TRANSIENT THERMAL ANALYSIS OF A STEAM TURBINE ROTOR

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ABSTRACT
In this study an effort has been made to estimate the effects of the transient thermal in the turbine rotor using Finite Element Analysis. A typical turbine rotor is considered for transient thermal analysis using the modeling software i.e. CAD software and ANSYS software.
The turbine rotor of a steam turbine is subjected to temperature variations in short periods of time due to the start and stop cycles of the turbine. This causes sudden changes in the temperature with transient thermal stresses being induced into the turbine rotor. The transient effects are due to the changes in the material properties like - Density, Specific heat and Youngs Modulus. The estimate of the thermal stresses induced in the turbine rotor due to change in temperature is important .
The rotor material is 30Cr and the properties of the material are updated to the model. The appropriate boundary conditions depicting the actual environment in which the turbine rotor works in steam turbine are also updated. The thermal stresses due to large temperature gradients are higher than the steady state stresses. The large thermal stresses occur before reaching the steady state value.
Keywords: Turbine, rotor, stresses, transient state stress.

INTRODUCTION
When we consider many start and stop cycles, then the Transient thermal analysis is the thermal analysis wherein boundary conditions and properties change with time. This is to say that the constraints such as ambient temperature, thermal coefficient and material properties etc. are time dependent. Transient thermal analysis is important in analyzing models that are subjected to boundary conditions and material properties that vary with time and temperature. Turbine rotors used in steam turbines are subjected to high temperature rise as they are subjected to large temperature variation, the material properties such as Specific heat, Enthalpy and Young's modulus undergo variation with time. In such conditions there is the probability of failure of the turbine rotor if the turbine rotor is not designed taking into consideration the transient effects. There are many finite element analysis, packages available for conducting the transient thermal analysis. We used the packages for modeling PRO-E, and for analysis we used ANSYS 11.
From an analysis using these packages, temperature distribution and instantaneous thermal stresses induced under transient conditions can be estimated. These packages allow the designer to vary the temperature with time, vary the convective thermal coefficients with time .
A typical turbine rotor has been analyzed for transient thermal using ANSYS 11. One degree section of a model of the turbine rotor, is considered for the analysis. From the analysis the temperature distribution is obtained. Although the analysis is straight forward using these package, the boundary conditions need to be applied judiciously in order to realistically model the actual situation. Moreover the choice of number of elements for modeling, time interval for calculation, type of elements and the locations at which boundary conditions are updated are essential for the accurate estimation of transient temperature and stress distribution.

MODEL OF THE ROTOR
The Rotor with Blade is modeled using a CAD package PRO-E. Since the disk is an axis symmetric body only a one degree model of the turbine rotor is modeled.

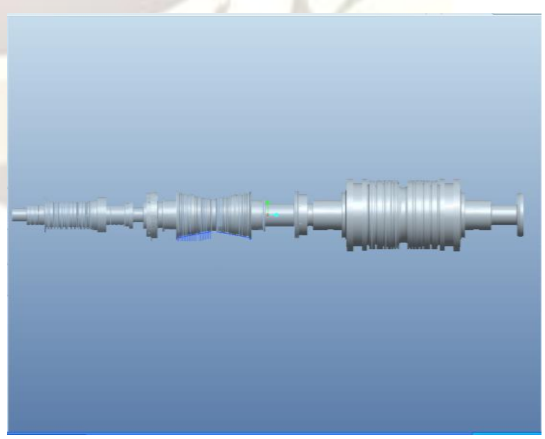


Figure 1: Modeled Rotor

Turbine disk is cut along a curved path. The camber line of the hub profile is offset on either side of the perpendicular blade by half the pitch distance. Then the turbine disk was cut by a wired plane consisting of camber line and of the disk as two edges of the plane.

