A cohesive zone framework for environmentally assisted fatigue

We present a compelling finite element framework to model hydrogen assisted fatigue by means of a hydrogen- and cycle-dependent cohesive zone formulation. The model builds upon: (i) appropriate environmental boundary conditions, (ii) a coupled mechanical and hydrogen diffusion response, driven by chemical potential gradients, (iii) a mechanical behavior characterized by finite deformation J2 plasticity, (iv) a phenomenological trapping model, (v) an irreversible cohesive zone formulation for fatigue, grounded on continuum damage mechanics, and (vi) a traction-separation law dependent on hydrogen coverage calculated from first principles. The computations show that the present scheme appropriately captures the main experimental trends; namely, the sensitivity of fatigue crack growth rates to the loading frequency and the environment. The role of yield strength, work hardening, and constraint conditions in enhancing crack growth rates as a function of the frequency is thoroughly investigated. The results reveal the need to incorporate additional sources of stress elevation, such as gradient-enhanced dislocation hardening, to attain a quantitative agreement with the experiments.