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"THERMAL STRESS ANALYSIS IN STEAM TURBINE ROTOR - A REVIEW"

Ms. Mohini R. Kolhe[1], Prof. A. D. Pachchhao[2],
Prof. H.G.Nagpure[3].

[1] M. Tech Student (CAD/CAM), Mechanical, St. Vincent Pallotti college of Engineering and Technology/ Nagpur University, India)
[2]Prof. & Head ,Mechanical Engineering, St. Vincent Pallotti college of Engineering and Technology/ Nagpur University, India
[3]Prof. Mechanical Engineering, St. Vincent Pallotti college of Engineering and Technology/ Nagpur University, India

ABSTRACT: *The present paper is a review of the past work done in the field of steady state and transient thermal analysis of steam turbine rotor using finite element method. The analysis of transient thermal stress values that are produced while the turbine is running are the key factors of study while designing the next generation turbines. The temperature gradients that can be established in the transient state are generally higher than those that occur in the steady-state and hence thermal shock is important factor to be considered relative to ordinary thermal stress. The rotor of 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 estimate of thermal stresses induced in the turbine rotor is important in determining the start up cycle of a steam turbine. The transient effect is due to the changes in the material properties like Density, Specific heat and Young's Modulus.*

Keywords: *Transient thermal Stresses, FEM, Turbine rotor, start up cycles, Ansys.*

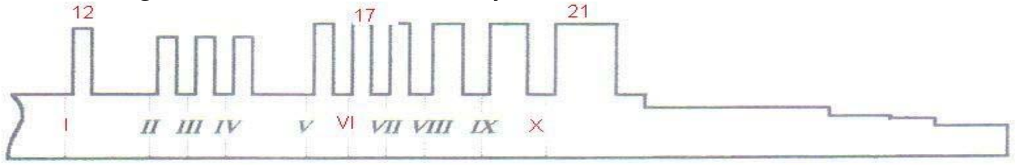
I.INTRODUCTION

Turbine rotors used in power plants are subjected to high temperature especially during start up cycle. The rotor of 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 effect is due to the changes in the material properties like Density, Specific heat and Young's Modulus. The estimate of thermal stresses induced in the turbine rotor is important in determining the start up cycle of a steam turbine.

Thermal gradients developed during thermal transients are the key source of stress generation in the rotor. Under such conditions there is the probability of failure of turbine rotor if the turbine rotor is not designed taking into consideration the transient effect. There are many Finite element packages available for conducting the transient thermal analysis. Some of the packages are NASTRAN , ABAQUS , ANSYS , NISA , PRO-MECHANICA etc. These packages allow the designer to vary the ambient temperature with time, vary the convective heat transfer coefficients and heat flux with time/temperature, and also allow heat generation to be applied. A significant amount of design effort invested to determine the optimal process Parameters for start-up (e.g. steam temperatures, run-up and loading gradients), in order to achieve the fastest possible starts without exceeding allowable material stress limits.

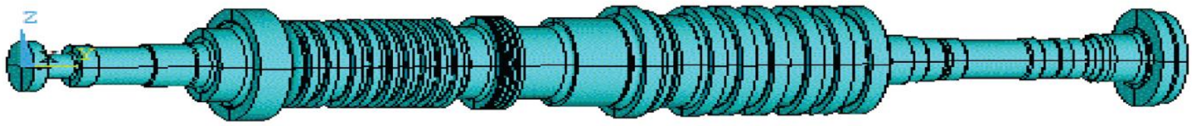
II. REVIEW OF PAST WORK CARRIED OUT ON STRESS ANALYSIS

[1] Zvonimir Guzoviæ et.al. In this paper authors suggested the algorithm and the results of non-stationary thermal stresses modeling in steam turbine rotor by means of the user's software package. Non-stationary thermal stresses are stipulated by pressure change on turbine exit. As in the low-pressure part of the rotor the high gradients of thermal andmechanical quantities (temperature, heat flux, deformation, stresses) are determined, so this region ofsteam turbine rotor is analysed in detail.



