Structural Analysis of Super Alloy Gas Turbine Blade using FEA

Chaitanya Krishna Patsa[1], Subhani Mohammed[2]

[1]IV Sem, M.Tech (CAD/CAM), Department of Mechanical Engineering, Sasi Institute of Technology and Engineering, Tadepalligudem, Andhra Pradesh, India-534101
[2]Assistant Professor, Department of Mechanical Engineering, Sasi Institute of Technology and Engineering, Tadepalligudem, Andhra Pradesh, India-534101.

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. Several methods have been suggested for the better enhancement of the mechanical properties of blades to withstand these extreme conditions. This project summarizes the design and analysis of Gas turbine blade, on which CATIA V5 R19 is used for deign of solid model of the turbine blade with the help of the spline and extrude options ANSYS 14.5 software is used analysis of F.E. model generated by meshing of the blade using the solid brick element present in the HYPERMESH 10 software and thereby applying the boundary condition.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 Monel-400, Haste alloy -x & Inconel 625 materials. Finally stating the best suited material among the three from the report generated after analysis. From this the results are stated and reported.

1. 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. The quantity of working fluid and speed required are more, so generally a centrifugal or axial compressor is required. The turbine drive the compressor so it is coupled to the turbine shaft, If after compression the working fluid were to be expanded in a turbine, then assuming that there were no losses in either component, the power developed by the turbine can be increased by increasing the volume of working fluid at constant pressure or alternatively increasing the pressure at constant volume. Either of there may be done by adding heat so that the temperature of the working fluid is increased after compression. To get a higher temperature of the working fluid a combustion chamber is required where combustion of air and fuel takes place giving temperature rise to the working fluid.

The turbine escapes energy from the exhaust gas. Like the compressor, turbine can be centrifugal or axial. In each type the fast moving exhaust gas is sued to spin the turbine, since the turbine is attached to the same shaft as the compressor at the front of the engine, and the compressor will turn together, The turbine may extract just enough energy to turn the compressor. The rest of the exhaust gas is left to exit the rear of the engine to provide thrust as in a pure jet engine. Or extra turbine stages may be used to turn other shafts to power other machinery such as the rotor of a helicopter, the propellers of a ship or electrical generators in power stations.

The present paper deals with the first type is centrifugal stresses that act on the blade due to high angular speeds and second is thermal stresses that arise due to temperature gradient within the blade material. The analysis of turbine blade mainly consists of the following two parts: Structural and thermal analysis. The analysis is carried out under steady state conditions using Ansys software. The study has been conducted with three different materials Monel-400, Hastealloy X & Inconel 625.

2. Literature Survey

John.v et.al(1) studied on 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. Here under we presented how Designing of a turbine blade is done in CATIA with the help of co-ordinate generated on CMM. And to demonstrate the pre-processing capabilities, static and dynamic stress analysis results, generation of Campbell and Interference diagrams and life assessment. The principal aim of this paper is to get the natural frequencies and mode shafe of the turbine blade.

V.Raga Deepu et.al(2) Studied on a Gas turbine is a device designed to convert the heat energy of fuel in to useful work such as mechanical shaft power. Turbine Blades are most important components in a gas turbine power plant. A blade can be defined as the medium of transfer of energy from the gases to the turbine rotor. The turbine blades are mainly affected due to static loads. Also the temperature has significant effect on the blades. Therefore the coupled (static and thermal) analysis of turbine blades is carried out using finite element analysis software ANSYS.

Kauthalkar et.al(3) 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. A high pressure of order 4 to 10 bar of working fluid which is essential for expansion, a compressor is required. The quantity of working fluid and speed required are more so generally a centrifugal or axial compressor is required. The turbine drives the compressor so it is coupled to the turbine shaft.

S.Gowreesh et.al(4) studied on 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. it has been felt that a detail study can be carried out on the temperature effects to have a clear understanding of the combined mechanical and thermal stresses.

In this paper the first stage rotor blade of the gas turbine is created in CATIA V5 R15 Software. This model has been analysed using ANSYS14.5. The gas forces namely tangential, axial were determined by constructing velocity triangles at inlet and exist of rotor blades. After containing the heat transfer coefficients and gas forces, the rotor blade was then analysed using ANSYS 14.5 for the couple field (static and thermal) stresses.

