DESIGN AND ANALYSIS OF FIRST STAGE ROTOR BLADES OF TWO STAGE GAS TURBINE

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Abstract: The structural, thermal and model analysis of first stage rotor blade of two stage gas turbine has been carried out using ANSYS 9, which is a powerful Finite Element Software. The design features of gas turbine have been taken from the preliminary power turbine for maximization of an existing turbojet engine. By using this software temperature distribution for a rotor blade has been evaluated. As the temperature has a significant effect on the rotor blades, along with mechanical stresses, thermal stresses are also studied for clear understanding of rotor blades.

Keywords: Rotor blade, Von-misses, thermal stresses, ANSYS 9.

I.INTRODUCTION

The purpose of turbine technology is to extract the maximum quantity of energy from the working fluid to convert it into useful work to get maximum efficiency by means of plant maximum reliability, minimum cost, and minimum supervision and within short period of time. The gas turbine obtains power by utilizing the energy of burnt gases and air which is at high pressure and temperature by expanding through the several rings of fixed and moving blades to get maximum pressure of 4 to 10 bar of working fluid which is essential for expansion. The pressure and speed requirement at inlet of turbine is very high hence require centrifugal or axial compressor at inlet of the turbine. To drive the compressor, turbine shaft is coupled to it. After compression processes the working fluid is expanded in a turbine, then assuming that there is no losses in either component, the power developed by the turbine can be increased by increasing the volume of the working fluid at constant pressure or else increasing the pressure at constant volume. Either of these may be done by adding heat so that the temperature of working fluid increased after compression. To get maximum temperature of the working fluid a combustion chamber is required where combustion of air and fuel takes place by giving temperature rise to the working fluid. The schematic gas turbine blade as shown in below figure 1.

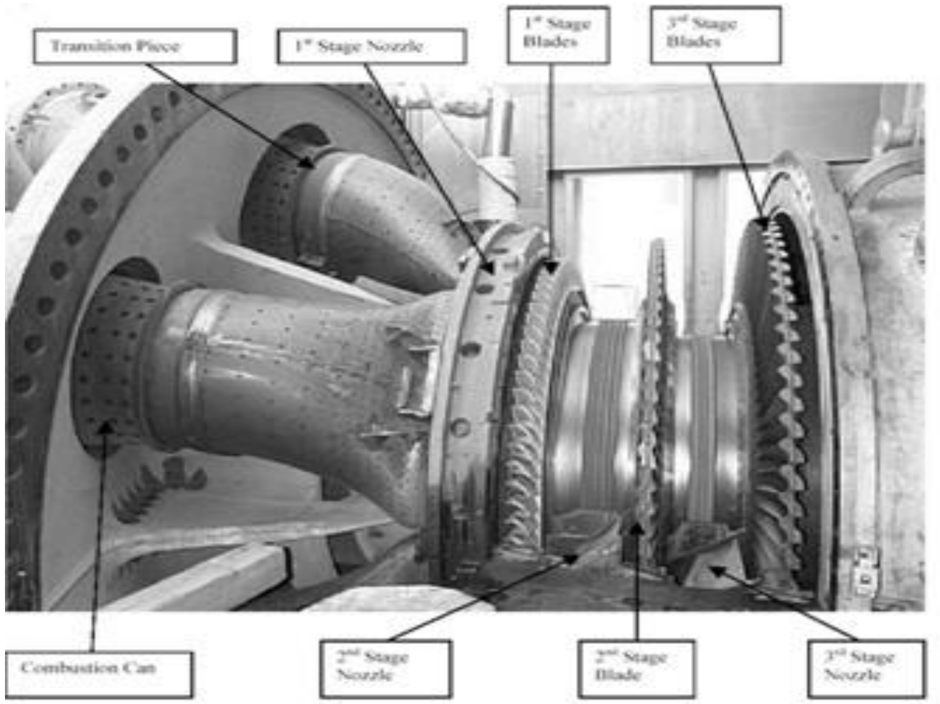

Figure 1: Setoff Gas turbine blades

Now a day's Finite Element Method (FEM) has become an important tool for engineering analysis. In modern technological environment the conventional methodology of design can't compete with the modern trend technique such as Computer Aided Engineering (CAE). The constant search for new innovative design in the engineering field is to build highly optimized product, which is the basic requirement for the survival in the global market today. The most important application of the finite element method is structural analysis. The term structural implies naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings as well as mechanical components such as pistons, machine parts, and tools. Seven types of structural analysis are available in ANSYS 9.

