REVIEW ON SHAPE OPTIMIZATION OF CEILING FAN BLADE GEOMETRY FOR STATIC AS WELL AS VIBRATION LOADING

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Abstract: Fan blades are one of the very common engineering parts which are used by every person in day to day life. Fan blades are designed to provide air velocities of blade in all the regions of room they are fit it. It is requirement that the blade which is being fixed to fan should not resonate, that means the driving rpm of the fan should be lower or higher than the natural frequencies of the blade. The objective of the paper is to review: the work carried out on the Shape optimization of ceiling fan blade geometry for static as well as vibration loading.

Index Terms- Review, ceiling fan blade, blade materials, blade angle.

1. INTRODUCTION

Ventilation is the intentional introduction of ambient air into a space and is mainly used to control indoor air quality by diluting and displacing indoor pollutants; it can also be used for purposes of thermal comfort or dehumidification. The correct introduction of ambient air will help to achieve desired indoor comfort levels although the measure of an ideal comfort level varies from individual to individual.

- **Fan**

In the present age, i.e. the 21st century, one of the most common seen mechanical devices in every household and office around the globe is the common type of ceiling fan and its variants. Presently we are in a situation where the average global temperature keeps on rising due to various reasons like global warming, pollution and a lot more and the term "being comfortable" has gained a whole new definition. We human beings have reached a state where these common ceiling fans have become a part and parcel of our day to day things and sadly, the design of it, even though it has improved dramatically in its aerodynamics and its design point of view, it still doesn't meet the expectations of humans, and thus alternate measures like air conditioners, coolers, etc. are all in demand.

Another highlighting factor is that in the age where electronics have taken over a huge share of the common day products and converted them into "intelligent" products, sadly it has not penetrated into this section and thus, our project, i.e. to try to create an intelligent fan, which moves its blade angle in accordance with the temperature, indirectly optimizing the blade angle at every given temperature. That is the project that we are going to analyze and try to make it a reality. A ceiling fan is a mechanical device, usually consisting of a center hub and 3 to 5 blades. It is electrically powered and suspended from the room.

The main working of the ceiling fan is by rotating the hub mounted paddles to circulate the air. Another point to be noted on the ceiling fan is it slow when in comparison with an electric desk fan, yet it cools the area pretty effectively by introducing slow, circular movement of air and giving rise to evaporative cooling. Fans never actually cool air, unlike air-conditioning equipment, but use significantly less power (cooling air is thermodynamically expensive). Conversely, a ceiling fan can also be used to reduce the stratification of warm air in a room by forcing it down to affect both occupants' sensations and thermostat readings, thereby improving climate control energy efficiency. Heat causes lot of discomfort for us humans.

- **Ceiling fan**:

A fan suspended from the ceiling of a room is a ceiling fan. Most ceiling fans rotate at relatively low speeds and do not have blade guards. Ceiling fans can be found in both residential and industrial/commercial settings.

Crack development in a beam is such that it leads to sudden failure of a system without any prior indication or warning. So in this paper it will be the primary objective to study recent literature related to crack detection method of vibration analysis. Also composite materials failure and types of cracks and parameters of the cracks in composite materials will be focused on.

- **Blade element theory**

In this theory, a small element (dr) is taken at a distance r from the root of the blade and all the forces acting on the element are analysed to get a solution. It is assumed that the flow through each section of small radial thickness dr is assumed to be independent of the flow through other elements.

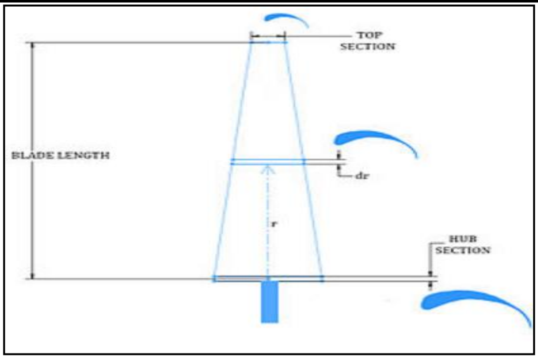

Fig.1. Long blade of propeller fan with varying cross section

Resolving Forces in the figure

$$\Delta F_x = \Delta L \sin(\beta) - \Delta D \cos(\beta)$$
$$\Delta F_y = \Delta L \cos(\beta) + \Delta D \sin(\beta)$$