3. Computer Aided Analysis Of Gas Turbine Rotor Blade

The model is created and analyzed using CATIA and ANSYS. For automatic mesh generation and node selection is used. The structural, thermal modal modules of ANSYS 14.5 are used for the analysis of the rotor blade. The rotor blade was analyzed for mechanical stresses, temperature distribution, combined mechanical and thermal stresses and radial elongations, natural frequencies and mode shapes.

The blade is then analyzed sequentially with thermal analysis preceding structural analysis. The model is discretised using solid 45element.

4. Nomenclature

Fa = Axial force
Fc = Centrifugal force
Ft = Tangential force
E = Young's Modulus
μ = Poisson's ratio
σ = Stress
L = Length
D = Diameter of shaft
N = Speed of Turbine in RPM
α = Coefficient of thermal expansion

4.1 Details of Turbine blade

D=1308.5 mm, N=3426 Rpm, L=117mm, d=2mm

Table 1: Mechanical properties of N155, Inconel 625 & Hastealloy X

Properties	Units	Monel alloy 400	Inconel-625	Haste alloy X
E	Pa	179 E09	150E09	144E09
P	Kg/cum	8800	8400	8300
K	W/m-K	21.8	10	25
μ	---	0.32	0.331	0.348
σ	E-06/^{o}C	13.9	15	16
C_P	J/KgK	427	410	450
Yield stress	MPa	240	1030	360

5. Results & Discussions

Structural analysis:

The von misses stresses are obtained as shown in the figure; it is observed that the maximum von misses stress is 79.762 N/mm^2 for Monel alloy 400, 77.2914 N/mm^2 for Haste alloy X and 78.8299N/mm^2 for Inconel 625 alloy.

The deformations are obtained as shown in the figure; it is observed that the maximum deformation is0.905 mm, 0.112 mm and 0.108 mm for Monel-400, Haste alloy X and Inconel 625 alloy respectively. From the above results it is observed that the stress is low for Haste alloy X and deformation are low for Monel-400 alloy.

Table 2 : Structural analysis results

Material Type	Stress (N/mm^2)	Deformation (mm)
Monel alloy 400	79.762	0.905
Inconel-625	78.91	0.108
Haste alloy X	77.2914	0.112

