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CYCLIC DEFORMATION, HYDROGEN DAMAGE AND CRACK PROPAGATION IN NICKEL-BASED SUPERALLOYS

Liguo Zhao[1,*], Xing Zhang[1], Shengbao Lu[1], Rudolph Kashinga[1]

[1]College of Energy and Power Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing, Jiangsu Province, 210016, China
*corresponding author: L.Zhao@nuaa.edu.cn

Abstract

As strategically important materials, nickel-based superalloys play a crucial role in the aerospace and energy sectors, particularly for manufacturing critical components such as turbine blades and discs of gas turbine engines. Damage tolerance of nickel-based superalloys under fatigue and hydrogen embrittlement conditions is crucial for ensuring the integrity and safety of critical gas turbine components in hydrogen-powered turbine engines. In this study, viscoplasticity and crystal plasticity have been used to model cyclic deformation of nickel-based superalloys at elevated temperature. Model parameters were determined from strain-controlled cyclic test data, with the consideration of varied loading rate. Model simulations were in good agreement with the experimental results for stress-strain loops, cyclic hardening and stress relaxation. Subsequently, the models were coupled with the phase field approach to predict crack growth under fatigue, in comparison with experimental results. Furthermore, computational simulations of hydrogen diffusion have been carried out to quantify hydrogen embrittlement in nickel-based superalloys. A coupled mechanical-diffusion analysis was then developed to account for the interaction between cyclic deformation and hydrogen diffusion under fatigue loading. In conjunction with the phase field method, the coupled model has been applied to predict hydrogen-assisted fatigue crack growth for triangular and dwell loading waveforms, in good agreement with experimental results. The work has significance in structural integrity assessment of hydrogen-powered gas turbine engines with critical rotating components made of nickel-based superalloys

Keywords
Cyclic deformation; Viscoplasticity; Crystal plasticity; Hydrogen embrittlement; Crack growth

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