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An Operative Design of a Typical Steam Turbine Blade using Modal Analysis

Aamer Sohail
Assistant Professor, Department of Mechanical Engineering, Global Institute of Engineering and Technology, Moinabad.

Abstractts: The blade is the most imperative part of the horizontal axis wind turbine. As good sized as its function inside the efficientthe characteristic of the turbine stands the correct predictions of static and dynamic performances of blades at some stage in the design segmentfor similar tendencies.In the prevailing paintings, the impact of ‘strain loading on the blade floor’ and ‘centrifugal loading’ on the steady state stress has been studied. 3-D blades from the given profile data for the closing degree of a standard steam turbine is generated by means of stacking 2D profile sections in a custom designed software program including blade root attachment. The generated model meshes in ANSYS bundle pushed by using a custom-designed software program and the strain distribution is mapped at the blade floor. Steady-state stress analysis generated to recognize the dynamic behavior of the blade.

Keywords-Turbine blade,Finite Element analysis, airfoil, root, Disk, stress analysis.

I. INTRODUCTION

The gas turbine obtains its power by utilizing the energyof burnt gases and the air which is at high temperatureand pressure by expanding through the several rings offixed and moving blades, to get a high pressure of orderof 4 to 10 bar of working fluid which is essential forexpansion a compressor is required. The quantity ofworking fluid and speed required are more, so generallya centrifugal or axial compressor is required. The turbinedrive the compressor so it is coupled to the turbine shaft,If after compression the working fluid were to beexpanded in a turbine, then assuming that there were nolosses in either component, the power developed by theturbine can be increased by increasing the volume ofworking fluid at constant pressure or alternativelyincreasing the pressure at constant volume. Either ofthere may be done by adding heat so that the temperatureof the working fluid is increased after compression. Toget a higher temperature of the working fluid acombustion chamber is required where combustion of airand fuel takes place giving temperature rise to theworking fluid.

The turbine escapes energy from the exhaust gas. Likethe compressor, turbine can be centrifugal or axial. Ineach type the fast moving exhaust gas is sued to spin theturbine, since the turbine is attached to the same shaft asthe compressor at the front of the engine, and thecompressor will turn together, The turbine may extractjust enough energy to turn the compressor. The rest ofthe exhaust gas is left to exit the rear of the engine toprovide thrust as in a pure jet engine. Or extra turbinestages may be used to turn other shafts to power othermachinery such as the rotor of a helicopter, thepropellers of a ship or electrical generators in powerstations.

The present paper deals with the first type is centrifugalstresses that act on the blade due to high angular speedsand second is thermal stresses that arise due totemperature gradient within the blade material. Theanalysis of turbine blade mainly consists of thefollowing two parts: Structural and thermal analysis. Theanalysis is carried out under steady state conditionsusingAnsys software. The study has been conducted withthree different materials N155, Hastealloy X & Inconel

II. RELATED WORKS

S.Gowreesh et.al [1] studied on The first stage rotorblade of a two stage gas turbine has been analysed forstructural, thermal, modal analysis using ANSYS11.0.which is a powerful Finite Element Methodsoftware. The temperature distribution in the rotor bladehas been evaluated using this software. The designfeatures of the turbine segment of the gas turbine havebeen taken from the preliminary design of a powerturbine for maximization of an existing turbo jet engine. It has been felt that a detail study can be carried out onthe temperature effects to have a clear understanding ofthe combined mechanical and thermal stresses.

Kauthalkar et.al [2] the purpose of turbine technology isto extract, maximum quantity of energy from theworking fluid to convert it into useful work withmaximum efficiency. That means, the Gas turbinehaving maximum reliability, minimum cost, minimumsupervision and minimum starting time. The gas turbineobtains its power by utilizing the energy of burnt gasesand the air. This is at high temperature and pressure byexpanding through the several rings of fixed and movingblades. A high pressure of order 4 to 10 bar of workingfluid which is essential for expansion, a compressor isrequired. The quantity of working fluid and speedrequired are more so generally a centrifugal or axialcompressor is required. The turbine drives thecompressor so it is coupled to the turbine shaft.

John.v et.al [3] studied on the design and analysis of Gasturbine blade, CATIA is used for design of solid modeland ANSYS software for analysis for F.E.modelgenerated, by applying boundary condition, this paperalso includes specific post-processing and lifeassessment of blade .How the program makes effectiveuse of the ANSYS pre-processor to mesh complexturbine blade geometries and apply boundary conditions.

