IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 1, Issue 5, Oct-Nov, 2013
ISSN: 2320 - 8791
www.ijreat.org

Composite material analysis of axial flow fans

G.Chandra shekar[1], Baswaraj S Hasu[2]

[1] **Department of Mechanical Engineering, CMR Institute of Technology, Hyderabad, Andhra Pradesh-501401, India.**

[2]**Department of Mechanical Engineering, CMR Institute of Technology, Hyderabad, Andhra Pradesh-501401, India.**

Abstract

The axial flow fans are widely used for providing the required airflow for heat & mass transfer operations in various industrial equipment and processes. These include cooling towers for air-conditioning & ventilation, humidifiers in textile mills, air heat exchangers for various chemical processes, ventilation & exhaust as in mining industry etc.

All the major industries of the national economy such as power generation, petroleum refining & petrochemicals, cement, chemicals & pharmaceuticals, fertilizer production, mining activities, textile mills, hotels etc. use large number of axial flow fans for the aforesaid operations.

The axial flow fans are conventionally designed with impellers made of aluminium or mild steel. The grey area today is the inconsistency in proper aerofoil selection & dimensional stability of the metallic impellers. This leads to high power consumption & high noise levels with lesser efficiency

The leading fan manufacturers in the world have been looking at FRP axial flow fans for higher energy efficiency. The improved design of FRP fan is aimed at higher lift to drag ratio and thereby increasing the overall efficiency. The new & improved aerodynamic fan designing, composite development, structural design combined with latest manufacturing process are also expected to result in consistent quality and higher productivity.

In this paper, an axial flow fan is to be designed and modeled in 3D modeling software Pro/Engineer. The design is to be changed to increase the efficiency of the fan and analysis is to be done on the fan by changing the materials Aluminium, Mild Steel and Carbon Epoxy. Analysis is done in finite element analysis ANSYS.

.

Keywords: *Axial flow, modeling, carbon epoxy,*

1.Introduction

1.1 Axial flow fans The axial flow fans are widely used for providing the required airflow for heat & mass transfer operations in various industrial equipment and processes. These include cooling towers for air-conditioning & ventilation, humidifiers in textile mills, air heat exchangers for various chemical processes, ventilation & exhaust as in mining industry etc.

All the major industries of the national economy such as power generation, petroleum refining & petrochemicals, cement, chemicals & pharmaceuticals, fertilizer production, mining activities, textile mills, hotels etc. use large number of axial flow fans for the aforesaid operations.

The axial flow fans are conventionally designed with impellers made of aluminium or mild steel. The grey area today is the inconsistency in proper aerofoil selection & dimensional stability of the metallic impellers. This leads to high power consumption & high noise levels with lesser efficiency

The leading fan manufacturers in the world have been looking at FRP axial flow fans for higher energy efficiency. The improved design of FRP fan is aimed at higher lift to drag ratio and thereby increasing the overall efficiency. The new & improved aerodynamic fan designing, composite development, structural design combined with latest manufacturing process are also expected to result in consistent quality and higher productivity.

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), Mumbai.*

The project involved improvisation of fan design by selecting the most appropriate aerodynamic blade shape to suite specific airflow applications, development of suitable composite materials and structural design to replace the use of metals such as aluminium & mild steel in the impellers. The Fibre Reinforced Plastics (FRP) fans have the following advantages:

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

As the fan efficiency is defined as *(Q x D Pt)/ (Shaft horsepower)*, thus with reduced shaft power requirement, there is a commensurate reduction in energy consumption.

Under the project, the following five types of fans were identified for development for their bulk requirement in the country:

1200 mm dia. fan for ***textile mill humidifiers*** against technical specifications provided by ATIRA, Ahmedabad.

2000 mm dia. fan for ***mine ventilation*** against specs. of Western Coalfields Ltd. (WCL), Nagpur of Coal India Ltd.

4267 mm (14 ft.) dia. fan for ***air heat exchangers*** against specs. of Engineers India Ltd., New Delhi.

1680 mm dia. fan for ***radiator cooling for diesel locomotives*** as per the specs. provided by RDSO, Lucknow.

10,000 mm. (34 ft.) dia. fan for ***cooling towers*** as per the specs. of M/s. Balcke Durr Technology India Ltd., a German MNC.

Raw Materials - The necessary raw materials for the fan impellers include glass fibre in various forms like chopped strand mat, rovings, woven rovings, cloth surface mat and resin (vinyl ester & polyester), catalysts, accelerator, hardener, pigments, surface treatment agents etc. All the raw materials are available indigenously.

