay-up Process

The process schematic is shown in Fig. (4), and the output of the process in form of fan hub is shown in Fig. (5).

Also Fig. (6) to (8) show, the photographs of moulded composite fan blade hub and blades respectively.

Fig. (5) : Mold of Fan Hub

Finished Product :

Fig. (6) : Front and Back Side of Composite Fan Hub

Fig. (7) : Mold of the Blades

TESTING SET UP:

An experimental setup was developed to test the composite fan[6] [7].

Fig. (8) : Front and Back Side of Composite Fan Blade

The experimental setup consisted of the radiator fan, 12 V DC motor, speed regulating device, a tunnel and wooden blocks for supporting the various members. The fan and the motor are mounted on the wooden block in such a way that the fan should be 300-600 mm higher than the ground level. The tunnel which is made up of galvanized iron (G.I.) and has a diameter of 330mm (13”) and has a thickness of 2 mm rests on the horizontal wooden blocks which are 150 mm over the ground level. Fig. (9) and Fig. (10) show the CAD model and actual test set up for experimentation respectively. The sample specimen of the developed composite was tested in the lab on UTM and it has exhibited 43.42 w/nm^2 yield stress and 60.00 w/nm^2 ultimate tensile stress.

There was provision to adjust the height so that the height of the tunnel is adjusted w.r.t. the center of the fan and the center of the tunnel lie on the same axis. There was provision to vary the speed of the fan rotor with suitable speed control devices. The speed was measured using tachometer and air velocity using anemometer.

Validation :

The composite fan was mounted on the engine, and the engine was operated for 8 hours. It has exhibited smooth, tore able force and vibration free performance for the source application.

Experimentation :

For experimentation no. of blades, blade angle and speed were taken as input parameters, velocity of the rotor and discharge were taken as output parameters[8[. La orthogonal array was used for experimentation.

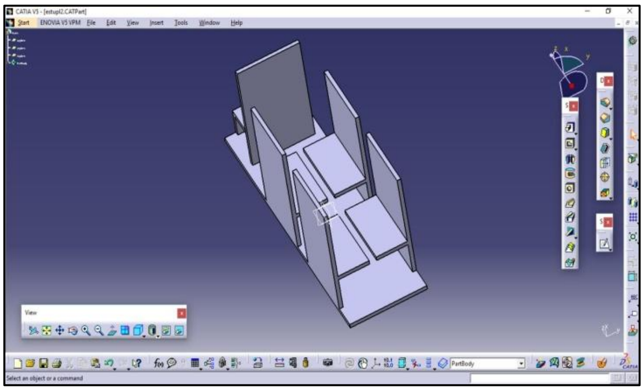

Fig. (9) : CAD Model of Testing Set Up

Fig. (10) : Wooden Supported Testing Set Up

Table (C): Air Velocity Measured on Anemometer

	No. Blade	Angle (Deg.)	Speed (RPM)	Velocity (m/s)
Exp1	3	30	750	1.701
Exp2	3	45	1250	2.223
Exp3	3	60	1750	2.952
Exp4	4	30	1250	2.358
Exp5	4	45	1750	3.402
Exp6	4	60	750	1.134
Exp7	6	30	1750	2.88
Exp8	6	45	750	2.1
Exp9	6	60	1250	2.64

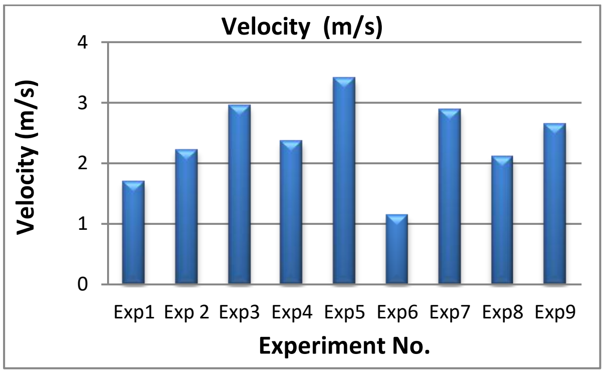

Fig. (11) : Bar Chart for Velocity in M/S

Table (D) : Calculated Velocity and Discharge Table

	No. Blade	Angle (Deg.)	Speed (RPM)	Velocity (m/s)	Discharge Q (m3/s)
Exp1	3	30	750	1.701	0.1202
Exp2	3	45	1250	2.223	0.1571
Exp3	3	60	1750	2.952	0.2086
Exp4	4	30	1250	2.358	0.1666
Exp5	4	45	1750	3.402	0.2404
Exp6	4	60	750	1.134	0.0801
Exp7	6	30	1750	2.88	0.2035
Exp8	6	45	750	2.1	0.1413
Exp9	6	60	1250	2.64	0.1865

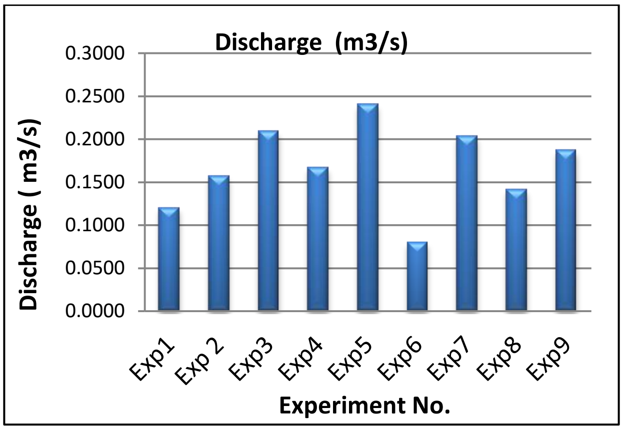

Fig. (12) : Bar Chart of Air Discharge (m^3/S)

III. RESULTS AND DISCUSSION

1) With change in various input parameters guided by La orthogonal array and the output parameters as velocity and discharge of the fan.It was observed that the combination in experiment 5 with 4 no. of blades, angle of blade setting 40^0, and rotor speed at 1750 is offering height air velocity which is 3.40 m/s.

2) The discharge for this velocity of 3.40 m/s, is also maximum, which is 0.2404 m^3/s.

Hence this combination can be typically selected for radiator fan.

IV. CONCLUSION

Use of non-metallic, especially composite with E-glass and expoxy vesin offer good performance to replace conventional radiator fans. Major issued related to metallic radiator fans can be evaluated with composite fans, for radiators. In days to come, such material will image as substitute to metallic rotary elements like radiator fans.

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