1.1. Symbol Description:

P = Load (N)

F_a = Axial load (N)

F_c = Centrifugal force (N)

$\propto$ = Coefficient of thermal expansion ($/^0$ C)

M_z = Moment Load (N.m)

E = Young's Modulus (N/mm^2)

II.OBJECTIVE

The stress analysis in the field of aerospace engineering is invariably complex and tedious to obtain analytical solutions. The most powerful techniques that have been developed in the engineering analysis are the finite element method for the analysis of structures/solids of complex shapes and complicated boundary conditions. By using Finite Element Analysis the various researchers had done lot of work to develop gas turbine blade. The objective of work involves:

- At higher temperature gradient thermal stresses are determined
- Maximum stresses developed in the turbine blade
- Temperature distribution along the blade profile.
- The natural frequencies for modal analysis can be determined.
- The temperature and stresses are within the limits.
- The parameters influencing the stress concentration in rotor blades can be determined.
- For different material properties mode shapes are evaluated. This enables the designers to develop the analysis of gas turbine rotor blade more effectively and easily.

III.FE MODELING

- Aerofoil profile of the rotor blade is generated on XY plane with the help of key points. Then the number of splines is fitted through the key point.
- By using these points, blade model is created in PRO-E, with the help of commands like splines, extruded, add etc.
- GAMBIT and meshed it by using commands like auto mesh or tetmesh and then exported into ANSYS 9.0
- The shaded areas are extruded upwards through the blade height along positive Z direction. Areas 4,5,6 are extruded downwards along the negative direction also the shaded areas are extruded along X- direction using SOLID-45 node Brick element and 3-D model of rotor blade is created.

3.1. ANSYS Parametric Design Language (APDL):

For simple task such as repeating the previous command certain number of times or calculating the root of 296.4 to more complicated task such as creating own ANSYS command or solving simultaneous equations. APDL stands for ANSYS Parametric Design Language that allows you to build model in terms of parameters (variables) which in turns allows making design changes easily and conveniently. APDL also encompasses a wide range of other features such as repeating a command, macros, If then else breading do-loops and vector and matrix operations.

APDL offers wide range of capabilities in analyzing of any processor at any time for more information on this language. Besides that it is foundation for sophisticated features such as design optimization, adaptive meshing and customization. APDL can be used to change the material properties, loading conditions and to change element type used in any analysis. It is very user friendly and this work built by using Geographical User Interface. There are several commands used for that. The complete finite element model can be built by using this language. The below Figure 1 shows a typical area diagram of gas turbine rotor blade

