INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211

EFFECT OF THERMAL SHOCK AND THERMAL LOAD FOR STEAM TURBINE BLADE FOR STUDYING ENDURANCE AND CREEP USING FINITE ELEMENT ANALYSIS- A Past Review

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Abstract:

The present paper is a review of the past work done in the field of thermal fatigue analysis to study creep and analysis in a steam turbine blade using Finite Element analysis. The steam turbines operating at high temperatures are subjected transient temperatures during start up and shutdown operation which gives rise to thermal stresses. Repetition of these thermal transients can result in thermal fatigue of the component. An example of thermal fatigue is thermal shock , where sudden temperature changes occur at the internal or external surface of a component leading to cracking. The differential expansion between surface and bulk material caused by repeated thermal shocks can induce fatigue or cyclic creep damage and endurance. 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. Transients temperatures and stresses in the rotor during start _up and shut down cycles are evaluated using finite element analysis.

Keywords: Steam Turbine ,Thermal Shock , Thermal Load, Creep , Endurance, FEA

Introduction:

Components operating at high temperature are subjected to heating and cooling transients during startup and shutdown and to regime changes during operation. Thermal stresses arise when thermal strain, which can be either expansive or contractive, is totally or partly constrained. Repetition of these thermal transients can result in thermal fatigue (TF) of the component. An example of TF is thermal shock (TS), where sudden temperature changes occur at the internal or external surface of a component leading to cracking. It is important to keep in mind that the rate of change in temperature influences the damage inflicted on the component. In many engineering applications, thermal stresses are superimposed on primary stresses, which arise from pressures, mechanical end loads (including centrifugal loading in rotating components), and constraint . Severe temperature changes in the presence or absence of mechanical loading may induce plastics deformation in surface layers, which in turn can result in initiation of cracks in 5 x lo4 or less cycles. Thermal and thermal-mechanical fatigue (TMF) is therefore mostly an isothermal low-cycle fatigue (LCF) process. Thermal (stress) fatigue, alternatively, corresponds to the case where constraint is internal, as encountered mostly in components. These internal constraints are typically found in components of high-temperature machinery, which are subjected to rapid heating and cooling,

Review Of Past Work Carried Out On Thermal Mechanical Fatique Analysis:

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In this paper the author shows the influence of different ways of operations on the turbine component strength stating lifetime and some safety aspects. The analyses are carried out by means of the FEM using the real measurements. This resulted in the size of the components' stress level and, consequently, in fatigue. In this paper the author points out to what extent the speed of start-up influences the stress state and durability of the steam turbine components. The analyses were done for the IP rotor of the large power turbine. The component shows some discontinuities (flaws), resulting from fatigue processes or faulty manufacturing, This problem is described in the following sections and also some conclusions are drawn. To evaluate the low cycle fatigue a fatigue curve is used . It defines the dependency between the stress strain curve and number of cycles. In this paper the author decided to use the fatigue curve. For each analyses start-ups the strain amplitudes were evaluated and then the fatigue was calculated by means of the rain flow method.

