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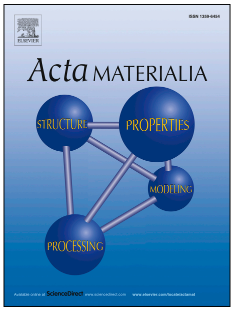

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Environmentally Enhanced Creep Crack Growth by Grain Boundary Cavitation under Cyclic Loading

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Abstract

Plane strain finite element calculations of mode I crack growth are carried out under small scale creep conditions with an imposed stress intensity factor that is a prescribed cyclic function of time. The finite deformation analyses are based on a constitutive relation that couples creep deformation and damage due to grain boundary cavitation including a simple model of the embrittling effect of solute (oxygen) diffusion along grain boundaries. Isothermal analyses are carried out for two sets of material and grain boundary parameters: (i) parameter values representative of HASTELLOY® X; and (ii) parameter values representative of P91. For a fixed imposed stress intensity factor range the detrimental environmental effect is found to increase with increased hold time. A stronger detrimental effect of environmentally assisted grain boundary embrittlement is found for HASTELLOY® X than for P91. The variation of the predicted cyclic crack growth rate with imposed stress intensity factor range is found to be in good quantitative agreement with experimental results in the literature for both HASTELLOY® X and P91. Paris law behavior, i.e. the cyclic crack growth rate depending on the imposed stress intensity factor range raised to a power, emerges naturally in the calculations. Parametric studies show that the cyclic crack growth rate and the Paris law exponent are more sensitive to variations in the grain boundary diffusivity, the solute diffusivity and a parameter characterizing the environmental embrittling effect than to parameters characterizing the creep response of the undamaged material. Also, an explicit analytical expression is found that gives a very good fit to the computed dependence of the cyclic crack growth rate on the solute diffusivity.

Keywords: Creep-fatigue interaction, Oxidation, Grain boundary embrittlement, Crack propagation, Finite element modeling

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