Design and Thermal analysis by using Finite Element Method for Gas Turbine Rotor Blade

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***Abstract* - Withstanding of gas turbine blades for the elongations is a major consideration in their design because they are subjected to high tangential, axial, centrifugal forces during their working conditions. The first stage rotor blade of a two-stage gas turbine has been analyzed for structural, thermal using ANSYS 12 which is powerful Finite Element Software. In the process of getting the thermal stresses, the temperature distribution in the rotor blade has been evaluated using this software. This project specifies how the program makes effective use of the ANSYS pre-processor to analyse the complex turbine blade geometries and apply boundary conditions to examine steady state thermal & structural performance of the blade for N 155, Hastealloy x & Inconel 625 materials.**

***IndexTerms* - Thermal Analysis, Modal, Finite Element Analysis, Gas Turbine**

I. INTRODUCTION

The gas turbine obtains its power by utilizing the energy of burnt gases and the air which is at high temperature and pressure by expanding through the several rings of fixed and moving blades, to get a high pressure of order of 4 to 10 bar of working fluid which is essential for expansion a compressor is required. Thermal efficiency and power output of gas turbines increase with increasing turbine rotor inlet temperature.

The turbine escapes energy from the exhaust gas. Like the compressor, turbine can be centrifugal or axial. Gas turbine blades are cooled internally and externally; this paper focuses on turbine blade internal cooling. In this type cooler air is bled from the compressor stage and then passing through internal passages incorporated into blade designs for cooling purpose.

II. LITERATURE SURVEY

The first stage rotor blade of a two stage gas turbine has been analysed for structural, thermal, modal analysis using ANSYS 11.0.which is a powerful Finite Element Method software. The temperature distribution in the rotor blade has been evaluated using this software. The design features of the turbine segment of the gas turbine have been taken from the preliminary design of a power turbine for maximization of an existing turbo jet engine.

The purpose of turbine technology is to extract, maximum quantity of energy from the working fluid to convert it into useful work with maximum efficiency. That means, the Gas turbine having maximum reliability, minimum cost, minimum supervision and minimum starting time. The gas turbine obtains its power by utilizing the energy of burnt gases and the air. This is at high temperature and pressure by expanding through the several rings of fixed and moving blades.

The design and analysis of Gas turbine blade, CATIA is used for design of solid model and ANSYS software for analysis for F.E.model generated, by applying boundary condition, this paper also includes specific post-processing and life assessment of blade . How the program makes effective use of the ANSYS pre-processor to mesh complex turbine blade geometries and apply boundary conditions.

III. METHODS OF COOLING

Internal Cooling

Internal cooling of blades can be achieved by passing cooling air from the air compressor through internal cooling passages from hub towards the blade tips. The internal passages may be circular or elliptical and or distributed near the entire surface of blade. The shapes of such blades may deviate from the optimum aero dynamic blade profile. The cooling of the blade is achieved by conduction and convection. Cooling air enters the leading edge region in the form of a jet and then turns towards the trailing edge.

External Cooling

External cooling of the turbine blade is achieved in two ways. The cooling air enters the internal passages from the hub towards the tips. Besides cooling the blade surface it decreases the heat transfer form hot gases to the blade metal.

IV. Finite Element Analysis of Gas Turbine Blade

Finite element analysis can play a vital role by simplifying the analysis. In this work a turbine blade is analyzed for its thermal as well as structural performance due to the loading condition. Six different models having different number of holes were analyzed in this paper to find out the optimum number of holes for good performance.

Steps involved in FEM

- Select the continuum of the body.
- Selection of the displacement models.
- Derive the stiffness matrix and global load vector.
- Using the force-displacement relationship, the unknown nodal displacements are obtained.
- Using the strain-displacement and stress-strain relationship the unknown values are calculated.
- Faster automatic calculations, which are repetitive in nature, simultaneous display of modifications & post processing results.
- Accurate prediction with adequate details for identifying critical areas of interest like highly stressed regions.

V. Thermal Structural Analysis

The finite element analysis of the gas turbine blade was done sequentially i.e., thermal analysis was performed first, and then the structural analysis was carried out, by taking into account the results of the thermal analysis.

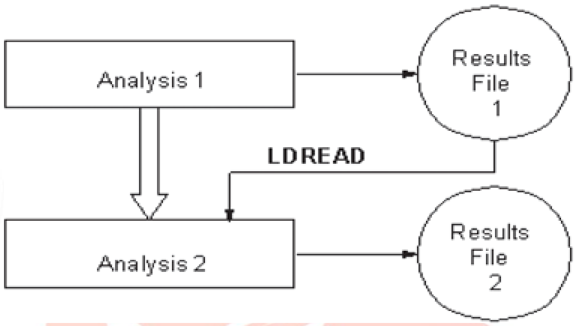

Figure 1 Block diagram of thermal- structural analysis

Thermal analysis

The transient thermal analysis was performed by applying the loading condition by using a time curve. For this, hot gas temperature was specified along the pressure side of the blade and the cool-ant temperature was applied on the cooling hole surface area. The hub being fixed to the rotor disc, it is constrained in all six degrees of freedom. Different thermal loads and convection boundary conditions were applied on pressure side of the blade model.

Structural analysis

For structural analysis, the model was re-meshed using Solid 92 elements. The pressure load was applied on the pressure side of the blade and the analysis was performed. Since hub side of the blade was fixed with disc, hub side of the blade was fully arrested. Then structural loads were applied on pressure side of the blade model.

