Optimization of Primary Air Fan Impeller using Ansys

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Abstract

An effort has been made for optimizing the design of constant thickness forward curved bladed radial fan impeller into aerofoil shape forward curved bladed radial fan impeller by finite element analysis (FEA) for material cost and weight reduction for power savings. The design is done by mechanical software named ‘ANSYS’. To achieve this, the thickness of every component of the impeller was reduced and constant thickness blades were replaced by aerofoil shape blades. Stress and deflection were analyzed for the modified and existing design within the limit and the final result showed a 14% weight reduction in the net weight of the impeller. Hence this project helped in the following ways: - Net weight reduction by 14%. - Material cost reduction. - Power savings. - Minimizing the vibration level. - Lower noise generation  
Keywords- Optimization, Radial Fan, Aerofoil, Forward Curved Blade, ANSYS, Impeller Trimming, Power Savings

I. INTRODUCTION

A. Primary Air Fan  
Two number of NDZV 20 radial fans are used for supplying the required primary air for transporting the pulverized coal from the mills to the furnace. The quantity of cold primary air taken before the Air pre heater and the hot primary air at the outlet of the Air pre heater are controlled in such a manner, that the flow to the mills is maintained at 55 T/Hr. and the coal air temperature at the outlet of the mills at about 80 deg.C. These fans are of double suction single stage centrifugal type in which the fresh air from the atmosphere enters the impeller axially and after passing through the impeller leaves radially.

Fig. 1: Primary Air Fan Cycle
A large part of the energy transferred to the air is converted into pressure energy as the air passes through the impeller. The spiral casing converts part of the kinetic energy in the air to pressure energy. These fans are driven by constant speed Squirrel Cage Induction Motor. The output of the fan is controlled by an inlet guide vane damper assembly. Each fan is provided with a shut off gate at the discharge duct. The fan and the motor shafts are coupled with pin type flexible coupling.

The spiral casing, suction chamber, rotor shaft with impeller, bearing assemblies and shaft seals are major sub-assemblies of PA fan. The spiral casing rests on its foundation and with respect to the rotor during expansion the spiral casing is suitably guided by the frames to maintain its orientation. Suction cone provided in the casing helps to achieve accelerated inlet flow to the impeller. The impeller sealing rings fixed in the suction cone, overlaps the impeller ring maintaining a specific clearance which provides necessary sealing of the impeller inlet flow from its discharge.

The rotor assembly consists of impeller and shaft, supported by Spherical Bearings located on either side of the impeller. The bearings are lubricated by separate lub oil system.

Sealing for the shaft where it passes through the spiral casing on both sides is achieved by labyrinth seals for axial sealing. The labyrinths are housed in a seal housing which is mounted on the bearing pedestal. The seal housing is connected to the spiral casing by flexible asbestos cloth for Radial Sealing.

A radial fan is a one in which the flow enters along the axis and leaves in the radial direction along the blades. Fan selection depends on the following parameters:
- Volume flow rate.
- Pressure.
- Type of material handled.
- Space limitations.
- Efficiency

Generally, Fans fall into following two categories:
1) Centrifugal Flow
2) Axial Flow

In Centrifugal flow, the air flow changes in direction. But in Axial flow, the air enters and leaves the fan with no change in direction.

Most of the manufacturing industries spend a lot of investment for materials and equipment running cost. This paper is discussing about the optimizing modified aerofoil shape forward curved bladed radial fan impeller from the existing constant thickness forward curved bladed radial fan impeller of primary air fan used in thermal power plants. Aerofoil shape blades have been greater efficiency than with constant thickness blades.

II. AEROFOIL SHAPE BLADED

A. Benefits of Aerofoil Shape Bladed Radial Fan Impeller
- Greater efficiency as compared to the constant thickness forward curved bladed radial fan impeller as it consumes lesser power and thus it is economical.
- Smoother air flow due to aerofoil shape is a curved body as compared to the constant thickness bladed radial fan impeller.
- It reduces vibration level to some extent.
- Noise level reduced as compared to the constant thickness forward curved bladed radial fan impeller.
- Cost reduction for material due to saving around 14% of its original weight.

Since the mass of the impeller is directly related to the thickness of the impeller parts, we aim to reduce the thickness, i.e., trimming of the entire parts of the impeller and analyzing using ANSYS software by Finite Element Analysis (FEA) has been carried out for the prediction of distribution of stress and deflection of the impeller.