<u>For Monel 400 alloy :</u>

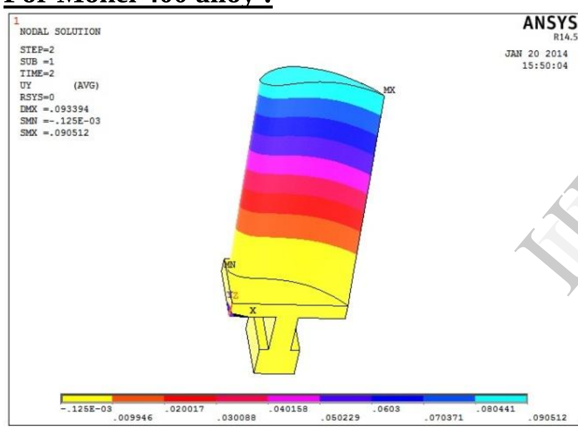

Fig.1 Deformation induced in Y direction, mm

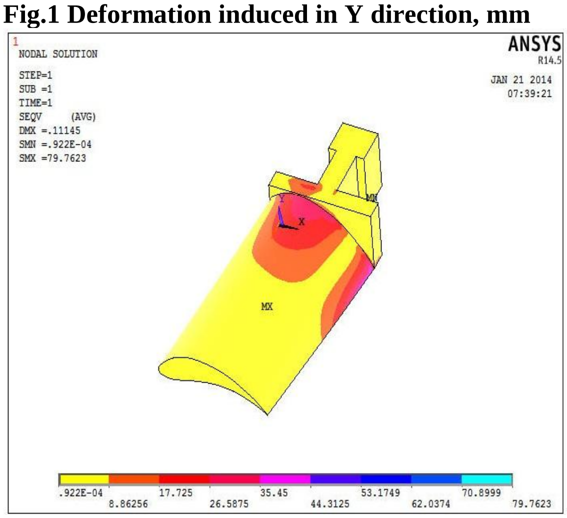

Fig.2 Stress induced in the blade, N/mm^2

<u>For Inconel 625 alloy :</u>

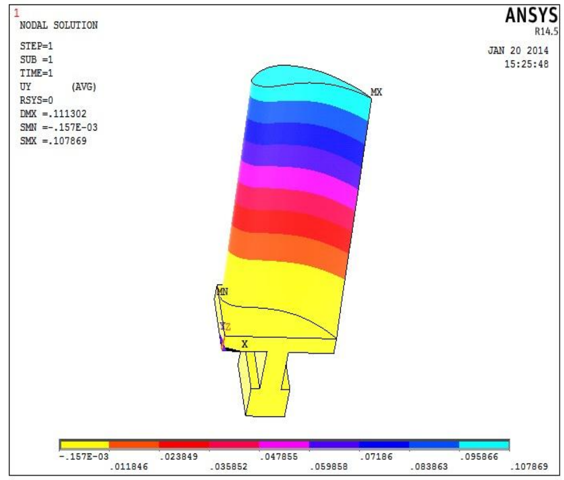

Fig.3 Deformation induced in Y direction, mm

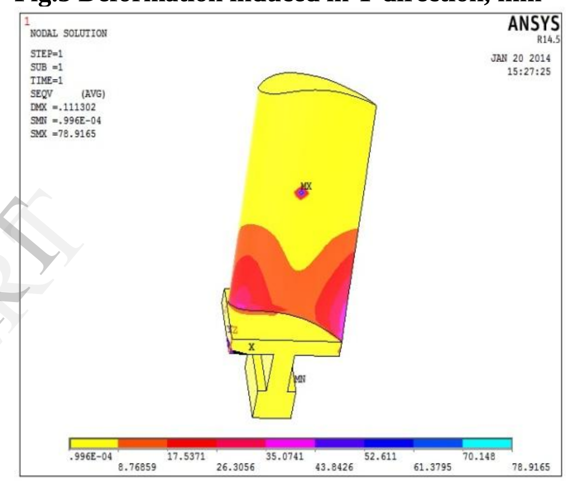

Fig.4 Stress induced in the blade, N/mm^2

<u>For Haste alloy X :</u>

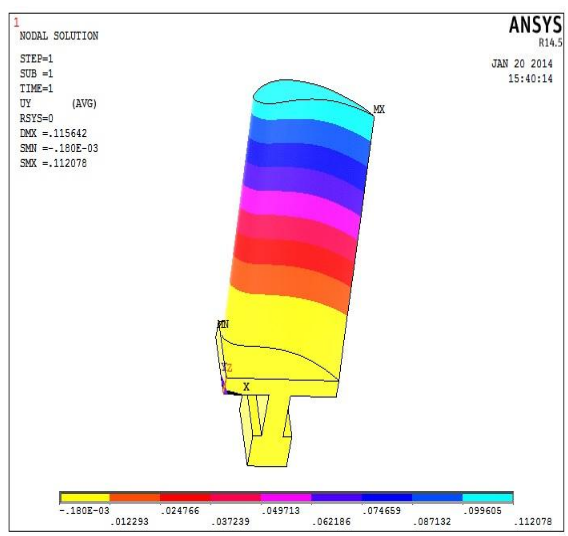

Fig.5 Deformation induced in Y direction, mm

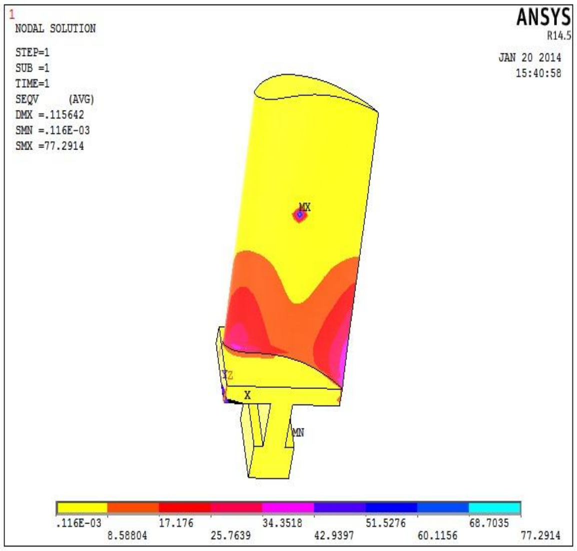

Fig.6 Stress induced in the blade, N/mm^2

Thermal analysis:

From the post processing, The stresses and deformations by static thermal analysis at steady state are obtained as shown in fig.
It is observed that the maximum von misses stress is 1310.09 N/mm^2 for Monel 400 alloy, 1341.79 N/mm^2 for Haste alloy X and 1136.41N/mm^2 for Inconel 625 alloy.