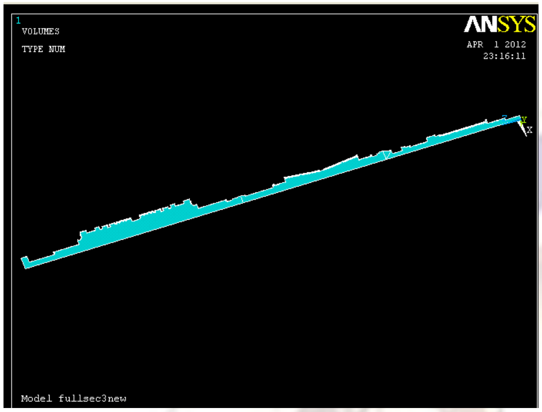


Figure 2: One degree model of the rotor

The figure 2 shows the one degree model of the Rotor without Blade. The model from PRO-E 5.0 is translated to IGES format using the Initial Graphics Exchange Specification (IGES) translator. This IGES formatted model was transferred to Display preprocessor for discritization.

DISCRITIZATION OF THE MODEL

The IGES format of the model is read in ANSYS 11. In ANSYS the IGES format is converted into a database file. The model is then discritized using Tetrahedral elements. The figure 3 shows the meshed model of the rotor

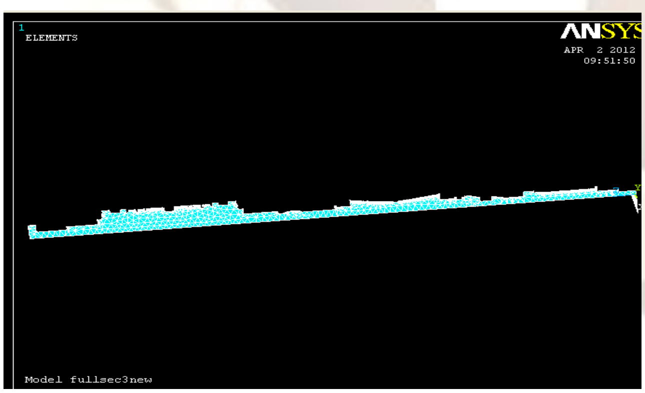


Figure 3: One Degree Meshed Model for FEA

The type of elements selected supports steady state and transient thermal analysis, Orthotropic material properties, Temperature dependent material properties, Nonlinear radiation and convection boundary conditions with temperature dependent emissivity and film coefficients, Time dependent heat transfer coefficient, Time dependent ambient temperature and Phase change. There are 33756 elements selected in the model.

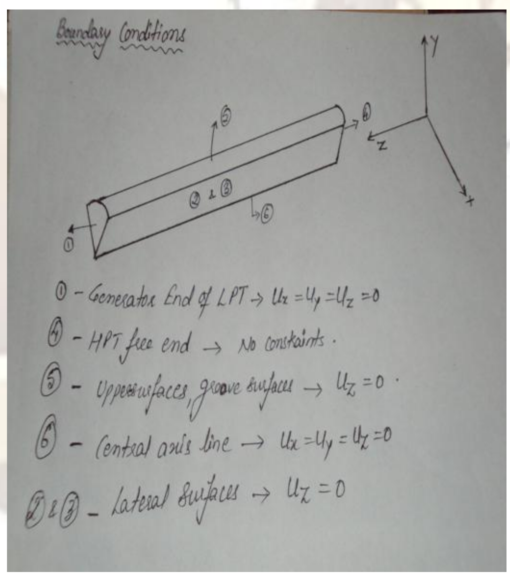
MATERIAL USED

Material properties used on the model serve as a basic link between the finite element entities and the actual - property values. For thermal analysis the material properties that are required are Density, .Thermal Conductivity, Specific Heat (Ref 10, 15). The material of the Rotor is considered as a 30Cr which has the following material properties at room temperature.

Young's Modulus 1.4-4x109 N/ml.
Density 8220 Kg/m3.
Poisson's Ratio 0.3
Thermal conductivity 12.30 W/m K.
Specific Heat 461.0 KJ/Kg K.
These material properties were used on the One degree model of the rotor without blades.