Lift Coefficient (C_L) and Drag Coefficient (C_D) are given as

$$\text{Lift}(\Delta L) = \frac{1}{2} C_L \rho w^2 (ldr)$$
$$\text{Drag}(\Delta D) = \frac{1}{2} C_D \rho w^2 (ldr)$$

From fig 1.9 it can be observed that

$$\tan(\phi) = \frac{\Delta D}{\Delta L} = \frac{C_D}{C_L}$$

$$\Delta F_x = \Delta L(\sin\beta - \frac{\Delta D}{\Delta L}\cos\beta) = \Delta L(\sin\beta - \tan\phi\cos\beta) = \frac{1}{2} C_L \rho w^2 ldr \frac{\sin(\beta-\phi)}{\cos\phi}$$

No. of Blades (z) and Spacing (s) are related as,

$$s = \frac{2\pi r}{z}$$

& the total thrust for the elemental section of the propeller is zΔFx.

$$\Delta p(2\pi r dr) = z\Delta F_x$$

$$\Delta p = \frac{1}{2} C_L \rho w^2 (\frac{l}{s}) \frac{\sin(\beta-\phi)}{\cos\phi} = \frac{1}{2} C_D \rho w^2 (\frac{l}{s}) \frac{\sin(\beta-\phi)}{\sin\phi}$$

Similarly, solving for ΔFy, ΔFy is found out to be

$$\Delta F_y = \frac{1}{2} C_L \rho w^2 ldr \frac{\cos(\beta-\phi)}{\cos\phi}$$

And Torque

$$\Delta Q = r\Delta F_y$$

Finally, thrust and torque can be found out for an elemental section as they are proportional to Fx and Fy respectively.

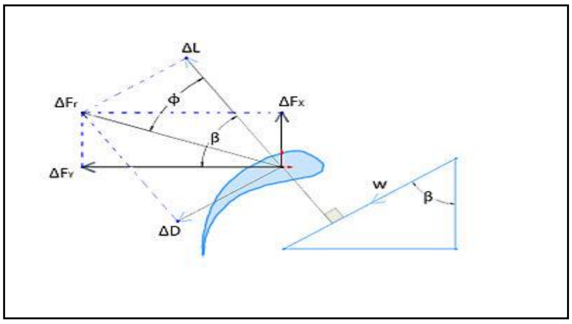

Fig.2. Velocities and Blade Forces for the Flow across the element dr

Where

w = Mean Velocity at a direction β from Axial direction.

ΔL = Lift Force (Perpendicular to w)

ΔD = Drag Force (Parallel to 'w').

The Axial and Tangential forces are ΔFx and ΔFy respectively and the Resultant force ΔFr is at an angle Φ to the Lift.

2. LITERATURE SURVEY

Various researchers have done various studies regarding crack detection in beam. Some of the studies are as follows,

Swaroop M P et.al. [1] Published paper in 2017 on "Optimization of Fan Blade Angle" This report represents the optimization of fan blade angle in accordance with the various room temperatures that can be in the tropical area like India. They have modelled the fan in modelling software (SOLIDWORKS) and imported that into analysis software (ANSYS) and results are generated on the various blade angles (0, 4, 8 and 12.5) degrees in accordance to room conditions. A trend line curve with the obtained data is expected as the result which can be crucial for designing of future fans. From the analysis that they have conducted, it can be seen that there is certainly an effect on air flow as the blade angle changes. The thing that struck them the most is that the velocity of air which comes through the outlet keeps on increasing up to a certain blade angle and then the velocity decreases after the optimum blade angle is reached. From 4 different analyses that they have conducted, they have found out the most effective blade angle to be at 8 degrees.

E. Adeeb, A. Maqsood, A. Musthaq and C. H. Sohn [2] published paper in 2016, on "Parametric Study and Optimization of Ceiling Fan Blades for Improved Aerodynamic Performance" This paper includes parametric study and optimization of non-linear ceiling fan blades by combining the techniques of Design of Experiments (DOE), Response Surface Methods (RSM) and Computational Fluid Dynamics (CFD). In this work, parametric study is carried out to find the effect of parameters on the ceiling fan. The data of air velocity for the benchmark design are collected experimentally. Using DOE, sixteen different experiments are designed based on four variables through full factorial approach. Reynolds Averaged Navier Stokes approach is used to simulate the designs. After a sensitivity analysis, the root and tip angle of attack are found to be more sensitive for volumetric flow rate, torque and energy efficiency. Forward swept parameter showed a moderate effect on response parameters.