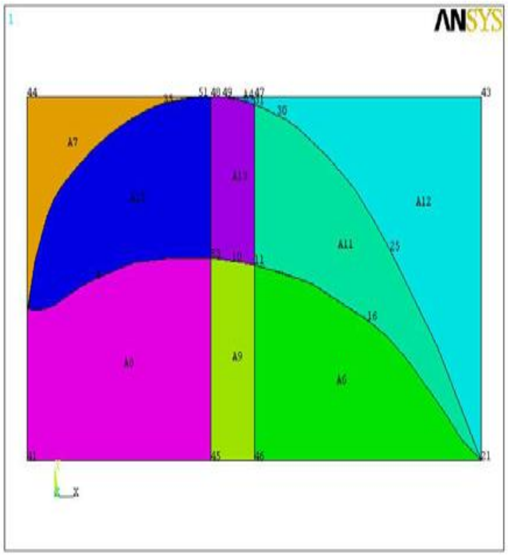

Figure 2: Area diagram of Gas turbine blade

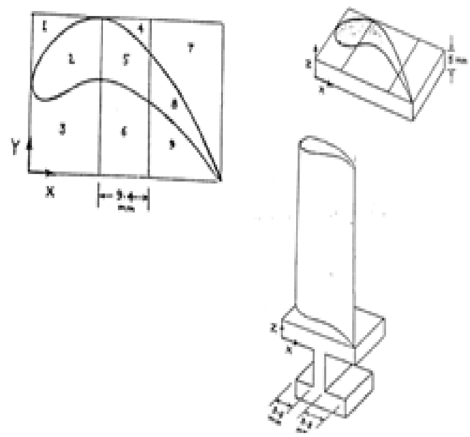

Figure 3: Model of rotor blade

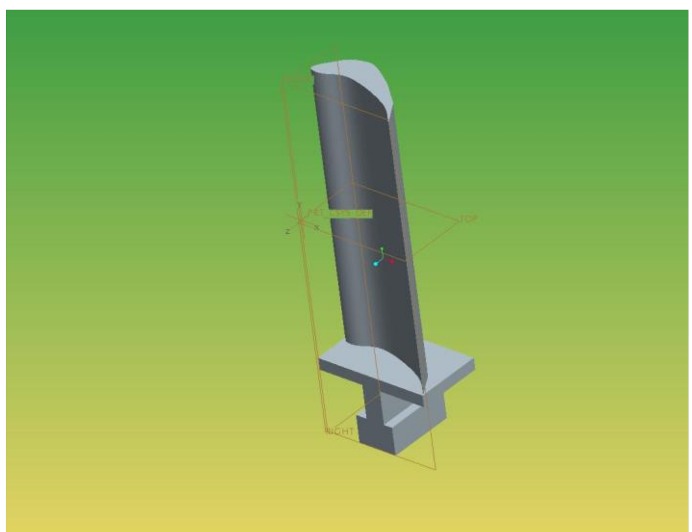

Figure 4: 3-Dimensional view of rotor blade

IV.RESULTS AND DISCURSSION

4.1. Analysis of Structural stresses:

The Von-Mises stresses are obtained as shown in figure, it is observed that the maximum Von-Mises stress is 296.177 N/mm^2 this value is less than the yield stress value. The maximum deformation in Z direction is obtained as 0.13799 mm which is safe on the strength criteria and rigidity criteria.