FRP Blades - The process called Resin Transfer Moulding (RTM) has been used to fabricate these fan blades. This is a low-pressure, closed mould semi-mechanized process.

The fibre reinforcement, which may be pre-shaped is placed in the required arrangement in the cavity of a closed mould and a liquid resin of low viscosity is injected under pressure into the cavity, which is subsequently cured.

After curing, the material is cooled in the atmospheric temperature and is subsequently placed in the electrically heated oven for post curing, if necessary. The main potential advantages of RTM can be summarized as the capability of rapid manufacture of large, complex, high-performance structures with good surface finish on both sides.

The Hub - The hub consists of four main parts viz. cast iron bush, aluminium block, supporting plates and hardware items such as nuts & bolts. The cast iron bush and aluminium blocks are manufactured by sand moulding and machined as per the required drawings. The four components are then assembled together and tested for static & dynamic balancing.

Fan Assembly - Apart from optimally designed impellers, an axial flow fan also comprises other critical components such as fan hub, support plates, fasteners, bushes for fixing the drive shaft etc.

The FRP fan blades and the hub are assembled together & are again subjected to static & dynamic balance test and inspected at various stages as per the quality assurance plan. FRP fans provide substantial energy savings as compared to conventional aluminium and MS fans thereby reducing initial equipment & operational cost.

The project on development of FRP Axial Flow Fans was launched in September 1998. All the development activities encompassing designing the fans, selection of raw materials, stabilizing fabrication procedure & finally performance testing of four fans were completed by December 1999. The fifth fan for radiator cooling application for diesel locomotives for Indian railways was successfully performance tested in January 2000.

Five fans as mentioned above have been developed successfully under the project. The performance evaluation of all the five types of fans established an efficiency differential of around 25% over conventional fans with aluminium impellers.

The air heat exchanger fan, fabricated by Resin Transfer Moulding (RTM) technique, tested at the refinery of Indian Oil Corporation (IOC) Ltd., Panipat with over 30% energy saving as compared to existing fans imported from overseas suppliers. Air-heat exchanger (forced convection) fan is a critical application with low pressure rise but high discharge volume with low noise levels operating at high temperature.

Another critical requirement of the fan is that no electrostatic charges should generate on the impeller of the fans. Parag Fans developed the fan incorporating surface resistivity characteristics by overlapping a copper wire mesh on the woven glass fabric. In addition, necessary safeguards for preventing erosion of FRP fans could be achieved by covering the leading edge of the impeller with stainless steel foil.

Radiator cooling fan for diesel locomotive was also fabricated by RTM technique and tested as per international standards with improved performance.

2. Design and Analysis of Axial flow fan

In this thesis, an axial flow fan is to be designed and modeled in 3D modeling software Pro/Engineer. Present used axial flow fan in the taken application has 10 blades, in this thesis the number of blades are changed to 12 and 8. Theoretical calculations are done to determine the blade dimensions, % flow change, fan efficiency and axial velocity of fan when numbers of blades are taken as 10, 12 and 8.

The design is to be changed to increase the efficiency of the fan and analysis is to be done on the fan by changing the materials Aluminum, Mild Steel and FRP. Analysis is done in finite element analysis ANSYS.