Here under we presented how Designing of a turbineblade is done in CATIA with the help of co-ordinategenerated on CMM.And to demonstrate the preprocessing capabilities, static and dynamic stressanalysis results, generation of Campbell and Interferencediagrams and life assessment. The principal aim of thispaper is to get the natural frequencies and mode shafe ofthe turbine blade.

V.RagaDeepu et.al [4] Studied on a Gas turbine is adevice designed to convert the heat energy of fuel in touseful work such as mechanical shaft power. TurbineBlades are most important components in a gas turbinepower plant. A blade can be defined as the medium oftransfer of energy from the gases to the turbine rotor.The turbine blades are mainly affected due to staticloads. Also the temperature has significant effect on theblades. Therefore the coupled (static and thermal)analysis of turbine blades is carried out using finiteelement analysis software ANSYS.

In this paper the first stage rotor blade of the gas turbineis created in CATIA V5 R15 Software. This model hasbeen analysed using ANSYS11.0. The gas forces namelytangential, axial were determined by constructingvelocity triangles at inlet and exist of rotor blades. Aftercontaining the heat transfer coefficients and gas forces,the rotor blade was then analysed using ANSYS 11.0 forthe couple field (static and thermal) stresses.

III. GEOMETRIC MODELING

A customized had been developed by the commercial vendorwhich uses ANSYS as the core engine. It is an ANSYSbased turbine blade analysis system with extensiveautomation for solid model and F.E. model generation,boundary condition application, file handling and jobsubmission tasks for a variety of complex analyses; theprogram also includes turbo machinery specific postprocessing and life assessment modules. This customizedsoftware having cutting-edge example for verticalapplications built on the core ANSYS engine using ANSYSAPDL and Tcl/Tk. The software having capabilities for preprocessing, static and dynamic stress analyses, generation ofCampbell and Interference diagrams and life assessment. Theprincipal advantage of this software is its ability to generateaccurate results in a short amount of time, thus reducing thedesign cycle time.The following are the modeling capability of the blade.

1. Cover Data
a) No Cover
b) Peened Tenon (Up-to three tenons)
c) Integral Cover
d) Over/Under (Up-to three tenons, currently notsupported)
2. Airfoil Data
3. Root Data
a) Straddle Mount
b) Axial Entry
c) T-Root
d) Finger root
4. Disks Data

5. Mesh Control and Boundary Conditions

a) Cover Mesh control
b) Airfoil Mesh Control
c) T-Root Mesh Contact and boundary conditions
d) Disk Mesh Control and boundary conditions

Operating Conditions of LP turbine: The moving blade of low pressure turbine of a typical steamturbine is considered for the analysis. The operatingcondition of steam turbine blades are mentioned Table .1.

Steam turbine LP blade material and their properties used foranalysis are given below in the Table .1.

Model generation: In model generation the parameter like Number of blades,Speed and its unit are provided.

1. In our analysis the LP blade is unshrouded, hence "nocover‟ is selected Radii to the airfoil upstream (leadingedge) and downstream (trailing edge) tip locations aregiven.

2. For the blade of LP Turbine 66 points for each airfoilsections are defined and 14 number of airfoil sections aretaken.

3. The blade of LP Turbine that is to be modeled uses a Troot type of attachment.

4. Mapped meshing has been done for entire blade includingairfoil, T-Root and disk. The root land is constrained withall DOFs and the movement between root and disk.

Table.1: Operating Condition

Inlet temperature of the moving blade	45^{0}C
Inlet pressure of the stage	0.37bar.
Exit temperature	65^{0}C
Exit pressure of the stage	0.20 bar
Power developed by the moving blades	2885.68 KW
Blade Material	X20Cr13
Number of moving blade in the stage	50
Rated speed of the turbine	3000rpm

IV. RESULTANALYSIS

The following results are obtained from the above analysis:

Radial Stress: Radial stress is stress towards or away from the central axisof a component. Figure .1 shows radial stress distribution onlast stage of LP turbine blade. At most part of the blade theradial stresses are below 250 MPa (compressive). It is foundthat in 2-3 elements at root lug locations the peak stressvalues is around 1680 MPa.