B. Fan Specification
- Application: Primary air fan
- Power: 1250 KW, 6.6 KV, 50 Hz
- Plant Capacity: 210 MW
- Fan size: NDZV 20 Herakles
  - ND - Radial Fan
  - ZV - Double suction simply supported
  - 20 - Dia. of Impeller in decimeter
  - Herakles - Type of Impeller
- Speed: 1480 RPM
- Total Header Pressure Developed: 12572 N/m²
- Volume of flow: 292 T/hr
- Type of fan Regulation: Inlet guide vane control
- Fan Reserve
  - Flow: 73.3%
  - Pressure: 58.7%

C. Dimension of the Impeller
- Back plate (Top): Dia. 2000 mm
- Back plate (Bottom): Dia. 1500 mm
- Cover plate: Dia. 1400 mm
- Ring: Dia. 1000 mm
- Flange: Dia. 600 mm

III. OPTIMIZATION PROCESS

A. Model Generation using Pre Processor
In ANSYS there are three stages. They are as follows:
- Preprocessor
- Solution
- General Postprocessor

So before doing analysis, the geometry of the model should be created. Modeling is done in ANSYS through preprocessor. There we have lot of option through which the geometry of the model is created.
B. **Meshing Contours**
After generation of the solid model using preprocessor, the model should be meshed properly. That is the model should be divided into number of small elements. For meshing of the model, we should generate meshing contours. That is the lines of the geometry should be properly divided. So that we can easily mesh the model otherwise without the contour the mesh won't be proper and we cannot solve it.

C. **Meshing of Areas**
After generation of the contours for proper meshing we should go for meshing of the model. There are two types of meshing. They are: 1. Free meshing and 2. Mapped meshing. To get an accurate result we choose the second one.

![Mapped Mesh of the Impeller Model](image)

**D. Defining Material**
After the above process, we have to define the material of the model. There are different properties which can define a material namely, density, young’s modules and Poisson’s ratio. These values differ between different materials. The material can be defined in preprocessor through the use of these properties. Young’s modulus is 200 GPa, Density is 7850 kg/m³, Poisson’s ratio is 0.30.

**E. Choosing Appropriate Element for Analysis**
The basic concept of FEA is too descriptive the model into a finite number of smaller elements. There are different element types available in ANSYS preprocessor. There are variations in the types of elements depending on the model. The choice of the appropriate element is needed for analysis. A 4-noded area element has been used for the analysis.

![4-Noded area element](image)

**F. Attributing Equivalent and Actual Boundary**
After discretizing and defining the material of the model, the boundary conditions have to be applied and also the loads wherever required for the analysis. First the application of the constraints.

![Mesh of Impeller with Constraints](image)
So wherever required, the degree of freedom should be arrested. After applying constraints, the loads are applied on nodes or element for the analysis.

G. 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

H. Viewing Results for the Original Design of the Impeller
The results are viewed in general postprocessor, the stress and deflection can be plotted on the screen with different colors. The maximum and minimum stresses are noted.

I. Viewing Results for the Modified Design of the Impeller
The results are viewed in general postprocessor, the stress and deflection can be plotted on the screen with different colors. The maximum and minimum stresses are noted.
J. Modifying the Geometry Model by Reducing the Thickness
Following an observation of the stress and deflection for the original design, the stress and deflection for the modified design require an in depth study. The design is modified by reducing the thickness of all components and blade profile. Then all the above steps follow for finding the stress and deflection value. Finally the results of the original and modified design should be compared in order to obtain the optimized design.

IV. RESULT AND DISCUSSION

A. Static Analysis
The stress distribution and the deflection of the impeller for the various components are found and the same is plotted in the figures.

B. Optimization
The thickness of each components of the impeller is reduced without disturbing the operation. After optimization, found that the stress and deflection values are within the safe limits

<table>
<thead>
<tr>
<th>Component</th>
<th>Stress Kgf/mm²</th>
<th>Deflection mm</th>
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<tbody>
<tr>
<td>Original fan impeller</td>
<td>8.576</td>
<td>0.101</td>
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<tr>
<td>Modified fan impeller</td>
<td>10.720</td>
<td>0.126</td>
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C. Weight Reduction
Optimization of the thickness of the fan impeller enables reduction in the net weight of the fan impeller. The existing weight of the fan impeller is 10 tones. i.e.,10,000 kg. After optimizing, the percentage of weight reduction is 14%. i.e., 10,000 x 14% = 1400 kg.

D. Cost Reduction Calculation
Cost of steel per kg = Rs.500. Savings of cost per impeller = Rs. 500 x 1400 kg = Rs.7,00,000. Each 210 MW thermal power plant have 2 Nos. of Primary air fans. Thus Cost savings per plant = Rs.7,00,000x2Nos.=Rs.14,00,000. In Thermal Power Plant, if there are 3 Nos. of 210MW Units, total cost savings for the plant = Rs.14,00,000 x 3 Nos. = Rs.42,00,000. The above figures are calculation of only material cost. If we consider the running cost of the modified designed fan, we may gain a more power saving cost.

<table>
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<th>Table 1: Comparison of thickness reduction</th>
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V. CONCLUSION
In this project, an attempt has been made to find ways of increasing the fan efficiency by optimizing the thickness of the various components and blade profile to aerofoil from the existing constant thickness bladed radial fan impeller and analyzing the stress distribution in them.

Optimization of the thickness of the fan impeller leads to decrease in the net weight of the fan impeller and in turn power required for driving the fan decreases.
The impeller with constant thickness bladed one weighs huge and which leads to high level of vibration and more chances to failure. So the analysis was done with aerofoil shape blades and weight reduction was found for safe stress and deflection limits. This analysis resulted in reduction of material and reduction in material cost with reduced vibration level 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

[3] Centrifugal fan impeller design with optimization of blade by Shalini Rai Assistant Professor and Dr. Prabha Chand Assistant Professor.