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Creep Analysis and Rupture Evaluation of High Temperature Materials

Authors : Yuexi Xiong, Jingwu He

Abstract : The structural components in an energy facility such as steam turbine machines are operated under high stress and elevated temperature in an endured time period and thus the creep deformation and creep rupture failure are important issues that need to be addressed in the design of such components. There are numerous creep models being used for creep analysis that have both advantages and disadvantages in terms of accuracy and efficiency. The Isochronous Creep Analysis is one of the simplified approaches in which a full-time dependent creep analysis is avoided and instead an elastic-plastic analysis is conducted at each time point. This approach has been established based on the rupture dependent creep equations using the well-known Larson-Miller parameter. In this paper, some fundamental aspects of creep deformation and the rupture dependent creep models are reviewed and the analysis procedures using isochronous creep curves are discussed. Four rupture failure criteria are examined from creep fundamental perspectives including criteria of Stress Damage, Strain Damage, Strain Rate Damage, and Strain Capability. The accuracy of these criteria in predicting creep life is discussed and applications of the creep analysis procedures and failure predictions of simple models will be presented. In addition, a new failure criterion is proposed to improve the accuracy and effectiveness of the existing criteria. Comparisons are made between the existing criteria and the new one using several examples materials. Both strain increase and stress relaxation form a full picture of the creep behaviour of a material under high temperature in an endured time period. It is important to bear this in mind when dealing with creep problems. Accordingly there are two sets of rupture dependent creep equations. While the rupture strength vs LMP equation shows how the rupture time depends on the stress level under load controlled condition, the strain rate vs rupture time equation reflects how the rupture time behaves under strain-controlled condition. Among the four existing failure criteria for rupture life predictions, the Stress Damage and Strain Damage Criteria provide the most conservative and non-conservative predictions, respectively. The Strain Rate and Strain Capability Criteria provide predictions in between that are believed to be more accurate because the strain rate and strain capability are more determined quantities than stress to reflect the creep rupture behaviour. A modified Strain Capability Criterion is proposed making use of the two sets of creep equations and therefore is considered to be more accurate than the original Strain Capability Criterion.

Keywords : creep analysis, high temperature mateials, rapture evalution, steam turbine machines
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