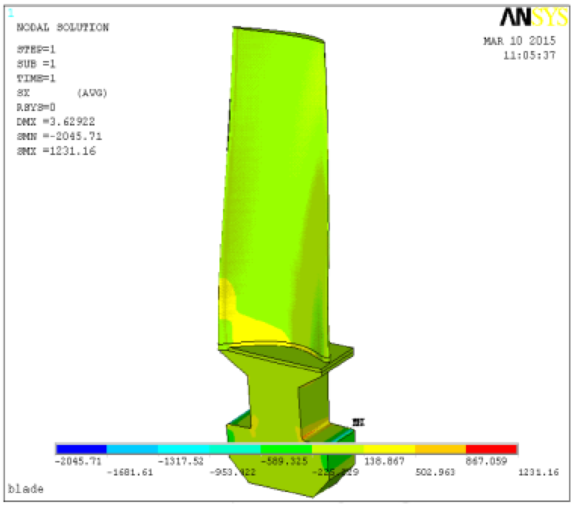
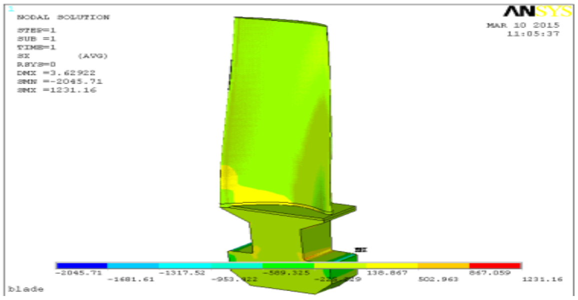


Figure 1: Radial stress distribution

Circumferential stress: A circumferential stress is a stress distribution with rotationalsymmetry i.e. which remains unchanged if the stressed objectis rotated about some fixed axis. Figure.2 showscircumferential stress distribution on last stage of LP turbineblade. At most part of the blade the radial stresses are below55 MPa (compressive). It is found that in 2-3 elements atroot lug locations the peak stress values is around 815 MPa.



Figuer2: Circumferential stress distribution

Axial stress: Figure.3 shows axial stress distribution on last stage of LPturbine blade. At most part of the blade the radial stresses arebelow 450 MPa (compressive). It is found that in 2-3elements at root lug locations the peak stress values is around900 MPa.

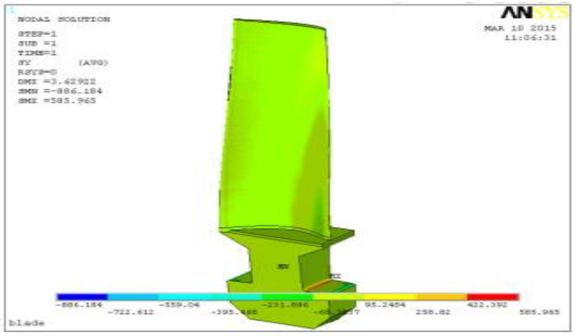


Figure 3: Axial stress

Figure 4shows max principal stress and Von-mises stress onlast stage of LP turbine blade.

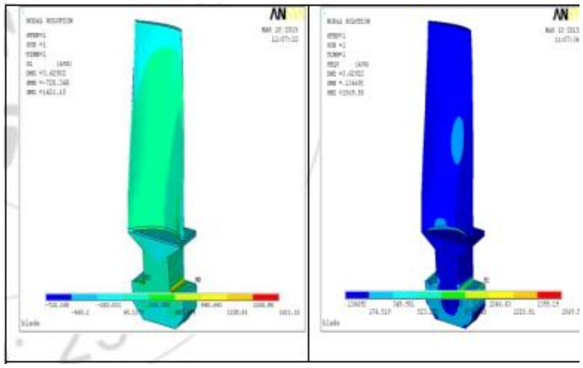


Figure 4: Max principal stress and Von-mises stressdistribution

To find out membrane stress and membrane + bending stressat some critical locations, stress categorization is carried outin ANSYS using path plot as follows.

1. A path is created at the root landing, where the peakstress gradient is high and Von-mises stress is analyzed.The path plot at the Root landing as shown in Figure.5.

Membrane stress = 351MPa ≤ 507MPa (2/3 of yield strength= (2*760)/3)

Maximum Membrane + Bending stress = 643MPa ≤ 760MPa(Yield strength)