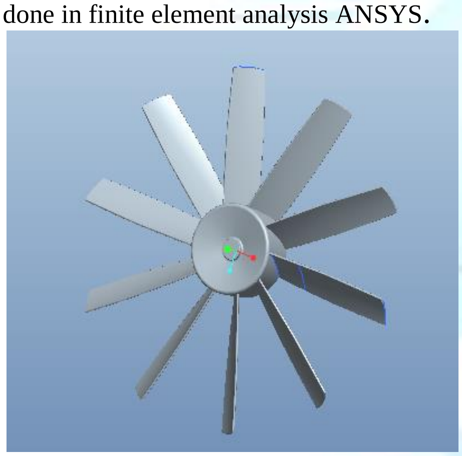
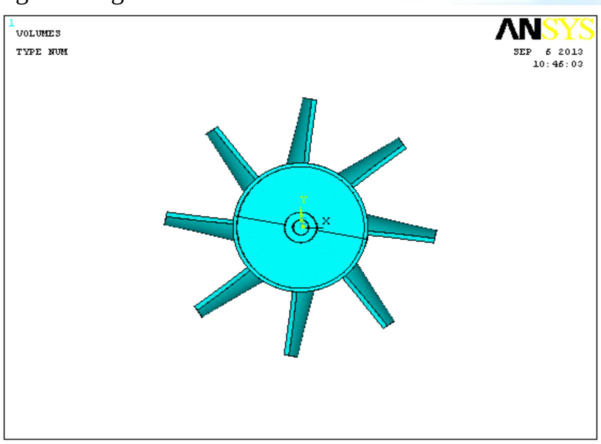
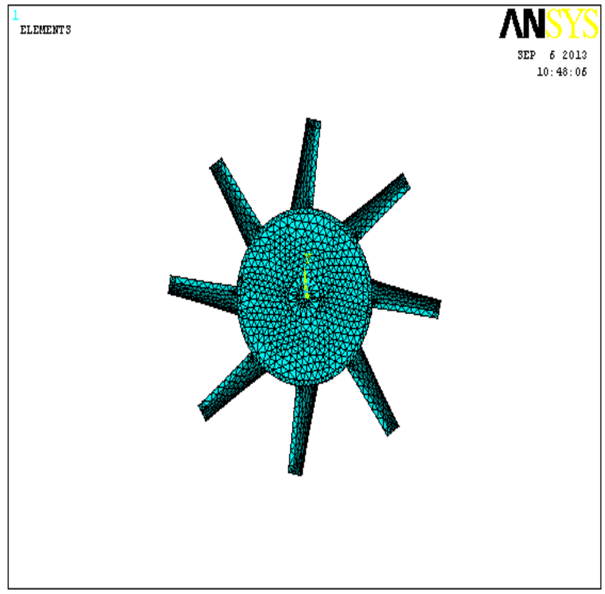


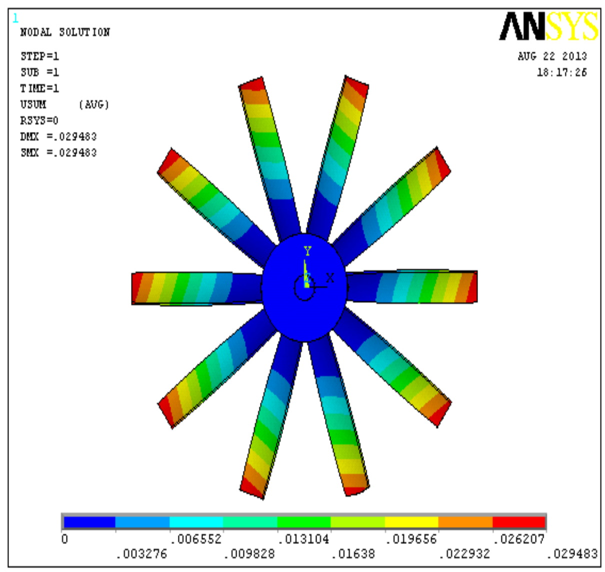
Fig.1. Design of Axial Flow



(a)



(b)



(c)

Fig 2 (a),(b),(c) FEA analysis

IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 1, Issue 5, Oct-Nov, 2013
ISSN: 2320 - 8791
www.ijreat.org

3.Results

3.1 Weight of axial flow fans (kg)

	MILD STEEL	ALUMINUM ALLOY 204	CARBON EPOXY
8 BLADES	14.63	5.121	4.07
10 BLADES	6.91	2.42	1.9244
12 BLADES	48.16	16.86	13.41

3.2 Theoretical Calculations

	8 BLADES	10 BLADES	12 BLADES
% OF FLOW CHANGE	13.79	0.862	0.854
AXIAL VELOCITY mm/s	65.861	36.589	23.862

3.3 Static results(Mild steel)

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT (mm)	0.737 E^{-03}	0.29483	0.002545
STRESS (N/mm^2)	0.350563	1.492	0.400588
STRAIN	0.166 E^{-05}	0.701E^{-05}	0.189 E^{-05}

Aluminum 7050-t7651

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT (mm)	0.001374	0.086753	0.007287
STRESS (N/mm^2)	0.170405	1.466	0.376254
STRAIN	0.239 E^{-05}	0.204 E^{-04}	0.527 E^{-05}

Carbon epoxy

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT (mm)	0.177E^{-03}	0.012088	0.990E^{-03}
STRESS (N/mm^2)	0.172925	1.511	0.403318
STRAIN	0.333 e^{-06}	0.292 e^{-05}	0.782 e^{-06}

