Design Optimization of Aerofoil Radial Fan Impeller

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Abstract **- In this paper, an effort has been made for optimizing the design of an aerofoil bladed radial fan impeller by finite element analysis (FEA) for reducing the material cost. The optimization of aerofoil bladed radial fan impeller is done by FEA in "ANSYS - MULTIPHYSICS". For optimization of aerofoil radial fan impeller, the thickness of every component of the impeller was reduced and stiffness was provided to curtail large deflections in the optimized model. Stresses and deflections were analyzed for the modified and pre modified model and the optimization results showed a 30% reduction in the net weight of the impeller. So, this helped in a reduction in material cost and also the space occupied. Stress and deflection analysis were performed in ANSYS – MULTIPHYSICS. These results were well within the limits.**

Keywords: Optimization, Aerofoil, Impeller, Suction Chamber

1. INTRODUCTION

This paper is dealt with optimizing the design of aerofoil radial fan impeller using FEA. Most manufacturing sectors invest more than a 65% of their funds for materials, i.e., material accounts for a substantial portion of the capital invested in an industrial concern. These emphasize the necessitate for effective material management because even a small saving in material can reduce the production cost to a fair extent and thus add to the profits.Aerofoil Radial Fan Impeller type blades are manufactured either as of laminar (flat, constant thickness) or aerofoil shape and generally hollow, as shown in Figure 8. Aerofoil blades have generally been regarded as having greater efficiency (up to 90%) than achievable with constant thickness blades, with the advantages of efficiency spread over the characteristic and lower noise generation. However, with careful attention to the design of blade curvature, inlet eye detail and impeller shrouding, comparable efficiency can be achieved with constant thickness blades.

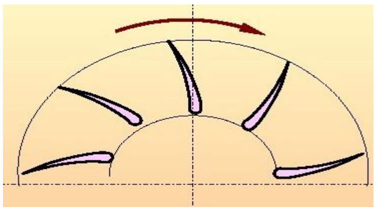

Fig. 1: Aerofoil Radial Fan

Advantages of aerofoil radial fan impeller

- Since the aerofoil is a profile curved body, it ensures a smoother flow than a blunt body with no flow separation, thereby minimizing losses.
- The higher efficiency compared to normal plate bladed impeller it consumes less power and hence it is economical.
- An aerofoil bladed fan has a high half load efficiency like an axial fan and the rigidity of a radial fan and hence the combined feature of both. But the aerofoil bladed is employed mostly as a primary air fan.

The purpose of this optimization is to reduce the weight of the aerofoil radial fan without exceeding the permissible stress. As the mass of the fan is directly related to the thickness of the impeller parts, our objective in this project is to minimize the thickness, considering the operating restrictions and design parameters.

To ensure the desired performance while considering the significance of physical operating situation for aerofoil radial fan, Finite Element Analysis (FEA) has been carried out for the prediction of stress distribution and strain energy distribution of the rotating impeller. The Ansys/Multiphysics package was used for the structural analysis.

The analysis was carried out using the default thickness of aerofoil radial fan impeller, which results in a massive weight of the fan, leading to large vibrations and as one of the reasons to failure. Ways were found out to reduce all these things, so the analysis was carried out using impellers with various reduced thicknesses and the optimum thickness of the impeller parts for the safe stress and strain limits was found.

2.0 LITERATURE REVIEW

There are various types of fans used in industries with different profiles. It is best to understand the selection of fan that can help in predicting system performance. A different type of fan may be considered when noise levels, maintenance requirements, energy costs, or fan performance does not meet expectations.

The price of consumable materials is being increasing that pressures the profit of a concern. Consequently without any negotiation on quality, the unpredictable cost has to be reduced. To ensure the desired performance the designer not only has to arrive an optimum design but also need to make a design analysis for prophecy of behavior in a given physical operating situation which need not necessarily be the design condition.

3.0 OPTIMIZATION OF AEROFOIL BLADED RADIAL FAN IMPELLER

The model is generated for the designed thickness using the ANSYS and various parameters are given as follows.

3.1 Solid Model Generation Using Preprocessor

There are three stages in ANSYS. They are pre-processor, solution and post processor. So the geometry of the model should be created before doing analysis. Modeling is done in ANSYS through pre-processor. There we have many options through which the geometry of the model is created, as shown in figure 8.