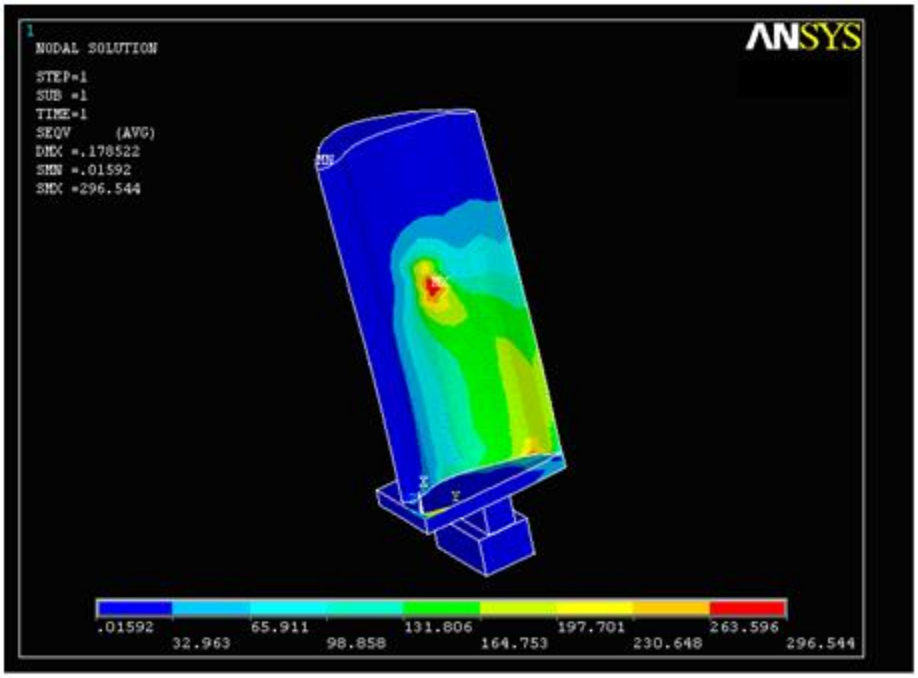

Figure 5: Von-Mises stresses induced in rotor blade

4.2. Analysis of Thermal stresses:

From the post processing, the temperature variation as shown in figure and it is observed that the variation of temperature from leading edge to tailing edge on the blade profile varying from 839.531^{0}C to 735.162^{0}C at the tip of the blade and variation is linear along the path from both inside and outside of the blade. Considerable changes are not observed from the first 6 mm length and from the next 36mm length the temperature decreases gradually to 781.5480c and for another 4mm length it is almost constant. At maximum curvatures the temperature variation is less and along X-direction temperature decreases gradually.

The thermal stresses are obtained as shown in figure and it is observed that maximum thermal stress is 1217 N/mm^2 which is less than the yield strength value i.e., 1540 N/mm^2. Based on this value can say that the design of turbine blade is safe.

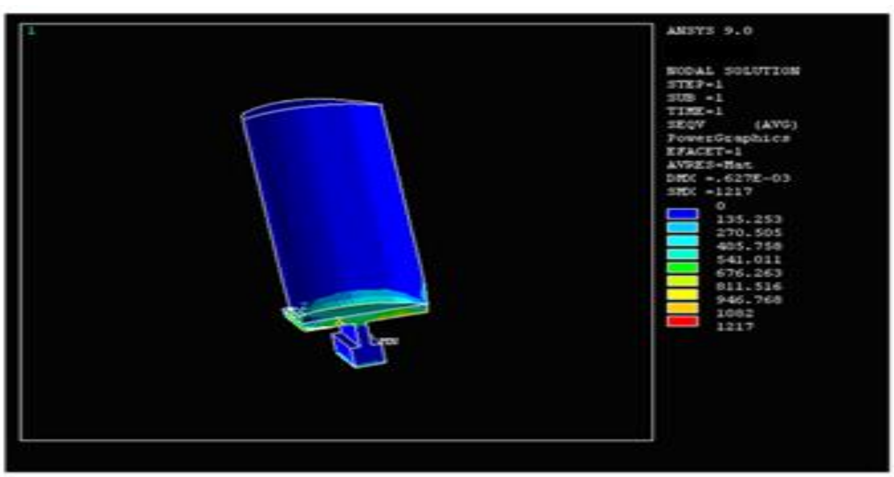

Figure 6: Thermal stresses induced in rotor blade

4.3. Analysis of Rotor Blade Deformation:

4.3.1. Model Analysis:

- Maximum deformation in Z (Uz) direction of gas turbine rotor blade at 20 HZ frequency.
- Sub step is 0.4093 mm and frequency is 20.22.
- Maximum deformation in Z (Uz) direction of gas turbine rotor blade at 20 HZ for second Sub step is 0.518181 mm and frequency is 30.621.
- Maximum deformation in Z (Uz) direction of gas turbine rotor blade at 20 HZ for third sub step is 0.453354 mm and the frequency is 102.576.