3.4 Dynamic results

Mild steel

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT(mm)	0.001066	0.059943	0.00498
STRESS (N/mm^2)	0.435849	3.095	0.921093

ALUMINUM 7050- T7651

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT (mm)	0.002339	0.176145	0.014507
STRESS (N/mm^2)	0.252159	3.049	0.878058
STRAIN	0.354 e^{-05}	0.426 e^{-04}	0.125 e^{-04}

CARBON EPOXY

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT (mm)	0.304 E-03	0.024315	0.001988
STRESS (N/mm^2)	0.263484	3.118	0.961396
STRAIN	0.508 e^{-06}	0.603 e^{-05}	0.187 e^{-05}

4.Conclusion

In this thesis, an axial flow fan is designed and modeled in 3D modeling software Pro/Engineer. Present used axial flow fan in the taken application has 10 blades, in this thesis the number of blades are changed to 12 and 8. Theoretical calculations are done to determine the blade dimensions, % flow change, fan efficiency and axial velocity of fan when number of blades is taken as 10, 12 and 8.

By observing the theoretical calculations, axial velocity and % of flow change is more when 8 blades are used. The weight of the fan when 12 blades is increased thereby reducing its efficiency. Present used material for fan is Mild Steel, which has more weight. By replacing it with Aluminum alloy 7050-T7651 and Carbon epoxy, the weight is reduced thereby increasing its efficiency. By using composite material Carbon Epoxy, the weight is less than Aluminum alloy.

Structural and Dynamic analysis is to done on the fan by changing the materials Mild Steel, Aluminum alloy 7050-T7651, and Carbon Epoxy. Analysis is done in finite element analysis ANSYS.

By observing the analysis results, for all materials, the analyzed stress values are less than their respective yield stress values, so using all the three materials is safe under given load conditions. The strength of the composite material Carbon Epoxy is more than that of other 2 materials Mild Steel and Aluminum Alloy. By observing the analysis results, the displacement and stress values are less when 8 blades are used.

So we can conclude that using composite material Carbon Epoxy and using 8 blades is better. But the disadvantage of using 8 blades is that its weight is increased compared with that of 10 blades.

5.References

[1] Railly, J. W., 1984, Computational Methods in Turbomachinery, Mechanical Engineering Publications, London.
[2] Kim, K. Y., Kim, J. Y., and Chung, J. Y., 1997, Three-dimensional analysis of the flow through an axial-flow fan, Journal of KSME, Vol. 21, No. 4, pp. 541-542.
[3] Hur, N. K., Kim, U., Kang, S. H., 1999, A numerical study on cross flow fan : effect of blade shapes on fan performance, Journal of. KFMA, Vol. 2, No.1, pp. 96-102.
[4] Jorjensen, R., 1976, Fan engineering, Buffalo, New York, pp. 217-222.
[5] Lakshminarayana, 1996, "Fluid dynamics and heat transfer of turbomachinery", Wiley. Interscience, pp.358-362.
[6] Ryu, I. K., 2003, Studies on the airflow characteristics with revision of impeller design and the noise characteristics with arrangement of silencer in an axial turbo fan, Hanyang University, Seoul, Korea.
[7] Hirsch, C., 1988, "Numerical computation of internal and external flows", Vol. 1, Wiley
[8] Patankar, S. V., 1980, Numerical heat transfer and fluid flow, McGraw-Hill, New York
[9]. A research report on blades for axial flow fan by Camargo Do, Amaranth Odilon Antonio (Rua Fernandes de Barros, 1455 apto. 07 -200 Curitiba, PR, CEP-80040, BR).
[10] A research report on basic guidelines for plastic conversion of metal axial flow fans by BASF CORPORATION.
[11] A Report on Basic Fan Laws - Axial Fan Blades by Air Turbine Propeller Company
[12] Energy Efficient Axial Flow FRP Fans by TIFAC, Department of science and technology, govt. of India.

[13] CFD solutions for turbo machinery design.
[14] CAD/CAM & Automation, Technical Prakashan Pune, 2003, (pp 4.143-4.144) by R.B. Patil and A.M. Chakradeo (2003)
[15]Mechanical Engineering Designs Second Edition McGraw-Hill Book Company, 1987, Joseph Edward Shingle.
[16] Research paper on Computational Fluid Dynamics (CFD) Modeling, Christopher Riff.