Hydrogen Assisted Cracking: Analytical and Numerical Study

Alla Balueva*
University of North Georgia
Mathematics Department
P.O.Box 1358 Gainesville 30503 USA
abalueva@ung.edu

ABSTRACT

Studying and preventing Hydrogen Induced Cracking is one of the main safety concerns in nuclear power plants, oil pipelines and platforms. At present, primarily because of corrosion, the pipelines are simply replaced periodically, for example, every twenty years. Understanding the mechanism of the protective coating delamination may improve pipeline longevity, which creates an essential industrial potential. In aerospace engineering, hydrogen is often used as fuel for rocket engines; it is also frequently stored in high pressure storage tanks. Hydrogen influences the metal in two ways: hydrogen being accumulated inside the cracks or microvoids in metal creates pressure which eventually leads to their growth and the damage of the pipeline; on the other hand, hydrogen in atomic form has tendency to diffuse to the sites of high stresses, which are around the crack tip, where it is accumulated. Then hydrogen was observed to facilitate dislocation emission at the crack tip. This in turn dramatically decreases the fracture toughness and facilitates the start of the crack growth.

While the rate of crack propagation is small, additional hydrogen has time to diffuse into the area of the crack tip; however as the rate of crack growth increases, fewer hydrogen atoms have time to enter the vicinity of the crack tip and effect the rate of delamination. Without the presence of aggressive media, the cracking resistance of a material can be described by a unique constant. If $K_I$ (stress intensity factor) is smaller than that unique constant, the crack is stationary. If $K_I$ is larger, the crack moves in a dynamic regime. Under conditions of aggressive media, crack growth is characterized by a smooth kinetic function $v(K_I)$, which is dependence of the crack velocity on the stress intensity factor and it is a characteristics of the material. In this study, we model hydrogen assisted cracks analytically, taking into account full kinetic functions $v(K_I)$, available in the literature. Even though, this task looks not being tackled analytically, we suggest an asymptotical solution for big times. The asymptotical result shows that nevertheless that the crack velocity increases accordingly with the kinetic function, $v(K_I)$, with time it reaches some value $v_c$, and remains at the same level afterwards. The fact that the hydrogen cracks start growing at a constant speed is confirmed by experiments on HIC and by numerical calculations by the author in the previous paper (Balueva, 1993). In the second part of the study, a molecular dynamic simulation (MD) was conducted on hydrogen embrittlement at the crack tip. The ab-initio calculations have been done for 14 atoms of Al cell with two H atom approaching (1,0,0) face of Al. Ab-initio calculation were performed, using density functionals (B3LYP) and frozen-core basis sets (CEP pseudo potentials).

References