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PII: S0142-1123(18)30080-X
DOI: https://doi.org/10.1016/j.ijfatigue.2018.02.032
Reference: JIJF 4597

To appear in: *International Journal of Fatigue*

Received Date: 23 December 2017
Revised Date: 19 February 2018
Accepted Date: 25 February 2018

THE LOW-CYCLE FATIGE LIFE PREDICTION METHOD FOR ONLINE MONITORING OF STEAM TURBINE ROTORS

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The paper presents a simple method for the low-cycle fatigue life monitoring of steam turbine rotors. The method makes use of the equivalent strain energy density rule of notch stress-strain analysis proposed by Molski and Glinka. The method is applied to low-cycle fatigue analyses of steam turbine rotors operating at non-isothermal conditions. A strain energy correction factor is introduced to include the distortion strain energy density. Assessment of the proposed method was done by comparing their predictions with the strain amplitudes obtained from the finite element analysis employing elasitc-plastic material model. The inclusion of energy correction factor obtained from the elastic-plastic finite element analysis significantly improves the accuracy of strain amplitudes and fatigue life predictions. The strain calculation algorithm is based on an analytical solution of the equivalent strain energy equation what makes it very useful for real time fatigue calculations.

Keywords: notch stress-strain, low-cycle fatigue, turbine rotors

1. Introduction

Steam turbine rotors are the most critical components of power plant units and experience failures due to various damage mechanisms [1]. High-temperature rotors can fail due to cracking under creep and/or fatigue conditions and numerous examples of cracks due to these mechanisms have been reported over the past decades. In all these cases, high cyclic stresses and high temperature were involved in crack initiation leading to rotor failure.

Low-cycle fatigue cracking of turbine rotors is mainly related to transient thermal stresses occurring during turbine start-ups and shutdowns [2]. High thermal and mechanical loads generate stresses exceeding the material yield stress at stress concentration areas, and their repetitive occurrence may lead to fatigue crack initiation after 1000 cycles or less.

Steam turbines are more and more frequently operated in cyclic duty due to the increased share of renewable energies in power generation [3]. The cyclic operation under variable thermal loading generates high thermal stresses which bring about fatigue damage and cracking at notches. In order to monitor and control the fatigue damage in real time, fast, accurate and robust methods should be used in online monitoring systems.

The first step of fatigue life determination under stress concentration should include the definition of local stresses and elastic-plastic strains in the notch root [4]. Non-linear finite element modelling can be used to accurately predict the stress-temperature histories and cyclic strain evolution. However, this approach becomes impractical when long stress histories are to be analyzed or real time calculations performed, and consequently, analytical stress-strain correction methods have to be considered [5-9].

The most widely used methods for elasto-plastic strain and stress analysis are the Neuber