BOUNDARY CONDITIONS

The Boundary conditions are the critical factors for the correctness of calculation. Boundary conditions are the conditions updated on the model to simulate the environment in which the turbine rotor operates. The following are the different Boundary conditions to be applied for the
transient thermal analysis. _



Start-up Curves:-

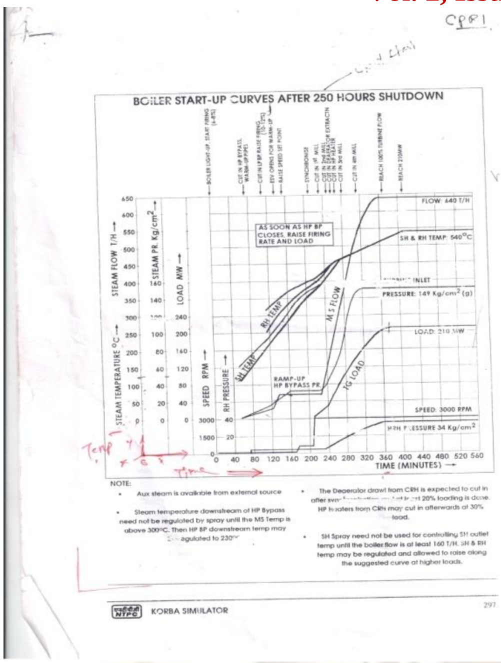


Figure 4: Cold Start-up Curve

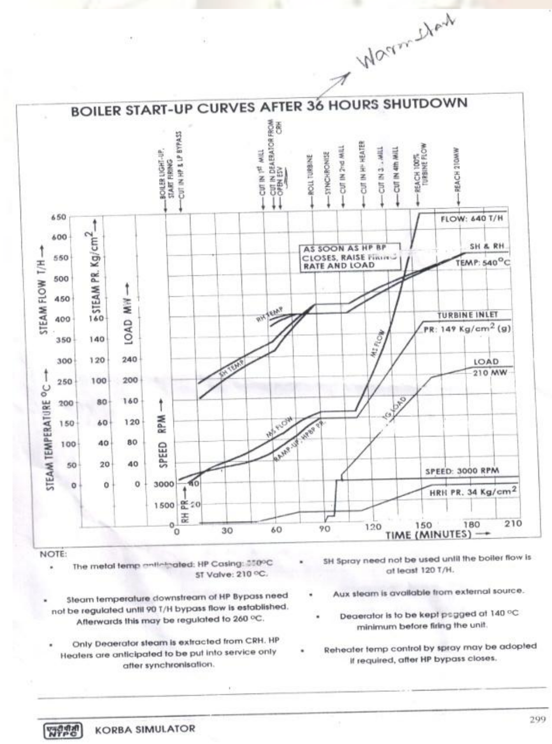


Figure 5: Warm Start-up Curve

From the graph it is observed that the initial temperature 100^0C and it varies up to 540^0C.

