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A PHASE FIELD METHOD FOR MODELING STRESS CORROSION CRACK PROPAGATION INDUCED BY ANODIC DISSOLUTION

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Abstract: The phase field method is a powerful tool for studying microstructural evolution in various domains of material science, including initiation and propagation of fracture. In this work, a new formulation is developed within the phase field method for modeling stress corrosion cracking induced by anodic dissolution. The effects of both electrochemical and mechanical processes are taken into account in the new frame work. The classical phase transformation model is coupled with mechanical problem in a robust manner, providing an efficient tool to study the competition between electrochemical and mechanical impact on the fracture phenomena.

1. Introduction

This work started from ideas presented in the work in [1], where the KKS model [2] is adopted with new normalization procedures to possibly describe the dissolution process (phase transformation from solid to liquid). We propose herein a coupling with mechanical equilibrium to model SCC induced by material dissolution. We adopt also a robust numerical framework by using the unilateral contact formulation and history functional following [3]. This ensures that the dissolution is only accelerated under tensile mechanical states. Moreover, the material orientation dependence is accounted for following [4]. The proposed model can simulate not only the anisotropy in the elastic behavior but also in fracture evolution. That is very promising when study the SCC induced crack propagation at the micro scale, when crystallography needs to be taken into account

2. Results

The effect of electrochemical and mechanical on fracture phenomena is studied. We consider a rectangular domain $L \times B = 200 \times 150 \mu\text{m}^2$ containing an initial crack, subjected to stress corrosion. The details of considered system are depicted in Figure 1. The structure will be assigned for both electrochemical and mechanical loadings. The mechanical loading y -displacements are applied along the upper edge ($y = B$). On the lower edge ($y = 0$), the y -displacements are fixed. Along these edges, x -displacements are free. For these boundary conditions, the time history is as follows: (1) during the first period $t = 0:3\text{s}$, the structure is subjected to mechanical loading until $U = 3 \mu\text{m}$; (2) then for $t = 3:120\text{s}$, the rupture of film passive to allow electrochemical processing is manually activated and the mechanical load is increased until $U = 6.51 \mu\text{m}$. The result of fracture morphology is depicted in Figure 2(a). The fracture evolution in the first period is quite similar as in the classical case of semi-circular corrosion growth. During the second period, when the loading is increased, the fracture morphology is sharper as expected for mechanically driven failure. This fracture geometry has been observed in the experiment, as depicted in Figure 2(b).

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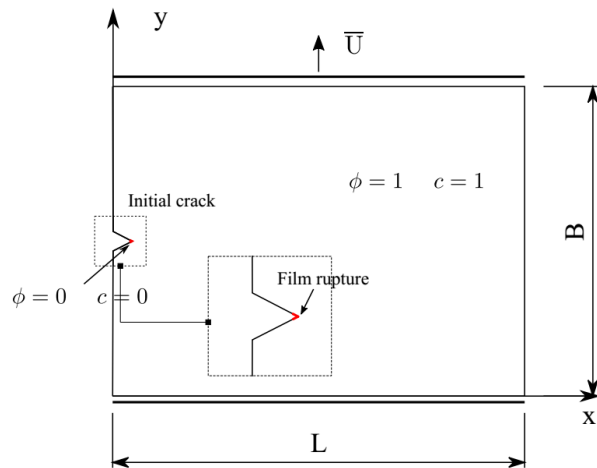


Figure 1. Geometry and boundary conditions of investigated domain for studying effect of electrochemistry and mechanics

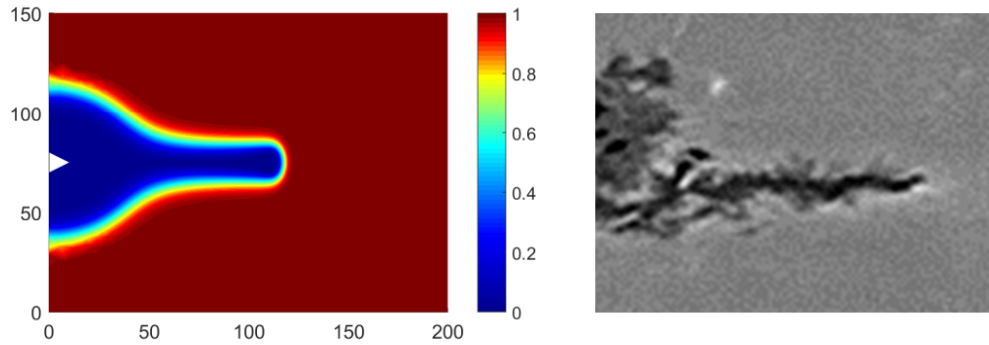


Figure 2. Comparison of crack morphology of predicted simulation (a) and experimental observation (b).

3. Conclusions

A phase field frame work is introduced in this work to simulate the fracture growth induced by stress corrosion. The mechanical problem is coupled with a dissolution model in a robust manner. The analyses of fracture morphology provided by various SCC conditions, qualitatively agree with experimental observations. That demonstrated the performance of the proposed framework to model all aspects of SCC.

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