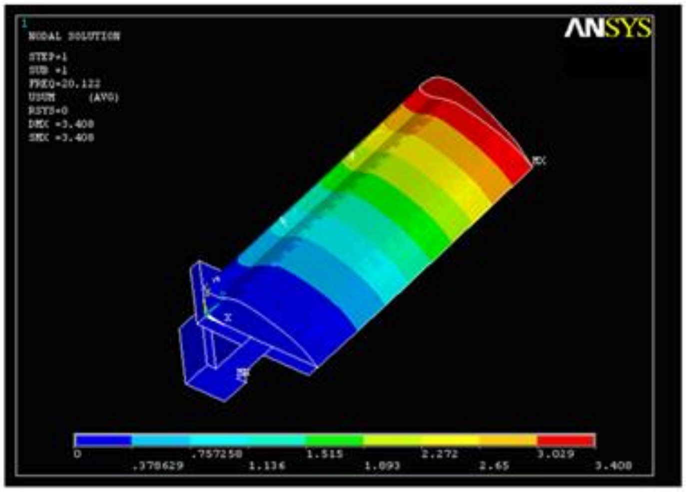

Figure 7: Resultant deformation at 20 HZ

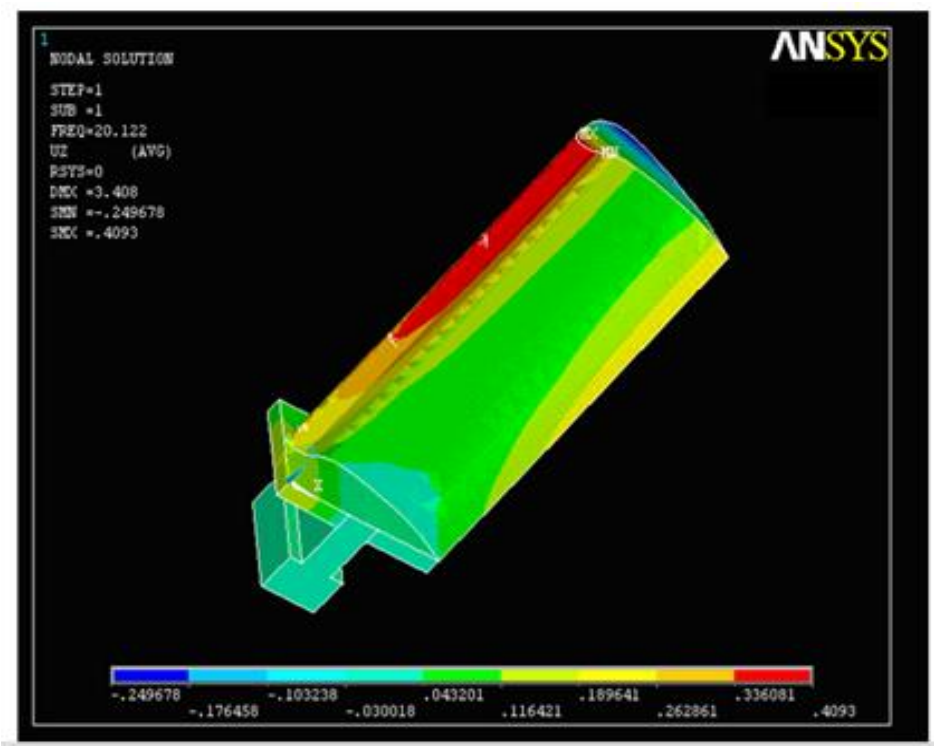

Figure 8: Deformation in Z (Uz) direction of gas turbine rotor blade at 20 HZ for first substep.