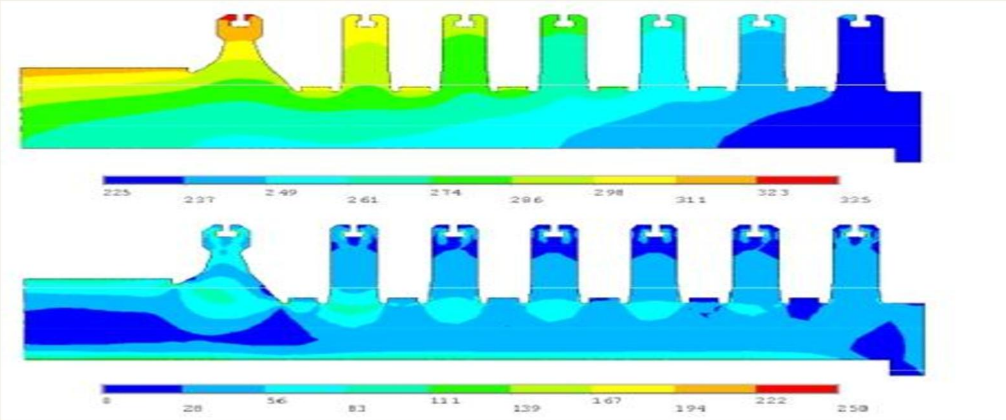
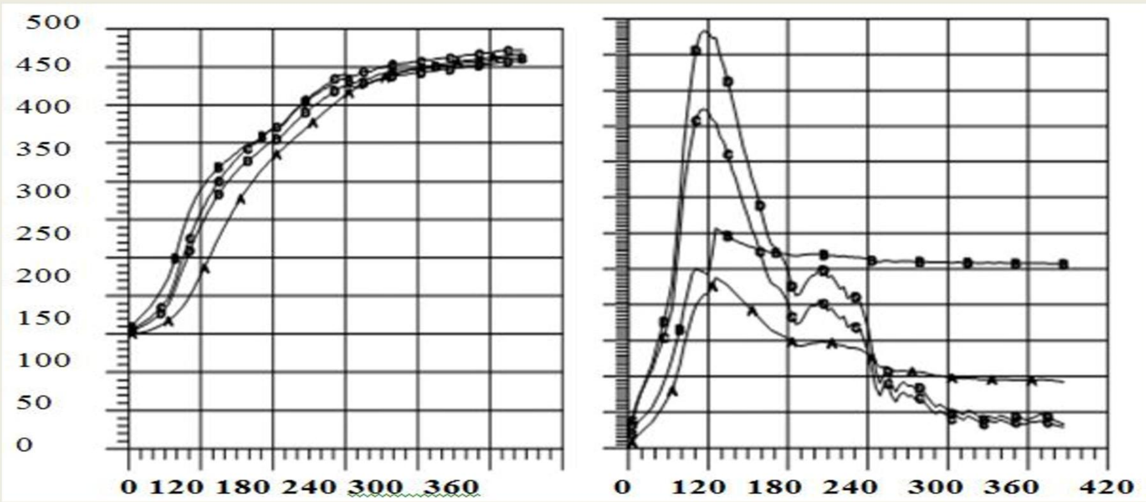


Figure1. Temperature (upper) and Stress (lower) distribution within IP rotor



Graph1. IP Temperature (Left) and Equivalent Stress (Right)distribution during start _up

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In this paper the transient temperatures and stresses in the rotor during start-up and shut down cycles were evaluated using finite element analysis. Predictions from linear damage summation are compared with the results of nondestructive study of an actual steam turbine rotor. In FEA for transient temperature distribution, rotor can be considered as solid at the blade grooves. However, for thermal stress analysis, details of the blade grooves are to be considered. Constitutive models suitable for cyclic loading like isotropic hardening and kinematic hardening are considered while evaluating the material stress-strain response. The duration to reach steady state after every thermal transient has been taken into account while computing. Variations as well as significance of circumferential component of stress are found to be more prominent as compared to that of radial component of stress. One startup-shut down cycle takes total time of approx. 1.8 * 10^5 sec. Damage accumulation due to creep is calculated by the relation

$t_r = \{\sigma_{eq}/478.8\}^{-8.569}$.Total damage in the span of approximately 5 years is obtained as 1.74.

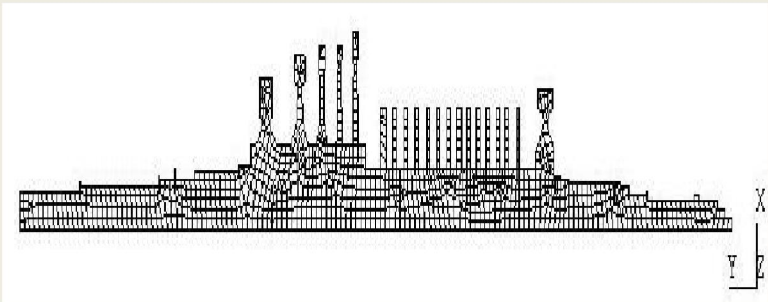
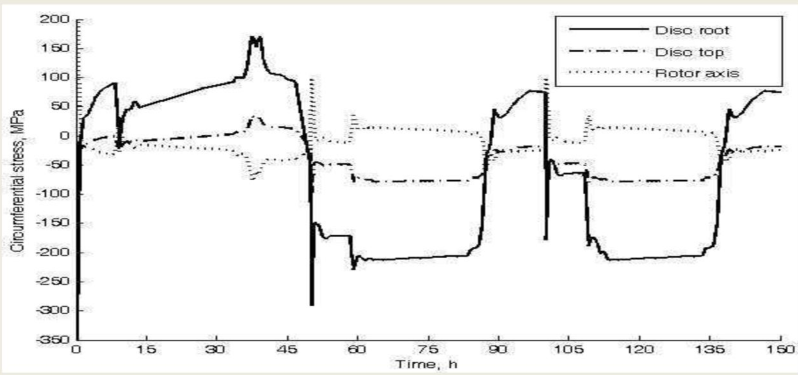


