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INTEGRATED MODELING OF STRESS CORROSION CRACKING IN SUPERALLOYS

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Abstract

The reliability of turbine blades is strongly dependent on the humidity, contamination, stress, and temperature to which they are exposed during operation. In many cases, cracks initiate simultaneously at multiple locations, which can result in crack arrest (shielding) or (coalescence). This presentation will explore an integrated computational and experimental approach that evaluates crack interaction in CMSX-4 superalloy using C-Ring tests with a layer of contaminant salt exposed to 550C. A phase-field model calculates the diffusion of species and reduces the material critical energy release rate accordingly. The model, which is parameterized to enable cracking above a threshold stress, predicts the critical crack spacing that results in shielding or coalescence. In addition, the integration of X-Ray microscopy (XRM) characterization with FEM modelling demonstrates univocally the role of crack interaction in stress corrosion cracking. We conclude discussing the value of integrating models and experiments to understand complex failure mechanisms.

1. Introduction

Crack interaction is a concern for components exposed to corrosive environments due to the large number of cracks initiating simultaneously. In particular, aero gas turbines components operating at high temperature and corrosive environments result in widespread crack surface initiation. These harsh environments often result in a high density of cracks on the surface, whose interaction determine the service lives of turbine components. This presentation explores modeling of stress-corrosion cracks in CMSX-4 single crystal superalloys at 550°C.

2. Modeling and Experimental Approach

We employ a phase field model implemented in Abaqus and parametrized with experimental data from C-ring tests shown in Figure 1. The C-rings were also characterized with X-Ray microscopy (XRM) and the results were integrated with FEM modelling demonstrates univocally the role of crack interaction as shown in Figure 2.

3. Results

The results demonstrate the model ability to predict crack density and the likelihood of cracks coalescing or arresting. Moreover, the parameterization supports the important role of Sulphur (or species with similar diffusion rates) on cracking. This modelling approach is an effective tool to perform crack prognosis and design crack-resistant components.

4. Conclusions

The integration of experimental and modelling approaches supports the understanding of the nature of stress corrosion cracking at high temperature in Ni-base superalloys. The model demonstrated that crack interaction is responsible for a crack spacing about 150 µm observed in experiments. Furthermore, integration of FEM with XRM provides further evidence of the mechanisms driving the cracks.

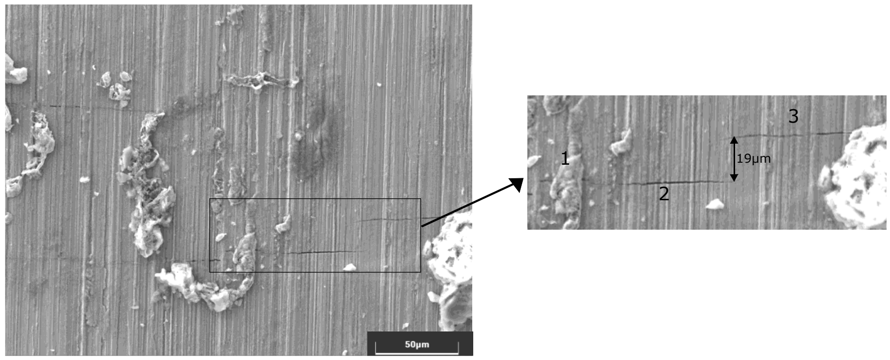

Figure 1: A magnified SEM image representing this crack tip convergence

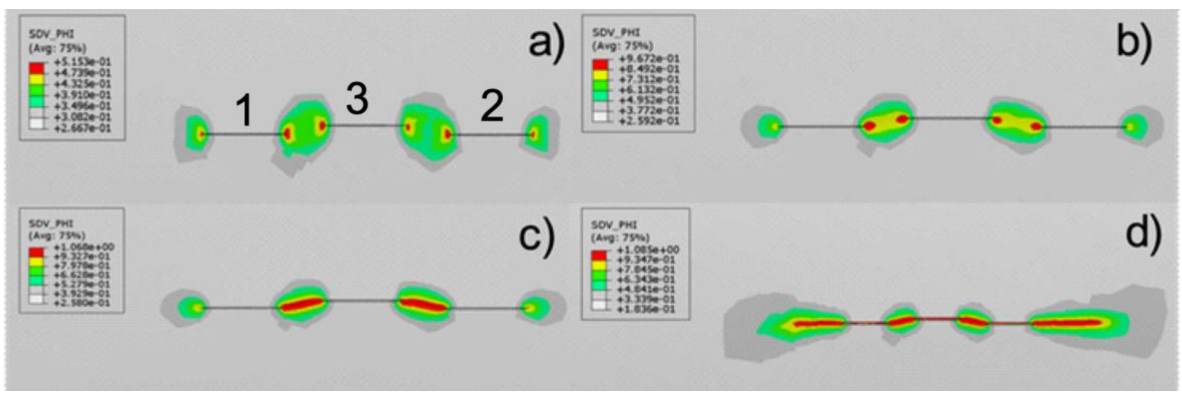

Figure 2: Simulation results representing effects of crack coalescence between off parallel cracks with a separation distance of 10μm or less