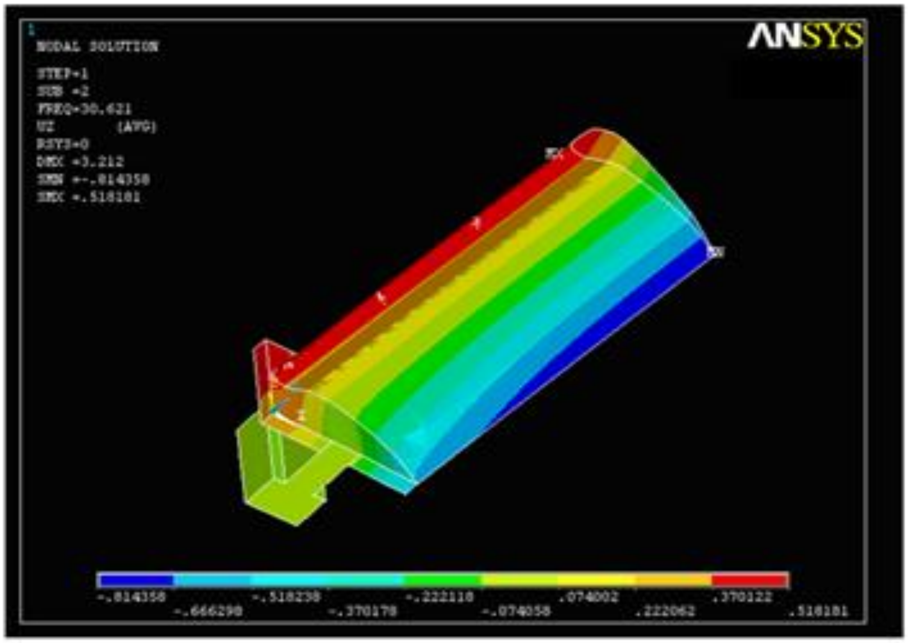

Figure 9: Deformation in Z (Uz) direction of gas turbine rotor blade at 20 HZ for second substep.

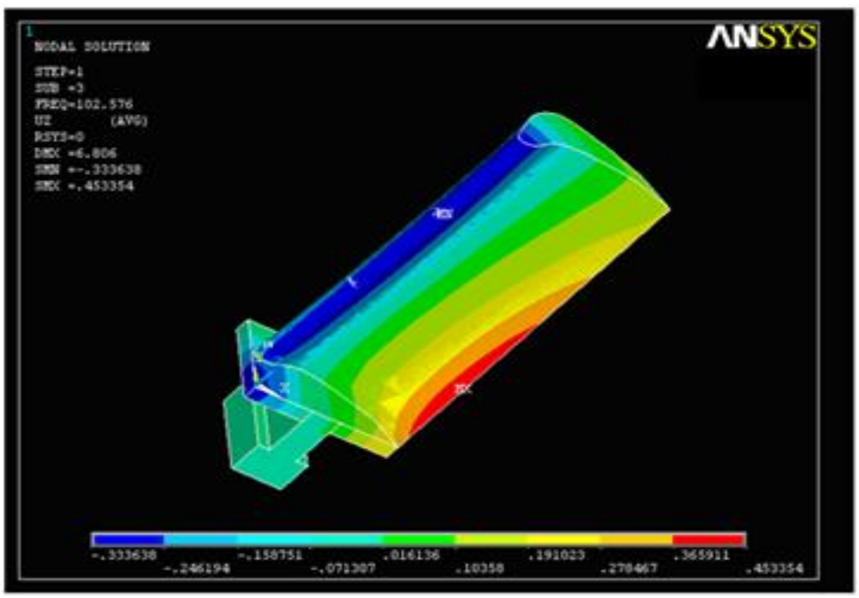

Figure 10: Deformation in Z (Uz) direction of gas turbine rotor blade at 20 HZ for third substep.

V. CONCLUSION

- The structural, thermal and model analysis is carried out for 20 nodded brick element of gas turbine rotor blade using finite element analysis.
- The significance of thermal stresses on the overall stresses has been observed.
- Maximum elongations and temperatures are observed at the tip of the blade and minimum elongations and temperatures are at the root of the blade.
- Temperature distribution is uniform at the maximum curvature of blade profile.
- Temperature is linearly decreasing from tip of the blade to root of the blade.
- The maximum thermal stresses induced are within safe limit and maximum from outside to inside.
- Maximum stresses and strains are observed at root of the blade surface.
- Elongations along X- direction are observed in blade length and elongations in Y-direction are gradually varying from different sections of rotor axis.

VI. FUTURE SCOPE

- Studies can be extending for advanced materials to obtain improved results.
- Life estimation for rotor blade can predict using SN- Diagram approach.
- Resonance condition can predict using CAMBELL diagram.

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