The deformations are obtained as shown in the figure; it is observed that the maximum deformation is0.115mm, 0.139 mm and 0.131 mm for Monel-400, Haste alloy X and Inconel 625 alloy respectively.

From the above results it is observed that the stress is low for Inconel 625 alloy and deformation is low for Monel 400 alloy.

Table 2 : Thermal analysis results

Material Type	Stress (N/mm^2)	Deformation (mm)
Monel alloy 400	1310.09	0.115
Inconel-625	1136.41	0.131
Haste alloy X	1341.79	0.139

For Monel 400 alloy :

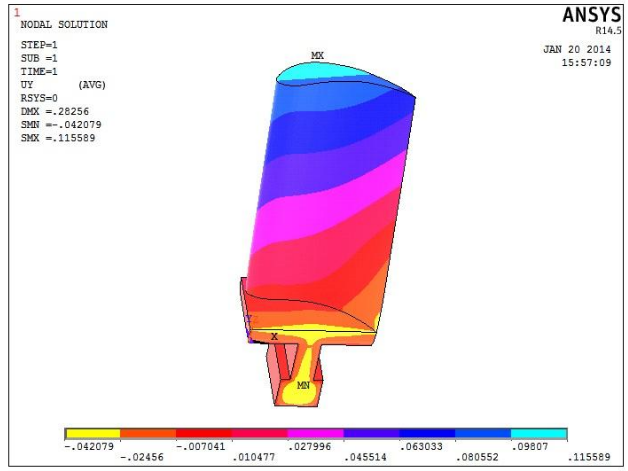

Fig.7 Deformation induced in Y direction, mm

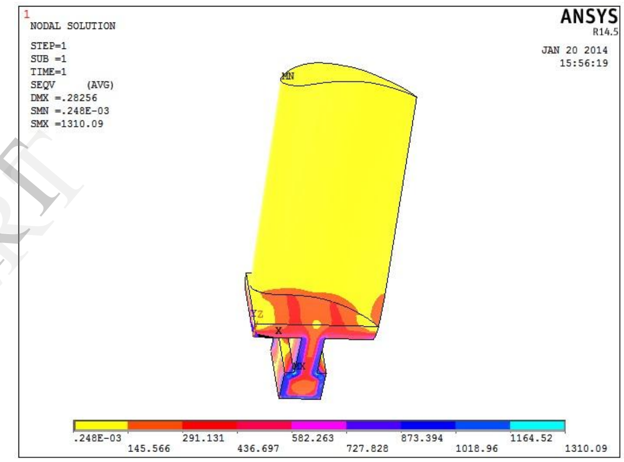

Fig.8 Stress induced in the blade, N/mm^2

For Inconel 625 alloy :