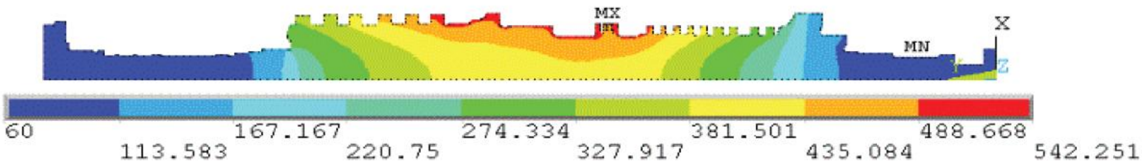
Cross-section of 30 MW power steam turbine

[2]Chunlin Zhang et.*al.* This paper used a 600MW supercritical steam turbine's rotor as the research object, and analyzed the variation of thermal stress in the warm starting up process. In this paper the analysis based on the operating data measured from actual operation and calculate the variations of the temperature field and stress field during the process of warm starting-up with the method of thermal-structure direct interaction analysis by Ansys. By analyzing the results, it proves that the maximum stress of the rotor is in the first stage of the intermediate pressure casing.

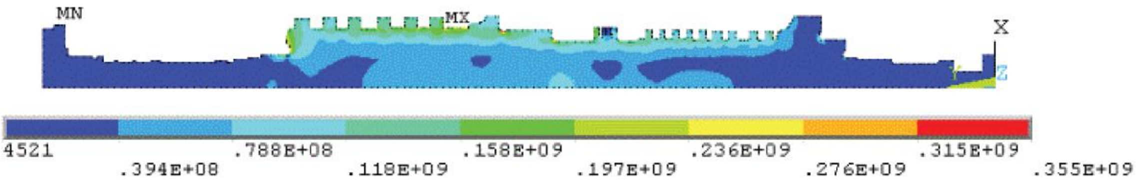


3D Modeling

2D Meshing Model



Temperature variation after 12000 secs



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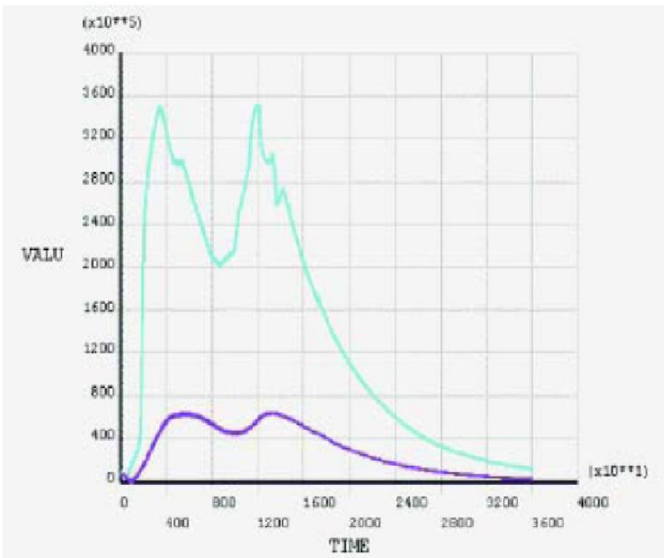
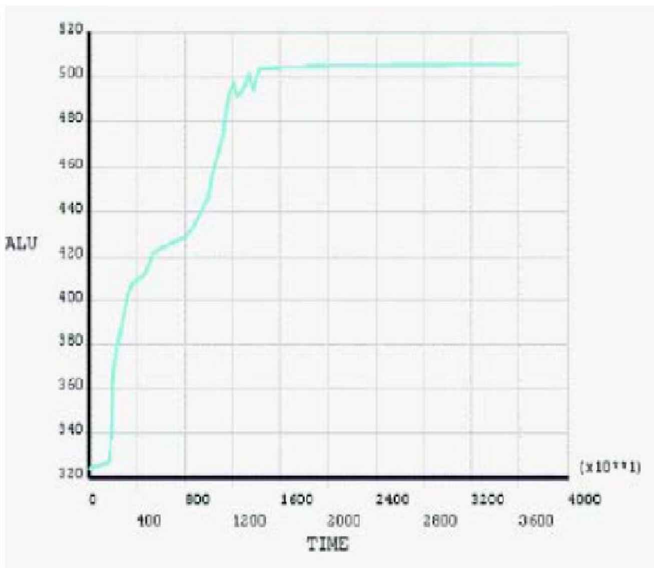
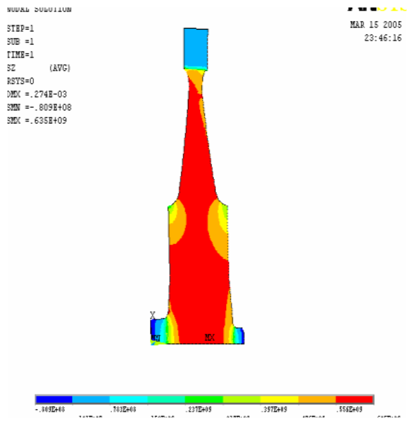