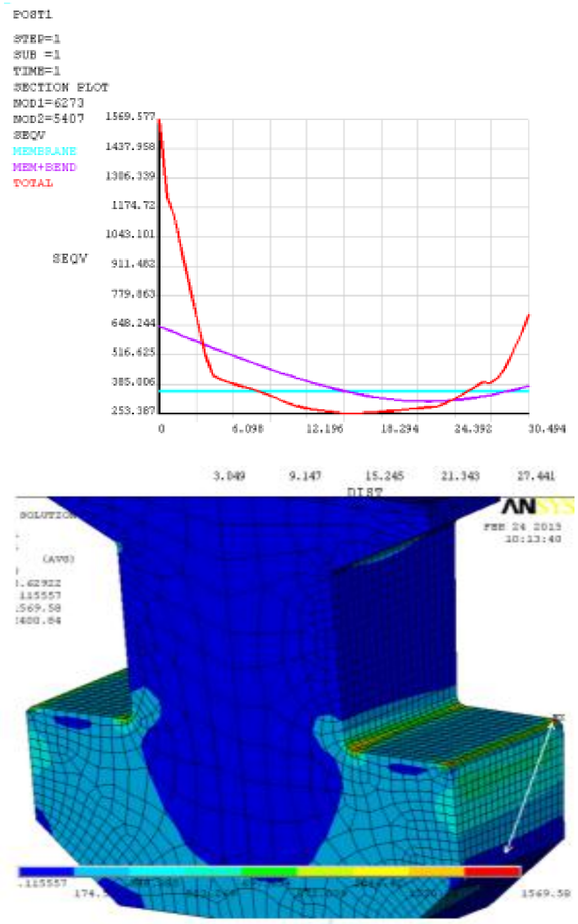
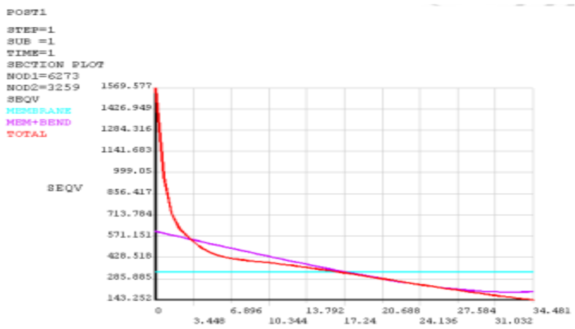


Figure 5: Stress categorization at room landing as shown byarrow

2. A path is created at the root landing, where the peakstress gradient is high and Von-mises stress is analyzed.The path plot at the Root landing as shown in Figure.6



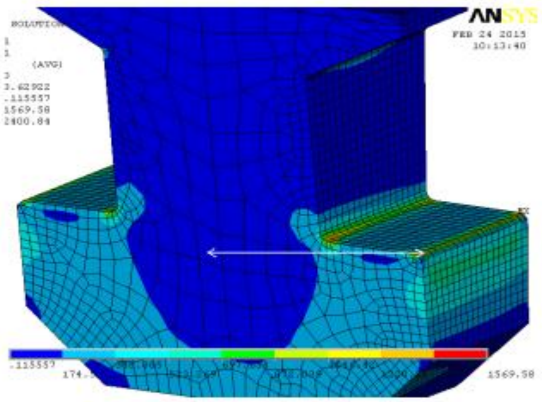


Figure 6: Stress categorization at room landing as shown byarrow

Membrane stress = 305MPa ≤ 507MPaMaximum Membrane + Bending stress = 601MPa ≤ 760MPaThe results obtained from the stress categorization path plotsat the root landing for both membrane stress & maximummembrane + bending stress were found to be within theallowable stress limits. Hence from the steady stress analysis,it is concluded that the blade under consideration is safe fromthe static stress point of view.

V. CONCLUSION

Finite element stress and modal analysis had beenachieved for the shifting blades of a low-stress steamturbine the usage of the customized software program, committed to the analysis ofsteam turbine blades. 3-D blades from the given profile data are generated through stacking 2D profile sections and attaching theroot the use of an easy to use GUI available within the customizedsoftware. And additionally, one region of the disk is modeled within thesoftware and assembly of blade and disk is made. The versionof the blade and disk meshes in the software program. Steady-statestrain analysis of the blade is finished by way of applying thecentrifugal and aerodynamic loading. Stress categorization atthe critical area of the blade root is accomplished to find outthe membrane and membrane + bending pressure at thoselocations. It is located that the stresses at the ones locations arelesser than the allowable stress and hence from the constantpressure analysis is it concluded that the blade underconsideration is secure from the static strain point of view.

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BIODATA:

Aamer Sohail currently working as Assistant Professor in the Department of Mechanical Engineering, Global Institute of Engineering and Technology, Moinabad with experience of 2 years. I have completed M.Tech(Machine Design) from Hi-Tech College of engineering (JNTU H affiliated) in the year 2015 and B.Tech(Mechanical Engineering) from Hi-Tech College of engineering (JNTU H affiliated) in year 2013.