Leye M Amoo [3] , presented a paper on " The design and structural analysis of jet engine fan blade structures " Author observes in the work done that structural engineers and designers rely up on the many analysis runs, rig tests and engine runs for the finalization of the design parameters of the engine blade architecture as well as dimensions. Optimization of engine architecture along with material can increase the confidence in the aviation design as well as it will help the aviation transport to be more economical in terms of travelling costs. Fan blade technology in aviation industry is mature technological level and further improvement will see the disruptive and advanced changes in the technology of the fan blade design. Continuous collaboration between academia, industry and governmental organization can prove very critical for the improvement of components like fan blades in the future.

S Prabhakaran & M Senthilkumar [4] presented a paper on "Development of Glass Fiber Reinforced Polymer Composite Ceiling Fan Blade" this work concludes saying Design, fabrication and testing of existing and composite fan blade (using glass fibre material) are completed and also composite blade is tested and compared with existing blade. In this project the composite blade has been designed and fabricated. This composite blade has more strength over existing fan blade. The existing fan blade weighs about 295grams whereas the weight of composite fan blade is 215grams, which is 28% lesser than existing blade. It is tested that the power consumed by the existing blade (0.052units) is more when compared to composite blade(0.037units). So when we use composite fan means we can reduce 30% of power consumed by the existing ceiling fan. Cost of composite ceiling fan blade is Rs. 279/- which is 44% less than existing aluminium blade. The strength of the composite blade also high when we compared with aluminium blade. From the study, it is concluded that fibre reinforced plastic material is a suitable material for manufacturing the composite ceiling fan blade.

Amazing Comfortson et. al. [5], Presented the paper named "Glass Fibre Reinforced Polymer Composite Ceiling Fan Blade" Energy crisis is the major problem faced widely. Though wide range of researches is being laid in the areas of alternate energy sources, proper management of the available energy sources will contribute in controlling this energy crisis, particularly in high populous countries such as India. Ceiling fan being one of the vital electric appliance, consumes considerable electric power in most domestic and Industrial application.

Junjie Zhou, Bo Liu, Dingbiao Wang & Xiaoqian li [6] presented a paper on "Dynamic Characteristics Analysis of Blade of Fan Based on ANSYS" In this paper, the finite element model of blade of R40 axial-flow fan has been built, using this model, the dynamic characteristics of blade have been analyzed with Ansys software. We can get the first 10 natural frequencies of blade under rated and resonant operating conditions, and get the harmonic response of exciting force. The results show that R40 axial-flow fan runs stable under resonant operating conditions, resonance does not occur; the larger rotation speed can increase the natural frequencies of blade; the blade has the maximum response of the exciting force at 120Hz.

A. Shaniavski [7] presented paper on "Failure Analysis of Fan Blade of D-L8 Engine Of "Ruslan" Aircraft" It says Blades from the Ti-alloy fatigued in service were investigated on the basis of the introduced synergetic approach to fatigue failures analysis. In-flight cascade of events initiated by two fan blades failures was reconstructed from the quantitative fractographic analysis. Good correlation between reconstructed from fractographic analysis and realised in flight situations is demonstrated. It was found that a loss of the air intake in flight was a result of fan blades failures. Air intake has damages only from failed fan blades parts. There were no traces of any foreign objects which may enter the air intake in flight and cause its malfunctioning and disturb an engine operation. A loss of air intake in flight was caused by failure of all the bolts which fasten air intake to engine because of very high energy of flying parts of broken fan blades.

Ebrahim Mustafa, Danardono, Triyono, Agus Dwi Anggono and Abdussalam Ali Ahmed [8] from Indonesia published work titled "Finite Element Analysis And Optimization Design Of Aluminium Axial Fan Blade" The purpose of this work is to optimize the blade design of an axial-flow fan. Four different chord length and five twisting angle of their blades were studied. The fan was designed by using NACA 5505 series. The first investigation is conducted to the blade design in the variation of chord length.

Santosh Kumar Dahare1 & Dr. Rohit Rajvaidya [9] , presented paper on "Design and Analysis of Nylon66 Ceiling Fan Blade Using Finite Element Method" The main objective of this paper work is to look into the fundamental issues regarding fan blade design and develop a new, easy to use software program that would allow for optimal, flexible blade designs. In this design of fan blade, material converted from existing aluminium into Nylon66. Fan blade design procedure for an optimum result according to FEM theory is performed.