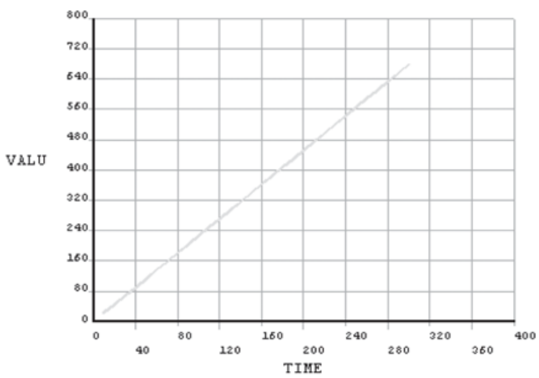

Figure 2 Temperature Vs time for existing design (12 holes)

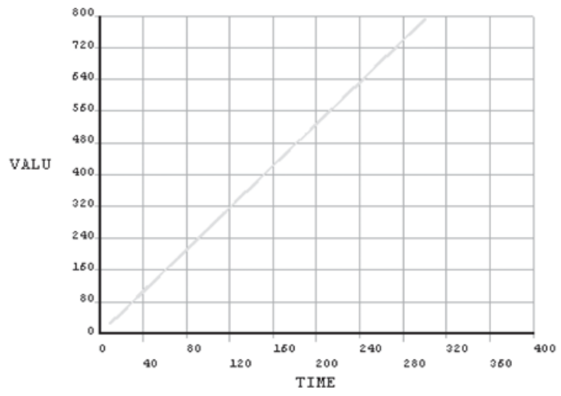

Figure 3 Temperature Vs time for optimized design (8 holes)

VI. Results and Discussions

The thermal-structural finite element analysis was performed for the turbine blade with different number of holes i.e., 12,11,10,9,8,7 number of holes by specifying thermal and structural loads with an objective of finding optimum number of holes for the best performance. First the existing blade design with 12 holes was analyzed by specifying 500º C as coolant temperature. Then by specifying 300° C as coolant temperature, the thermal analysis and structural analysis was performed on all the six different blade models and thermal and stress distributions were obtained.

The temperature distribution on existing design of turbine blade (with 12 holes) when analyzed with coolant temperature of 300º C is much less than that of same blade when analyzed with coolant temperature 500°C. When the coolant temperature of 300°C is intended to be used, it leads to over cooling and affects the performance since an average temperature of 800ºC is the required allowance blade temperature for the maximum performance of the blade. The temperature distributions for different holes are shown in table 1.

No. of holes	Temperature distribution (°C)
12	679.6
11	707.1
10	755.2
9	784.8
8	792.8
7	827.6

The temperature as obtained when analysed with 300ºC with coolant temperature against the number of holes is graphically shown in figure 4. It can clearly see from the graph that when the numbers of holes are increased in the blade, the temperature distribution comes down. Only on the blade configuration with 8 holes, the temperature near to the required temperature i.e., 800°C is obtained.

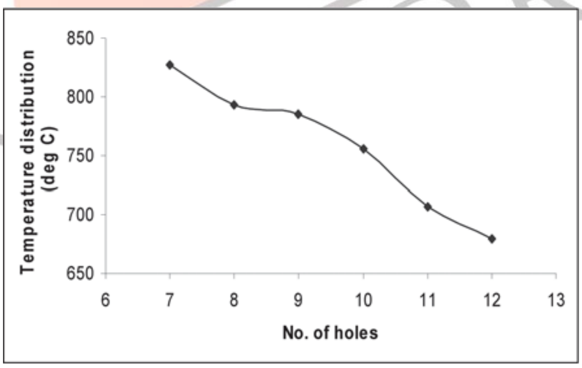

Figure 4 Temperature distribution Vs Number of holes

For other configuration like blade with 7 holes or blade with 9 holes the temperature distribution is either on a higher side or below the required blade temperature of 800ºC. Since the performance of the turbine will be less if the temperature distribution is either more than or much less than the required blade temperature of 800°C. The blade with 8 holes is the most optimum number of holes for turbine blade.

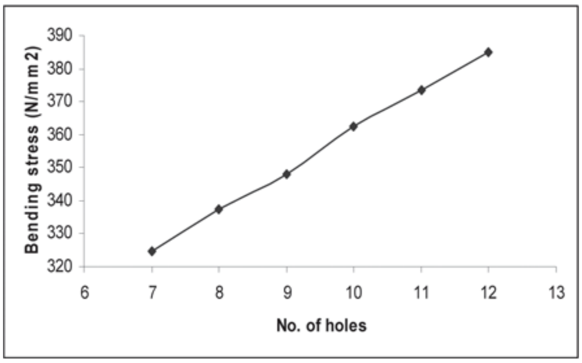

Figure 5 Bending stress Vs Number of holes

VII. Conclusion

In this paper, using finite element analysis as a tool, the structural and thermal analyses were carried out sequentially. The blade with different no. of holes 7, 8, 9, 10, 11 and 12 were used for analysis. The temperature has a significant effect on the overall turbine blades. Maximum elongations and temperatures are observed at the blade tip section and minimum elongation and temperature variations at the root of the blade. The bending stress, obtained from finite element analysis shows lower stress level for the blade with 8 holes. These results indicate that the blade with eight holes will have optimum performance for the prescribed loading conditions.

VIII. Acknowledgment

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