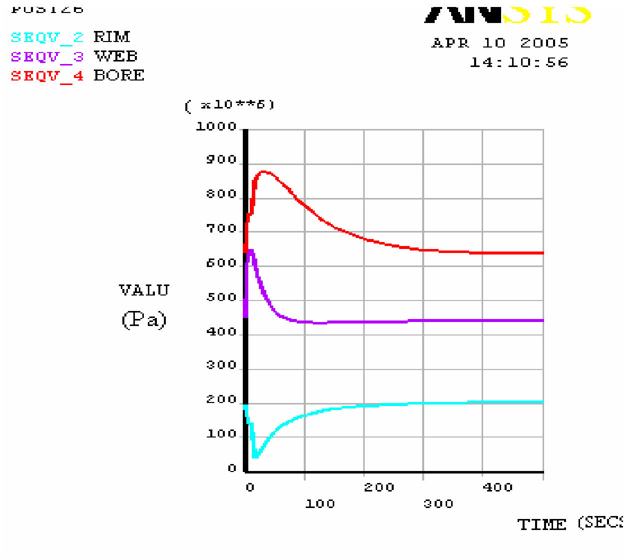


Stress variation with respect to time Temperature variation with respect to time

[3]Sukhvinder Kaur Bhatti,Shyamala Kumari,M.L.Neelappu,C.Kedarinath,Dr.I N Niranjan Kumar (3)-Their paper has primarily focused on the Transient heat transfer characteristics, centrifugal and the thermal stresses arising in the disk. Interesting results obtained in terms of maximum operational radial stress, maximum

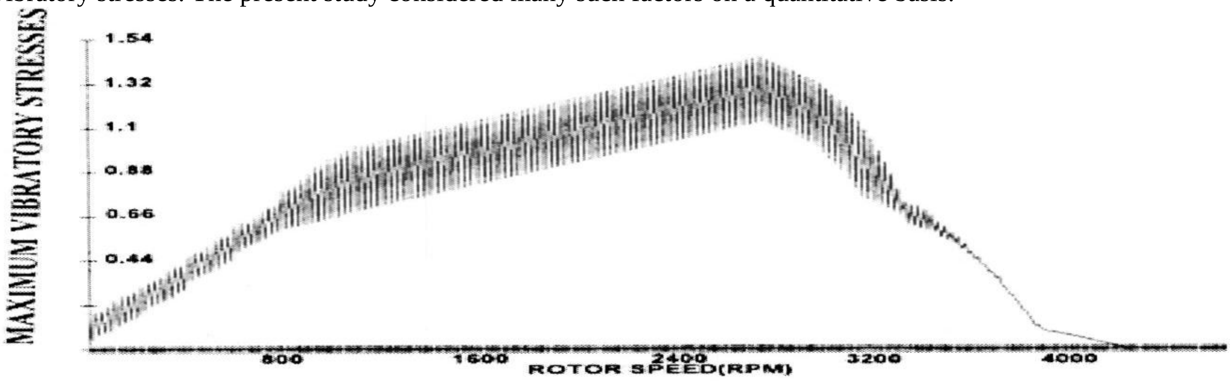
operational hoop stress, maximum operational Vonmises stress, the temperature field etc. So the disk isexpected to perform well in spite of all the stringent operating conditions. The object is to provide understanding and information for designers to improve the life and efficiency of future generations of engines. The finite element model used in this analysis. The analysis is run assuming a uniform initial metal temperature of 30 deg C. The heat transfer coefficients are applied on the model along with the gas bulk temperatures. The initial time step size for transient analysis is quite important from the accuracy and the convergence standpoint.