M. NagaKiran, T. R. Sydanna , G. Siva Prasad , K. Sagar Kumar & M. Venkateswarlu [10] presented a paper "Finite Element Analysis of Axial Flow Fan" In this thesis, an axial flow fan is to be designed and modelled in 3D modelling 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.
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 Alloy 204, Mild Steel and E Glass. Analysis is done in finite element analysis ANSYS.

Jin-Hyuk Kim, Jae-Ho Choi, Afzal Husain3 and Kwang-Yong Kim presented paper on "Design Optimization of an Axial Fan Blade through Multi-Objective Evolutionary Algorithm". [11]
This paper presents design optimization of an axial fan blade with hybrid multi-objective evolutionary algorithm (hybrid MOEA). Reynolds-averaged Navier-Stokes equations with shear stress transport turbulence model are discretized by the finite volume approximations and solved on hexahedral grids for the flow analyses. The validation of the numerical results was performed with the experimental data for the axial and tangential velocities. Six design variables related to the blade lean angle and blade profile are selected and the Latin hypercube sampling of design of experiments is used to generate design points within the selected design space. Two objective functions namely total efficiency and torque are employed and the multi-objective optimization is carried out to enhance total efficiency and to reduce the torque. The flow analyses are performed numerically at the designed points to obtain values of the objective functions. The Non-dominated Sorting of Genetic Algorithm (NSGA-II) with -constraint strategy for local search coupled with surrogate model is used for multi-objective optimization. The Pareto-optimal solutions are presented and
trade-off analysis is performed between the two competing objectives in view of the design and flow constraints. It is observed that total efficiency is enhanced and torque is decreased as compared to the reference design by the process of multi-objective optimization. The Pareto-optimal solutions are analysed to understand the mechanism of the improvement in the total efficiency and reduction in torque.

Ki-Sang Lee, Kwang-Yong Kim* and Abdus Samad [12] presented paper on "Design optimization of low-speed axial flow fan blade with three-dimensional RANS analysis."

This work presents a numerical optimization procedure for a low-speed axial flow fan blade with polynomial response surface approximation model. Reynolds-averaged Navier-Stokes equations with SST turbulence model are discretized by finite volume approximations and solved on hexahedral grids for flow analyses. The blade profile as well as stacking line is modified to enhance blade total efficiency, i.e., the objective function. The design variables of blade lean, maximum thickness and location of maximum thickness are selected, and a design of experiments technique produces design points where flow analyses are performed to obtain values of the objective function. A gradient-based search algorithm is used to find the optimal design in the design space from the constructed response surface model for the objective function. As a main result, the efficiency is increased effectively by the present optimization procedure. And, it is also shown that the modification of blade lean is more effective to improve the efficiency rather than modifying blade profile.

Sensiau, B. Fayard, J.-M. Roux and M. Lebrun, [13] presented paper on
"An optimization loop for aero-acoustics fan blade design"

In this paper is introduced, in a simplified way, a problem related to the fan blade design of an aircraft engine. The need of a compromise between performance criteria at high rating points and broad band noise at off-design points is emphasized. To minimize fuel consumption the fan design maximizes cruise efficiency, to reach

environmental requirements, the fan blades have to be quiet (and thus efficient) during take off but also during landing at low power level. To deal with this kind of multi-disciplinary and multi-objectives problems, optimization methods are used. In this work, a simplified blade design is discussed and a special attention is paid to the fan mass flow rate and efficiency at high rotating speeds, as well as the interaction broad band noise at off design points.

Rula M. Coroneos Glenn Research Center, Cleveland, Ohio [14] presented paper on "Structural Analysis and Optimization of a Composite Fan Blade for Future Aircraft Engine"

An optimized design for a turbofan engine blade sized for a large aircraft engine was developed from a given baseline solid metallic model to a sandwich composite fan blade. The optimized composite blade design meets the aerodynamic and geometric considerations throughout the design process while the solution ensured that the final design was efficient and conformed to constraints imposed on radial displacement limitations and ply failure. The result was a lighter blade design, with mass savings of

72 percent compared to the metallic blade, when the combined pressure and centrifugal loads were considered. The maximum stresses and radial displacement for the final optimized composite blade were at much higher values than the metallic blade but still within their allowable limits. It was shown that the deformation behaviour can be greatly influenced by the fibre orientation. It was also shown that the final design did not exhibit any ply failures considering an additional safety factor of 1.5 in the design process. Analyses and optimization was performed utilizing the OpenMDAO Framework, developed at NASA Glenn Research Centre, which allows flexibility in case any modifications are required. The study performed in this paper highlights the continuing development of an optimization process for composite

material lay-ups. Further research and development will continue, considering the application of an Integer programming algorithm to further refine the optimization process. Ply angle orientation may be optimized in addition to, or instead of, ply thickness depending on manufacturing considerations.