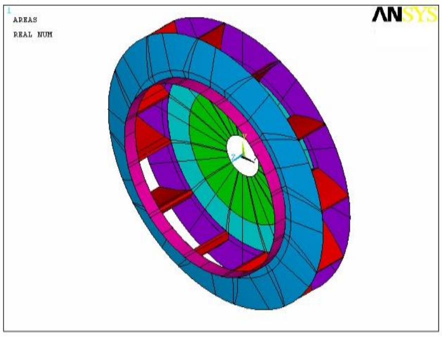

Fig. 2: Solid Model Generation

3.2 Meshing Contours

After the generation of the solid model using the pre-processor, the model should be meshed properly. In other words the model should be discritisized into a number of small elements. Meshing of the model requires generation of meshing contours. That is, the lines of the geometry should be properly divided. To enable easy meshing of the model, in the absence of the contours, the mesh will not be proper and the problem cannot be solved.

3.3 Meshing Areas

The generation of contours for proper meshing should be followed by meshing of the model. There are two types of meshing. They are the free mesh and the mapped mesh. The problem can be solved using a free mesh but the results would be far from accurate. Hence, there is needed to go in for the mapped mesh to ensure accurate results. Mapped mesh can be obtained by doing line element sizing properly. This is shown in figure 9.

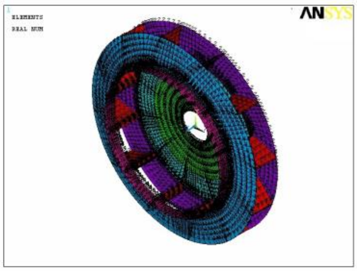

Fig. 3: Meshing of Areas

3.4 Defining Material

The follow up for completing modeling and meshing is the defining of the material of the model. There are different properties which define a material namely density, young's modulus and Poisson's ratio. These values differ between different materials. The material can be defined in pre-processor through the use of these properties. For this model, the constant Isotropic material has been used and their values are

1. Young's modulus EX = 21000 kg/mm^2
2. Density DENS = 8.002 e-10 mN/mm^3
3. Poisson's ratio NUXY = 0.3

3.5 Choosing Appropriate Element for Analysis

The basic concept of FEA is to discritize the model into a finite number of smaller elements. There are different element types available in ANSYS pre-processor. There are variations in the types of elements depending on the model. The choice of the appropriate elements is needed for analysis.

A 4-noded area element (SHELL 63) has been used for the analysis. SHELL 63 elements are well suited for mapped meshing for this model. Usually model of any area can be meshed using 4-noded area element (SHELL 63) in a uniform manner (mapped meshing). It is a kind of mesh in which the points of the mesh are arranged in a regular way all through the continuum and can be stretched to fit a given geometry to ensure high accuracy when compared to free mesh results.

3.6 Attributing Equivalent and Actual boundary

After discritizing and defining the material of a model, the boundary conditions have to be applied and also the loads wherever required for the analysis. The first step is the application of the constraints. So wherever required, the degrees of freedom should be arrested. After applying constraints, the loads are applied on nodes or element for the analysis.

3.7 Solving the Problem Using Solver

Solution is the second stage in ANSYS where the solution of the given problem is done. Here the solution module generates the element matrices and finds the stress and deflections according to the parameters applied.

3.8 Viewing Results for the Designed Thickness

The results are viewed in post-processor, the stress and deflection can be plotted on the screen with different colors. The maximum and minimum stresses are noted.

3.9 Modifying the Geometry Model by Reducing the Thickness

Following an observation of the stress and deflection for original design, the stress and deflection for modified design require an in depth study. The design is modified by reducing the thickness. Then all the above steps follow for finding the stress and deflection value. Finally the results of the original and modified design should be should be compared in order to obtain the optimized design.

4.0 MODELING OF FAN IMPELLER ASSEMBLY

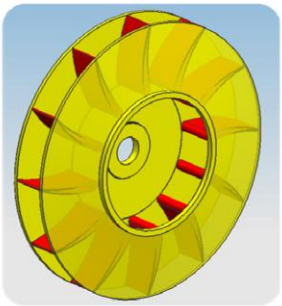

Fig. 4: Fan Impeller Assembly

5.0 RESULTS AND DISCUSSION

5.1 Static Analysis

The stress distribution and the deflection of the impeller for the various components are found. The stress distribution and the deflection plot for the various components of the impeller are plotted in the figures.

5.2 Optimization

The thickness of each component is reduced by 20%. After optimization, stress value is reduced by 25% and deflection value by 40%. There by the optimum thicknesses of the impeller parts are found for the safe stress and strain limits.