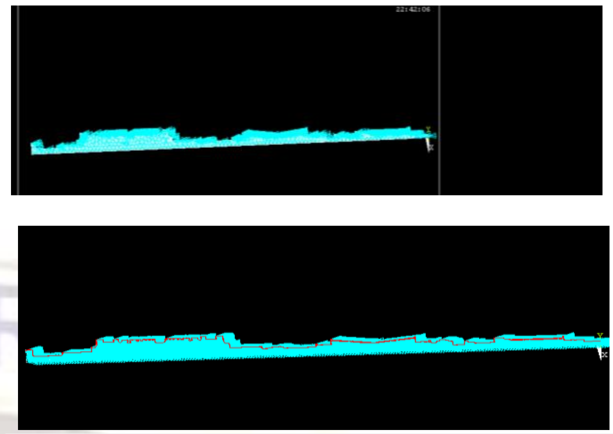


Figure 6: Thermal loads convective

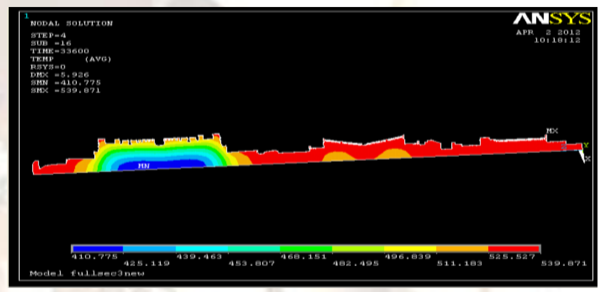


Figure7: Temperature distribution at 560 min

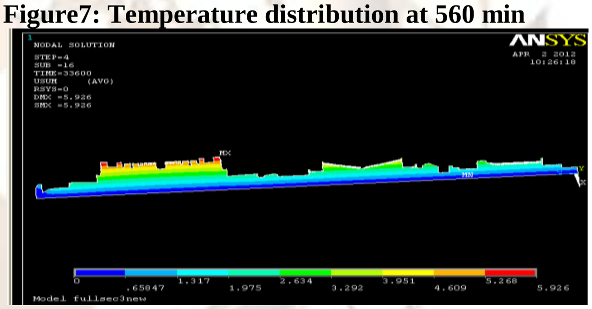


Figure 8: Displacement Vector sum at 560 min

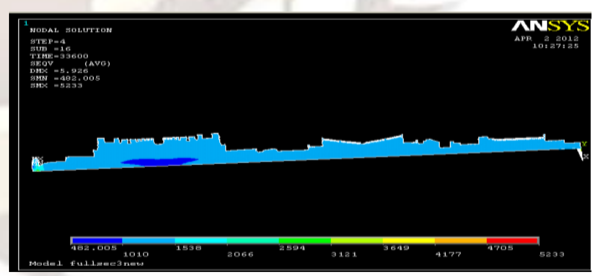


Figure 9: Von mises stress distribution at 560 min

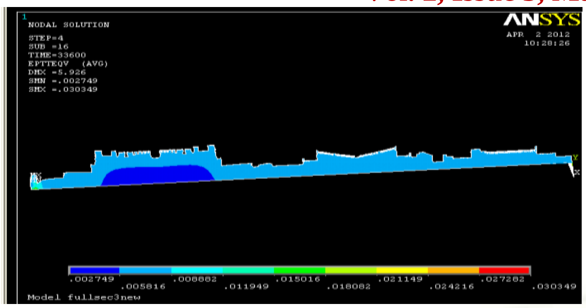


Figure 10: Von mises strain distribution at 560 min.

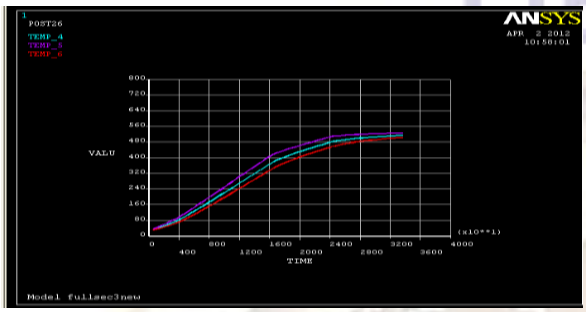


Figure 11: Temperature distribution at different nodes

Phase Change

During the above operation temperatures of upto 540 degrees are reached and this may cause a phase change. But in this analysis Phase change is not considered.

ANALYSIS OF DATA

These data are required for the purpose of specifying the parameters like time step size, total time of the analysis etc., for analyzing the model. The following are the data.

Heat Control Data :-

This data is important for steady and transient thermal analysis as it defines the control parameters for iterations, tolerances, convergence etc. of the solution. For the Rotor and blade the following iteration and tolerance values have been assumed. Maximum No of iterations - 10

Time Integration Data

This data defines the time _ integration control parameters needed for the analysis. It
defines the type of integration scheme, the initial time step, maximum time for the analysis, time step size. The initial time step is taken as zero seconds. Total number of time steps are 56. The maximum time of analysis is 10 min. and the time step size 600 seconds.

Temperature History Data

This data is used to specify the nodes for which temperature history plots are desired. By specifying the nodes we can get an output that will be a graph of temperature Vs time. In-,the example the nodes along the tip of the blade, the midsection and the hub were considered. For the disk the nodes at the hub and rim of the disk were considered.

RESULTS

Transient thermal analysis is carried out for the Rotor under the following conditions:

Rotating shaft are considered to be isothermal. Shaft material is completely elastic at stress distribution induced by mechanical forces and thermal loads. Stress is proportional to strain. The initial temperature is at 100° C. The ambient temperature around the blade alone rises from 100° C to 540^0 C in 560 seconds and then remains at540° C.

CONCLUSION

The transient thermal analysis is carried out. The initial temperature of the rotor is at 100^0C. The ambient temperature for the blade rises from 100^0C to 540^0C in 560 seconds and then remains at 540^0C.

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