R. S. Amano, E. K. Lee, C. Xu, Jianhui Xie[16] presented paper on

"Investigation of the Unsteady Flow Generated by an Axial Fan: Experimental Testing and Simulations"

In this study, the experimental and CFD analyses have been performed to investigate the performance of an industrial axial fan. In order to design more efficient fans that provide uniform airflow while consuming less power, a better understanding of axial fan blade airflow and the resulting stresses in the fan blade are needed. From the results presented in this paper, several conclusions can be drawn.

(1) Experimental measurement and CFD simulation of the performance of an axial fan have been carried out. The experimental part includes the measurement of

the velocity profile, the measurement of the stress and strain on the fan blade, and flow visualization. CFD simulation is done by using unstructured mesh generation

coupled with rotating reference frame to predict the flow field and pressure distributions on the blades.

(2) The difference in the flow and pressure generated by the addition of a radiator in front of the axial fan is studied.

(3) The addition of a radiator to the axial fan hinders the inflow and changes the flow pattern. It also produces approximately 10–20% stresses (from measurement)

and forces (from simulation) on the blade surface.

(4) Maximum stresses occurred in the area of strain gages no. 2 and no. 3 both with and without radiator on the front and back of the fan. Thus, these locations are

most likely to fail over an extended period of time.

(5) Simulation results show that the addition of a radiator causes an increase in the maximum static pressure at the tip of the blade, and the pressure increases about

10–20%.

(6) The flow visualization technique verifies the results predicted by simulation.

The results presented in this paper can be used as a guideline for future study of rotating machinery.

Rupesh V.Bhortake1 , Pravin S. Lachure2 , Sandeep R. Godase3 , Vikram V.More4 , Kiran S. Chopade [17] presented paper on "Experimental Analysis of Air Delivery in Ceiling Fan"

Ceiling fans are one of the mostly used comfort device in domestic use. Air delivery produced from fan is multiple of the rotational frequency of the fan. Air delivery is one of the most important parameter. To analyse the air delivered from the fan was important to identify the parameters affecting it. Ceiling fans are extensively used to create an indoor breeze, improve the space air distribution and hence enhance the feeling of comfort. The fan speed, room size, number of blades and down rod length all play an important role in deciding the induced flow pattern features in space. Few previous studies have investigated fan induced flow and its characteristics under different geometric and operating conditions .In this study ,response surface methodology was used to predict air delivery from the fan. The experiments were conducted based on three different Fan Blade, three different room volume, three different down rod lengths, three different fan speeds and mathematical model was developed .For targeted air delivery optimum levels of input parameters were selected using optimization analysis

Shubham Kumar Verma , Yatheshth Anand , Sanjeev Anand [18] presented paper on "CFD based Modelling of a Ceiling Fan in a Room"
Ceiling fans have been utilized from decades as a means for giving thermal comfort in tropical nations. Although, recent years have seen a huge increment in the utilization of air conditioning as a way to accomplish comfort, and also, the aggregate energy utilization and related CO2 emissions. Ceiling fans are as yet practical choices to restrict utilization of air conditioners or in combination with air conditioners systems without negotiating on thermal comfort and still accomplishing energy saving. Ceiling fans create non-uniform velocity profiles, and hence generally non-uniform thermal environment, whose parameters might be hard to investigate with straightforward modelling methods. This issue can be examined by utilizing Computational Fluid Dynamics (CFD). Although, to date, there are only few works related to Ceiling fans, CFD and thermal comfort. More exact models are in this manner required to predict their performance. The paper presents a three-dimensional transient implicit CFD model of a typical Ceiling fan accessible in India and also studied the flow and velocity profile of air in three different planes in a confined volume of a single person hostel room located in Shri Mata Vaishno Devi University.

Y. Momoi1 , K. Sagara1 , T. Yamanaka1 and H. Kotani [19] presented paper on
"Modelling of Ceiling Fan Based on Velocity Measurement for CFD Simulation of Airflow in Large Room"
This study examines the way of utilizing a ceiling fan for airflow control in a large air-conditioned room. Although it seems that CFD simulation is useful in predicting the airflow around a ceiling fan, modelling of a ceiling fan as a body of rotation is very complicated. Therefore, in this study, airflow of a ceiling fan is modelled as boundary conditions of air velocity data measured near the ceiling fan. In this paper, the measured airflow pattern around a ceiling fan is compared with the CFD simulation result using the airflow model of the ceiling fan, in order to examine the validity of the airflow model. The CFD result was in good agreement with the measurement result concerning the average of air velocity.