5.3 Weight Reduction

Optimization of the thickness of the Fan impeller enables reduction in the weight of the Fan Impeller.

The Existing weight of the Fan Impeller =10 tonnes =10,000 kg

After optimizing, the % of weight reduced in the

Fan Impeller = 30% of weight saved

= (30/100)*10,000 = 3000 kg. = 3.0 tones

Cost of steel/kg = Rs.300

In the BHEL-RANIPET 12 Fans are made per year.

Total cumulative weight saved = 12*3000 = 36000 kg

= 36 tones

Total cumulative saving in cost per year = 36000*300

= Rs. 1, 08, 00,000

5.4 Stress Results of Fan impeller after Optimization

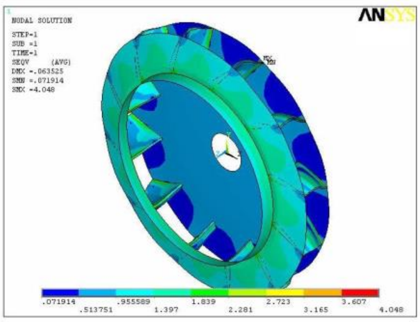

Table 1: Comparison of Results (Before Optimization)

S. No	Components	Thickness (mm)	Stress (kgf/mm^2)	Deflection (mm)
1	Fan Impeller	-	5.371	0.103
2	Top Back plate	25	1.072	0.021
3	Bottom Back plate	15	1.364	0.036
4	Blade	5	5.371	0.103
5	Cover plate	16	2.459	0.053
6	Ring	50	1.813	0.047
7	Flange	45	0.908	0.009

Table 2: Comparison of Results (After Optimization)

S. No	Components	Thickness (mm)	Stress (kgf/mm^2)	Deflection (mm)
1	Fan Impeller	-	4.048	0.062
2	Top Back plate	20	0.808	0.0126
3	Bottom Back plate	12	1.028	0.0216
4	Blade	4	4.048	0.062
5	Cover plate	12.8	1.853	0.0318
6	Ring	40	1.36	0.028
7	Flange	36	0.684	0.0054

6.0 CONCLUSION

In this work, an attempt has been made to find ways of increasing the Fan efficiency by optimizing the thickness of the various components in the fan impeller, and analyzing the stress distributions in them.

Optimization of the thickness of impeller leads to a decrease in the weight of the fan impeller and in turn the power required for driving the fan decreases.

The impeller with default thickness (Before optimization) resulted in enormous weight of the fan, which lead to huge vibrations and failure. So the analysis was done by different impeller thicknesses and the most favorable thickness of the impeller parts were found for safe stress and strain limits.

This analysis resulted in reduction of material and reduction in material cost with less vibrations for the preferred design and operating conditions.

Pre -stress conditions have been applied to this model, therefore the strengthening and weakening of the impeller is predicted.

REFERENCES

[1] Austin.H.Church (Prof,M.E,NewYork University) (1944), 'Centrifugal Pumps and Blowers', John Willey& Sons,inc,
[2] Albert Benz (1966), 'Introduction to Theory of Flow Machines',Permagon Press,NewYork.
[3] Charles.L.Hubbard (1910), 'Fans Ventilation and Heating',NewYork City.
[4] John F.Abel, Chandra Kant S Desai (1987), 'Introduction to the Finite Element Method'- CBS Publishers and distributors, New Delhi.
[5] Kalyanmoy Deb 2000, 'Optimization for engineering Design'- Prentice hall of India (p) Ltd, New Delhi.
[6] Krishnamoorthy C.S. (1994), 'Finite Element Analysis' -Tata McGraw-Hill publishing company, New Delhi.
[7] R.G.Patron (1972), Conference on Fan Technology and Practice 'Stress in Centrifugal Fan Impeller', London (pg: 80-90).
[8] Robert.D.Cook, David S. Malkus, Michael E.Plesha (1989), 'Concepts and Applications of Finite Element Analysis'- John Willey& Sons,inc, Singapore.
[9] Thirupathi R.Chandrapatla, Ashok D.Belegundu (1997), 'Introduction to finite elements in Engineering'- Prentice hall of India (p) Ltd, New Delhi.
[10] V.M.Cherkasky(1980),'Pumps, Fans and Compressors', Mir Publishers, Moscow.
[11] William.C.Osborn(1977),FANS 2nd Edition (in SI/Metric Units),Pergamon Press, Oxford.