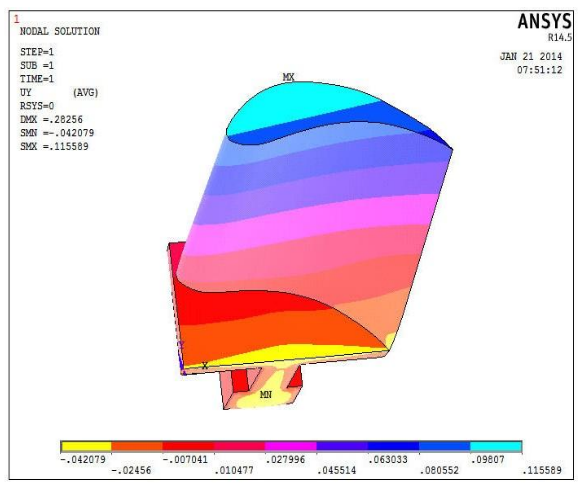

Fig.9 Deformation induced in Y direction, mm

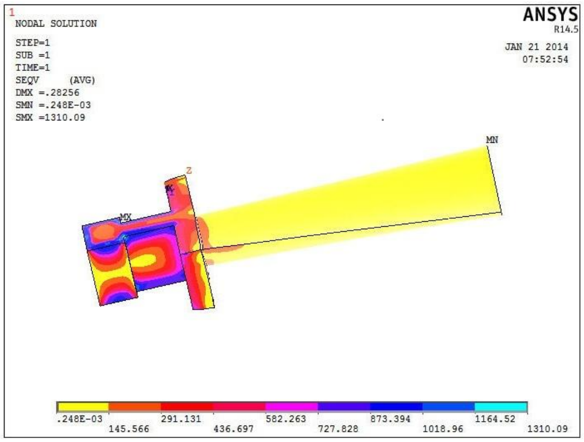

Fig.10 Stress induced in the blade, N/mm^2

<u>For Haste alloy X :</u>

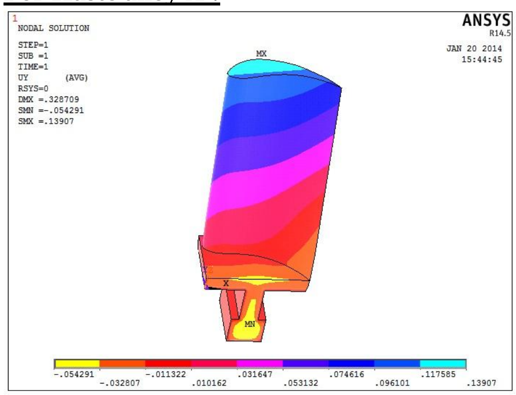

Fig.11 Deformation induced in Y direction, mm

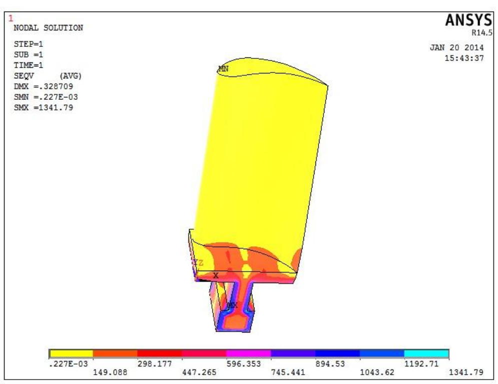

Fig.12 Stress induced in the blade, N/mm^2

6. Conclusion

The finite element analysis for structural and thermal anaysis of gas turbine rotor blade is carried out using solid45 element. The temperature has a significant effect on the overall turbine blades. Maximum elongations and minimum thermal stresses are observed at the blade tip section and minimum elongation and maximum thermal stresses at the root of the blade. Maximum stresses and strains are observed at the root of the turbine blade and upper surface along the blade roots three different materials of construction i.e., Monel 400,Inconel 625 & Haste alloy X materials. It is found that the temperature has a significant effect on the overall stresses induced in the turbine blades. From the analysis of results, Inconel 625 is best material for gas turbine blade.

REFERENCES

[1] John.V, T.Ramakrishna. "THE DESIGN AND ANALYSIS OF GAS TURBINE BLADE",International Journal of Advanced Research and Studies, Vol 2, No.1, Dec 2012.

[2] V.Raga Deepu, R.P.Kumar Ropichrla."DESIGN AND COUPLED FIELD ANALYSIS OF FIRST STAGE GAS TURBINE ROTOR BLADES", International journal of Mathematics and Engineering, Vol 13, No.2, Pages: 1603-1612.

[3] P.Kauthalkar, Mr.Devendra S.Shikarwar, and Dr.Pushapendra Kumar Sharma. "ANLYSIS OF THERMAL STRESES DISTRIBUTION PATTERN ON GAS TURBINE BLADE USING ANSYS", International journal of Engineering Education and technology, Vol.2, No.3, Nov 2010.

[4] S.Gowreesh, N.Sreenivasalu Reddy and N.V.Yogananda Murthy. "CONVECTIVE HEAT TRANSFER ANALYSIS OF a AERO GAS TURBINE BLADE USING ANSYS", International journal of Mechanics of solids, vol4, No.1, March 2009(ppt55-62).

[5] S.S.Rao,"The Finite Element method in Engineering", BH Publications New Delhi, 3rd Edition, 1999.