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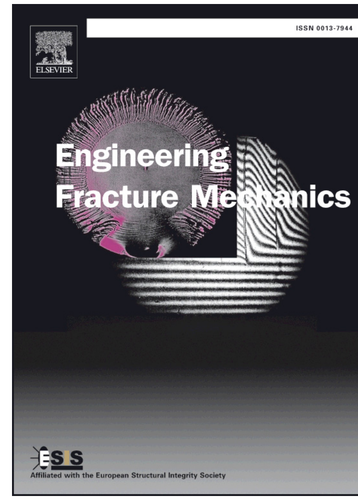

Under-estimation of crack growth rate due to negligence of timescale distinction during hydrogen assisted cracking through diffusion

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Under-estimation of crack growth rate due to negligence of timescale distinction during hydrogen assisted cracking through diffusion

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Abstract

Some alloys in mechanical and civil applications are observed to fracture easily in the presence of hydrogen. Many diffusion-based models have helped describe this phenomenon. The crack grows when critical hydrogen concentration ahead of the crack tip is reached. In existing models, the crack growth is constantly coupled with hydrogen diffusion. However, diffusion and crack growth are observed to occur at distinct timescales - diffusion being a much slower process. This motivates the use of distinct timescales to describe crack growth and diffusion. It is found that the crack growth rate predicted is underestimated if timescale distinction is ignored.

Keywords: hydrogen, cracking, timescale, crack, crack growth rate

1. Introduction

As a natural phenomenon, Hydrogen Assisted Cracking (HAC) is a catastrophic and complex process in which a metal alloy fails by the superimposed effects of applied load and hydrogen environment, earlier (or easily) than it would have in an inert environment. However, fractographic studies [1, 2] have given some insight into the process like dependence on the temperature, microstructural changes, variation in diffusion coefficient, etc. giving an extensive idea about the process. Many experimental and atomistic studies have been conducted to better understand the exact mechanism of HAC, however, a general agreement is lacking till date.

Gaseous HAC has been experimentally observed and surface kinetics identified to be the major reason behind stable crack growth in FeSi- and Ni-crystals [3]. HAC due to diffusion in aluminum using multiscale quantum mechanical simulations have been conducted [4] to show that adsorption and nucleation of hydrogen at crack-tip causes crack growth. For non-hydride forming metals, the hydrogen enhanced localised plasticity (HELP) mechanism has been argued to be more acceptable, however the occurrence of hydrogen-enhanced decohesion (HEDE) is also acknowledged [5] after some studies on Fe-Si single crystals have shown cleavage mechanism. Atomistic simulations of HEDE have been carried out to infer that the continuum models of Griffith/Rice are accurate at low hydrogen concentrations [6]. Crack growth in aqueous hydrogen has also been experimentally observed in steels and trapping of diffused hydrogen has been modelled to explain the observations [7].

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