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Enhanced fatigue damage under cyclic thermo-mechanical loading at high temperature by structural creep recovery mechanism

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Abstract

Creep-cyclic plasticity of a benchmarked holed plate subjected to thermo-mechanical loading is investigated by means of nonlinear finite element analysis. From the analyses, a structural creep recovery response is found within a dwell period, which has serious repercussions on structural integrity. The structural creep recovery can take place by reversing the creep stress in sign during the stress relaxation due to the creep stress redistribution, consequently enhancing unloading plasticity which causes a substantial increase of total strain range within a cycle. Based on this critical observation, further analyses and discussions are provided to investigate the root cause of this precautious structural response. Various cyclic loadings with a dwell at the peak thermal load are analysed to define factors influencing the structural creep recovery mechanism, and to investigate how the mechanism affects the lifetime of the structure. To show the effectiveness of the structural creep recovery mechanism under cyclic loading, Chaboche nonlinear kinematic hardening model is adopted. Limitations of applying elastic follow-up in predicting creep strains and appropriate creep-fatigue damage calculation methods are discussed in the presence of this structural creep recovery mechanism. This research work confirms that when a structure experiences the structural creep recovery it can reduce creep damage, nevertheless the structure may experience significant fatigue damage due to creep enhanced plasticity.

Keywords: Creep-cyclic plasticity, Stress redistribution, Creep enhanced plasticity, Creep ratchetting

1. Introduction

Failure mechanisms of high temperature have been observed in many components in industries such as power generation, aircraft gas-turbine engines, petrochemical process, and so on. The nuclear