Figure2. Finite element model of rotor geometry



Graph2. Variation of radial component of stress

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This paper deals with the fatigue analysis of a low pressure blade that is used for the last stages of large steam turbines. The FE analysis was performed using the Finite element computational software ANSYS 11.0 to determine the stress and strain components at the critical location of the blade .Repetitive plastic deformation is the main cause of low cycle fatigue failure. Local Plastic Stress and Strain Analysis (LPSA) approach was selected for fatigue assessment. Number of startups to crack initiation is determined using uni-axial damage parameters and linear Palmgren-Miner approach of damage cumulating. The fatigue life equation for this method is based on the Manson-Coffin curve. Number of cycles to crack initiation N_i can be determined using equation

$$P_L = \varepsilon_a = \frac{\sigma'_f - \sigma_m}{E}(2N_i)^b + \varepsilon'_f(2N_i)^c.$$

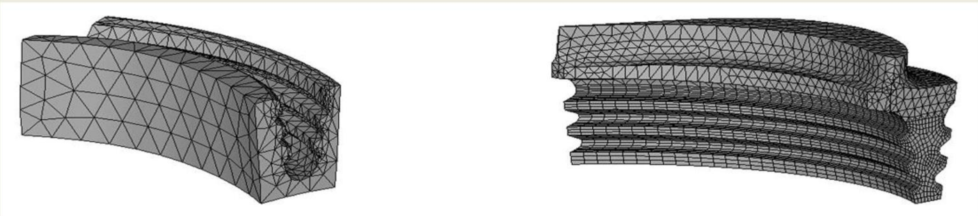
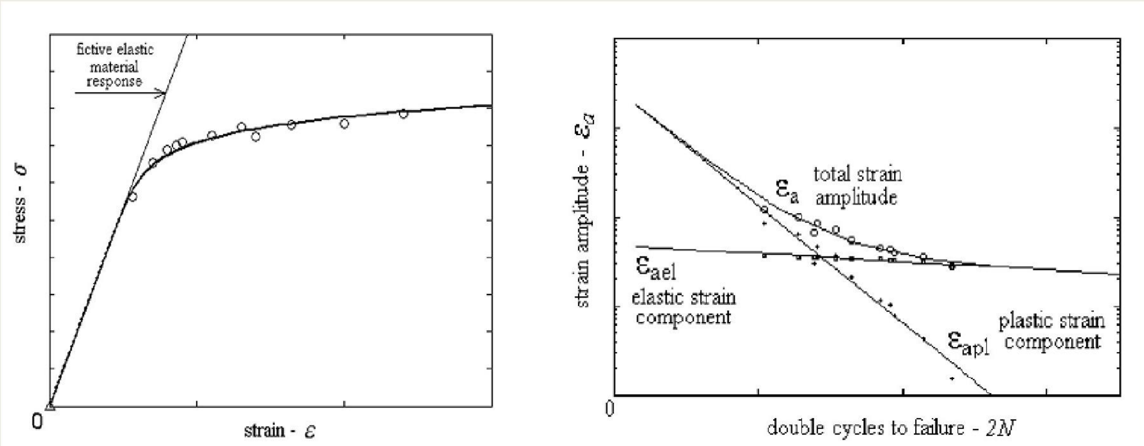


