8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

A Multi-Scale and Multi-Physics Model for Stress Corrosion Cracking

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Key Words: *Stress Corrosion Cracking, Hydrogen Embrittlement, Multiphysics Modelling.*

ABSTRACT

Stress corrosion cracking (SCC) is a very common failure mechanism. It is characterized by slow, environmentally induced crack propagation in structural components. Time-to-failure-tests and crack-growth-rate tests are widespread practices for studying the response of various materials undergoing SCC. However, due to the large amount of factors affecting the phenomenon and the scatter of data, they do not provide enough information for quantifying the effects of main SCC mechanisms.

Several mechanisms have been proposed to explain the SCC phenomenon. They can be classified as [1]: (i) anodic mechanisms, e.g. active dissolution and removal of material from the crack tip; and (ii) cathodic mechanisms, e.g. hydrogen evolution, absorption, diffusion and embrittlement. In this study, we focus on the latter group, particularly in the characterization of SCC driven by impurity-enhanced decohesion.

In the present paper we developed a new 3-dimensional, multi-scale and multi-physics model for understanding the intergranular SCC of polycrystalline materials under the effect of impurity-enhanced decohesion. This new model is based upon: (i) a robust algorithm capable of generating the geometry of polycrystals by exploiting tools from algebraic topology and configurational mechanics; (ii) a continuum finite element model of the grains including crystal plasticity; (iii) a grain boundary diffusion model informed with first-principles computations of diffusion coefficients; and (iv) an intergranular cohesive model described by concentration-dependent constitutive relations also derived from first-principles. Results are be validated and compared against crack-growth-rate [2] and time-to-failure [3] tests.

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