Fatigue Life and Damage Evolution of Martensitic Steels for Low-Pressure Steam Turbine Blades in the VHCF Regime

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Motivation

- Last-stage blades of a low-pressure steam turbine for power plant applications
  - Rotational speed: 50 Hz
  - Last-stage blade length: ~1.5 m
- High-frequency bending and torsion vibrations (f > 1 kHz) due to the asymmetric flow of steam
- Extremely high superimposed mean stresses due to the centrifugal forces
- Almost 50% of the failures are related to material fatigue, stress corrosion cracking and corrosion fatigue [N. K. Mukhopadhyay et al., Engineering Failure Analysis 5, 181 (1998)]

Objectives

- Mechanism-oriented description of the damage evolution of cyclically loaded martensitic steel above 10^8 cycles
- Contribution to a model describing the influence of mean stress on the behaviour of a technical relevant class of materials in very high-cycle fatigue

Results

- At lifetimes of about 10^8 cycles or more, subsurface fish-eye cracks can be detected initiated at CaO-Al2O3 and MgO-Al2O3 inclusions with diameters of approximately 20 µm
- At lower number of cycles to failure, crack initiation occurred at persistent slip bands with clearly visible stadium I and stadium II crack growth
- No significant frequency effect could be observed at frequencies of 100 Hz and 20 kHz

Conclusions

- Prospective fatigue tests will be conducted at load ratios R > 0.5. The aim is to achieve a load ratio of up to 0.9 to approach the actual loads in the last-stage blades of low-pressure steam turbines
- Fractured specimens will be studied via Transmission Electron Microscopy (TEM) and Focussed Ion Beam (FIB) with regard to the crack initiation sites and their characteristic dislocation structures

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