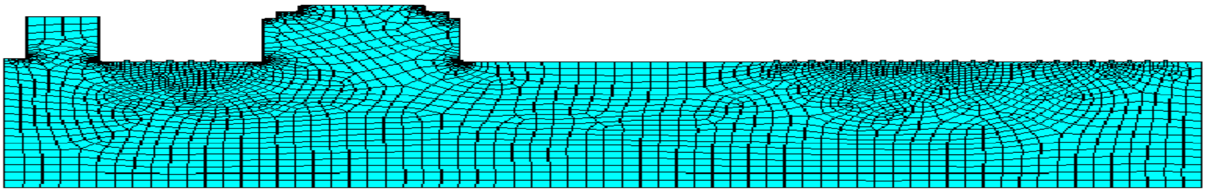
Structural Analysis Vonmises Stress Distribution (Pa). Vonmises stress variation in differentParts of the disk with time

[4]Deepak Dhar, A.M.Sharan [4]. This paper is concerned with life estimation of a turbine blade taking into account the combined effects of centrifugal stresses, vibratory stresses and thermal stresses. The stresses are determined by accounting for the rotor acceleration. The blades are subjected to aerodynamic excitation force obtained from thin cambered aerofoil theory under incompressible flow. One of the important factors was the effect of temperature on the fatigue life. Studies of the past had not quantitatively calculated the temperatures in the blade in the determination of the fatigue life. The same applies to the aerodynamic flows which create vibratory stresses. The present study considered many such factors on a quantitative basis.

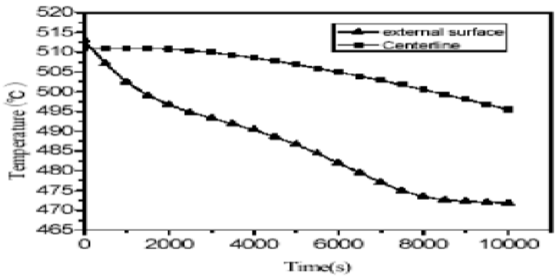


Vibratory stresses at various rotor speeds

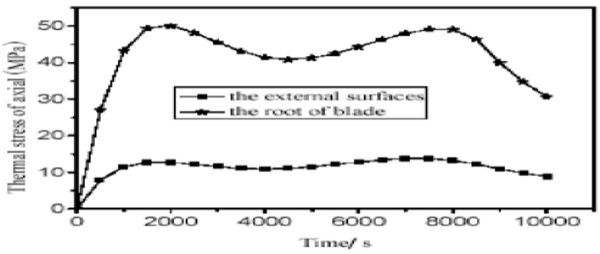
[5]Yong Li et.al. In this paper thermal stresses in 600MW steam turbine in different governing modes is discussed. The computational object is intercepted from hp-ip rotor of the 600MW steam turbine in this paper. The distribution of the temperature and thermal stress in the governing stage and the first stage of high pressure cylinder is calculated two-dimensionally. The changes of the temperature and stress in different governing modes are analyzed. The result of calculation provides a reliable basis for on-line monitoring of the rotor thermal stress.



Meshed 2D Geometry

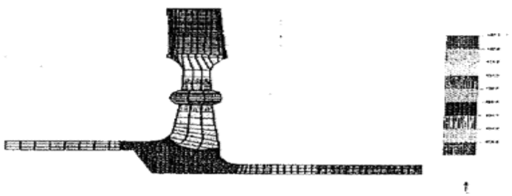


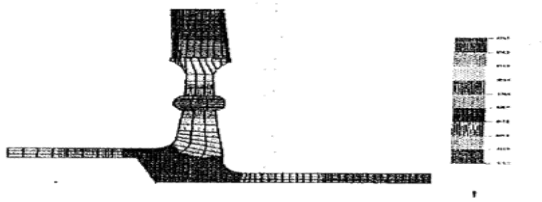
Temperature variation over time



Stress variation over time

[6] Sudheendra V.S et.al. .The Paper estimates the effects of the transient thermal stresses in the turbine rotor using Finite Element Analysis. A typical turbine rotor in the form of bladed disc called Blisk is considered for Transient Thermal Analysis using the Numerically Integrated Structural Analysis(NISA) package. The Blisk material is considered as MAR M 247 and the properties of the material is updated to the model.





Temperature Distribution after 1 Sec. Temperature Distribution after 20 Secs.

[7] Stuart R Holdsworth , Edoardo Mazza & Arnd Jung et.al. The paper estimate tests were conducted on two heats of the rotor steel using service-like cycles without and with hold times at peak temperature. The temperature and mechanical strain control profiles of the cycles were devised to represent conditions which could occur at critical locations in a high temperature steam turbine rotor during operation, both with respect to shape and transient-rate.

III.CONCLUSION

The transient thermal stresses are larger than the steady state thermal stresses and these occurs before the steady state is reached. Thus estimation of these transient thermal stresses occurring due to presence of larger temperature gradients during start up cycles plays an important role in designing the turbine rotor and the start up cycle.

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