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On the Fatigue Damage of GH4169 Based on Thermodynamic Entropy Generation

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ABSTRACT

This paper presents the assessment of fatigue damage for GH4169 under cyclic loading based on thermodynamic entropy generation at elevated temperature. According to the second law of thermodynamics, fatigue crack propagation is an irreversible thermodynamic dissipative process in which damage accumulates and entropy generates with each cycle until fracture occurs. In this work, crack growth process is simulated by commercial finite element software ABAQUS, and the concept of cyclic entropy generation rate (CEGR) is proposed to present the entropy generation of the crack tip region in a single loading cycle, where the calculation of CEGR is dependent on the evolution data of stress, plastic strain rate and temperature at the crack tip region. The accumulated entropy generation of crack growth process is obtained by integrating CEGR. The influence of temperature and the amplitude of uniform far-field stress on CEGR and accumulated entropy generation is discussed. Results indicated that the rise of temperature and the increase of far-field stress amplitude can both increase the dissipation of plastic strain energy at crack tip region, leading to the increase of CEGR eventually. When the temperature and the far-field stress amplitude remain unchanged in fatigue progress, CEGR increases continuously until fracture occurs. Results showed that the entropy generation per unit crack length ds/da is almost a constant in crack growth process. The fatigue fracture entropy (accumulated entropy generation at fracture point) has an approximate quadratic function relationship with the amplitude of uniform far-field stress. The fatigue damage is defined as the ratio of accumulated entropy generation to fatigue fracture entropy in this paper, and an estimation model for fatigue damage using the normalized cycles N/N_f is proposed. The estimated fatigue damage is compared to literatures.

KEYWORDS

Fatigue damage; crack propagation; entropy generation; elevated temperature

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