Figure3. Detailed depiction of the Finite element mesh at the critical location



Graph3. Cyclic deformation curve (left); Manson-*Coffin curve (right).*

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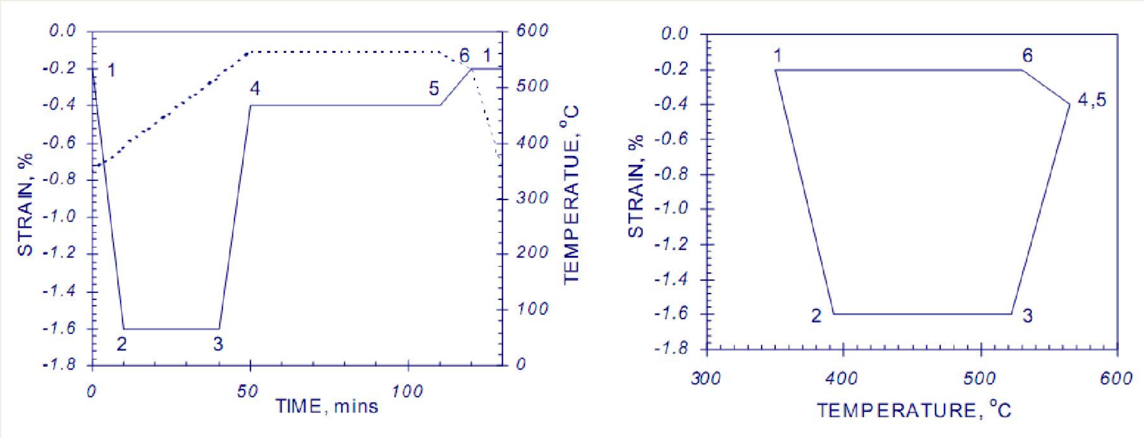
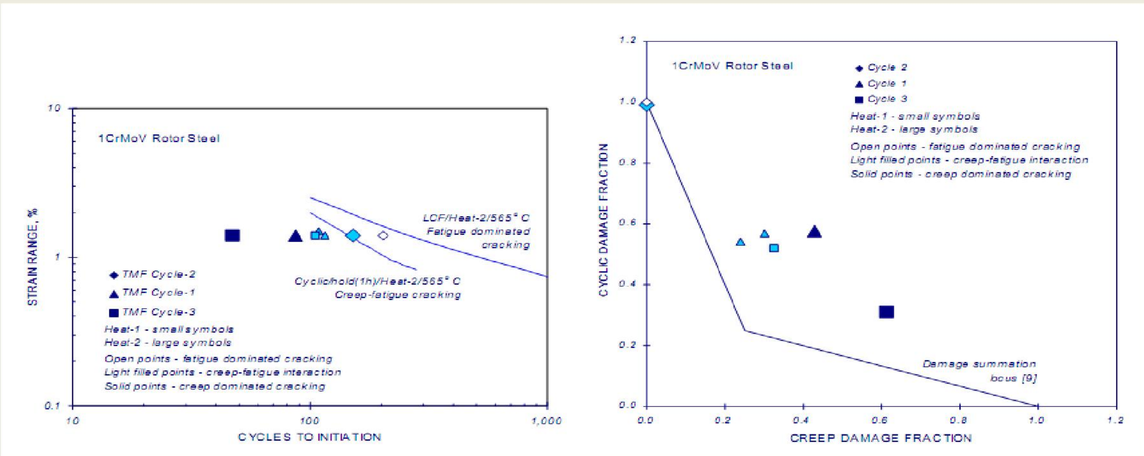
In this paper service-cycle thermo-mechanical fatigue (TMF) tests have been performed on a 1CrMoV steam turbine rotor steel were conducted on two heats of the rotor steel using service-like cycles without and with hold times at peak temperature Three service-cycle types were applied, with the same cycle shape. In each case the mechanical strain range was 1.4% and the temperature varied between 350 and 565°C. For a nominal mechanical strain range, the observed necking leads to a significant reduction in the Heat-2 endurances in Cycle-1 and in particular Cycle-3 TMF tests relative to those observed in equivalent isothermal tests at the maximum test temperature.



Graph4 .Service-like thermo-mechanical fatigue cycles (NB: the times given are those for Cycle-1)

POSITION IN CYCLE	TEMP °C	STRAIN %	CYCLE-1 min	CYCLE-2 min	CYCLE-3 min
1	350	-0.2	0	0	0
2	393	-1.6	10	5 [1]	5 [1]
3	522	-1.6	40	10 [2]	10 [2]
4	565	-0.4	50	15	15
5	565	-0.4	110	15	185
6	530	-0.2	120	20	190
1	350	-0.2	130	30	200

[1] 421°C, [2] 493°C



Graph5. Necking at centre of gauge length of service-cycle TMF test piece and Graph6. Variation of area reduction with endurance fraction and cycle type.

Conclusion

In this paper we have proposed thermal mechanical fatigue analysis from a variety of aspects, such as references, features, analytical treatment and technologies. Moreover we have illustrated several representative platforms for the scope of this analysis in future applications. In FEM the theoretically calculated results are compared with the measured ones (result validation) and found a good conformity. The result obtained is promising and has the potential as an alternative processing Method for thermal mechanical fatigue analysis for different mechanical components. This study has primarily focused on thermal fatigue analysis to study creep and endurance. From the results obtained it is noticed that the effects of various operating conditions has to be taken into consideration to know the causes of failure

Future Work

Our review suggests that in forthcoming efforts, analysis of stresses in turbine rotors could be best possible with Finite Element Method with ANSYS or ABAQUS as one of the helping software. In future we explore the creep and fatigue analysis of steam turbine blade especially due to thermal shock thermal stress which is the cause of concern of various applied industries. Our future work is to propose a better analysis technique using FEM with ANSYS for analysis of Thermo-Mechanical fatigue in turbine rotor.

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