Senthil Kumar S , Riyaz Haja Mohideen.S ,Sarath Babu. , Ram Kumar.M , Soundar.K [20] presented paper on "Development of Ceiling Fan Components using Glass Fibre Composites"
Energy crisis is the major problem faced widely. Though wide range of researches is being laid in the areas of alternate energy sources, proper management of the available energy sources will contribute in controlling this energy crisis, particularly in high populous countries such as India. Ceiling fan being one of the vital electric appliance, consumes considerable electric power in most domestic and Industrial application. Imparting fibre reinforced composite in ceiling fans reduces the weight of the fan, thereby considerably reducing the power consumption. In this work the fabrication of composite ceiling fan made up of glass fibre reinforced polymer is carried out and the performance of this fan is compared with the conventional fans. Compared to existing ceiling fan , the composite fan saves 26% of power, and reduces the cost by 28%. The weight is reduced by 27% thus reducing the power consumption. It is also determined that the flow velocity through the composite fan is 15% more than that of the conventional fan.

Peter J. Schubel * and Richard J. Crossley [21]presented paper on, "Wind Turbine Blade Design"
A comprehensive look at blade design has shown that an efficient blade shape is defined by aerodynamic calculations based on chosen parameters and the performance of the selected aerofoils. Aesthetics plays only a minor role. The optimum efficient shape is complex consisting of aerofoil sections of increasing width, thickness and twist angle towards the hub. This general shape is constrained by physical laws and is unlikely to change. However, aerofoil lift and drag performance
will determine exact angles of twist and chord lengths for optimum aerodynamic performance. A basic load analysis reveals that the blade can be modelled as a simple beam with a built in support at the hub end. A uniformly distributed load can be used to represent aerodynamic lift during operation. The increasing bending moment towards the support indicate that structural requirements will also determine blade shape especially in areas around the hub which require increased thickness. Currently manufacturers are seeking greater cost effectiveness through increased turbine size rather than minor increases through improved blade efficiency. This is likely to change as larger models become problematic through construction, transport and assembly issues. Therefore, it is likely that the
general shape will remain fixed and will increase in size until a plateau is reached. Minor changes to blade shape may then occur as manufacturers incorporate new airfoils, tip designs and structural materials. A conflict of increased aerodynamic performance in slender aerofoils versus structural performance of thicker aerofoils is also evident.

Zhang Lanting, [22] presented paper on "Research on Structural Lay-up Optimum Design of Composite Wind Turbine Blade"
According to theoretical calculating result of stress, four different lay-up structures of 1.2MW horizontal axis wind turbine blade, which can effectively endure various loads, are designed primarily. Based on composite laminate theory and finite element method, through analyzing their stress-strain, the optimal lay-up schema is confirmed. The verified analysis of stiffness and strength were performed under extreme load conditions. Numerical analysis results show that the designed blade structure was safe, and the value of stress and strain was low.

Khandare R.S1, Londhe B.C.2, Ganore D.J.3 [23] presented paper on "Vibration Analysis of Fiber Reinforced Plastic Fan Blade"
Structural vibration problems causes a major hazard and design limitations for a very wide range of engineering products. The Aim of this paper is to analytically extract the natural frequencies of cooling tower fan blades of different sizes. So that, Designer can ensure that natural frequencies will not be close to the frequency of the main excitation forces in order to avoid resonance. Three dimensional models of blades have been developed in Unigraphics NX 5 and modal analysis is carried out by ANSYS 15. Also, an experimental study carried out for FRP composite blades. Concurrence between ANSYS results and Experimental results has been found for the frequency range of interest.

3. CONCLUSION

From the literature review it is found that:-

- Less amount of work is done For Vibration Analysis of fan blade.
- Less attention is given to the Resonance and natural Frequencies of Fan Blade.
- Very less focus is given on the effect of vibrations and the shapes of the blades for obtaining optimum efficiency of the fan.
- Most of the study in the field of fan blade is conducted for structural failure of the fan blade design using FEA.
- The effect of composite materials and blade design parameters on the flow of the air also studied by most of the researchers.

So there is a scope for the study of fan blade design to get optimum shape of the blade for static and also for vibrational loading. For the same FSI (Fluid Structural Interaction) technique can be used.

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