EFFECT OF HYDROGEN PARTIAL PRESSURE ON CRACK INITIATION AND GROWTH RATE IN X52 VINTAGE STEEL

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Ongoing efforts to decarbonize our energy systems highlight hydrogen as an attractive alternative to fossil fuels. One such opportunity involves adapting existing natural gas infrastructure for use with hydrogen, which primarily consists of vintage (pre-1970s) pipeline steels. While the deleterious effects of hydrogen on the fatigue and fracture resistance of these materials have received more attention in recent years, there is a lack of data on crack initiation for low hydrogen partial pressure conditions, relevant for some of these applications. To address this gap, the current work presents a series of fatigue tests performed on vintage API Grade X52 steel in air and gaseous hydrogen at different partial pressures in the range of 1 to 210 bar. All tests were performed at room temperature and with a load ratio R = 0.1. Circumferential notch tension (CNT) specimens were tested while recording the direct current potential difference (DCPD) across the notch to develop S-N curves for both crack initiation and failure. Fractography was performed to correlate the reduction in fatigue life due to hydrogen to changes in the fracture surfaces. Moreover, a series of interrupted CNT tests were also performed, followed by crack geometry observations, to infer relationships between normalized DCPD voltage and crack length. Fatigue crack growth rates were also determined from standard fracture mechanics tests using the compact tension (CT) geometry. These were then compared to CNT data to further estimate the stress intensity factor ranges of all the conditions tested. Results show that hydrogen degrades the fatigue properties of this material even at pressures as low as 1 bar, with larger reductions in lifetime for larger applied stresses. While some existing infrastructure can likely accommodate hydrogen, its effects are quite apparent at low hydrogen partial pressure and must be carefully considered in structural integrity analyses.