Fatigue Crack Growth Rate of Vintage Pipeline Steels in Gaseous Hydrogen - Effect of Frequency and ΔK

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Abstract

There is currently significant focus on developing carbon neutral energy solutions. As part of this effort, there is an increasing effort aimed at using hydrogen as a fuel. This in turn requires it's in the existing natural gas pipeline infrastructure as an efficient delivery method. The existing natural gas pipeline infrastructure is over 50 years old, with large parts of the infrastructure consisting of vintage steel pipes manufactured in the 1950's and 1960's. These pipelines are often subject to various fatigue loading events. Over the course of normal operations, the pipelines are subject to frequent low amplitude ripples, as well as occasional large amplitude pressure cycling. The role of hydrogen on accelerating fatigue behavior of steels has been extensively studied at high pressures of H_2 and under modestly high frequencies (~1Hz). However, these pressures and loading conditions are not typical of pipeline operations, in addition, there has been very little work performed on vintage grade pipeline steels.

A program was performed to develop relevant fitness for service data on vintage pipeline steel at hydrogen partial pressures in the range of 300 psia. The intent was to develop crack growth rate information to perform fitness for service assessments under conditions associated with typical pipeline operating conditions, that would transport hydrogen. The fatigue crack growth rate (FCGR) associated with low stress intensity factor amplitude (ΔK) was evaluated to understand the near threshold behavior. The effect of low frequencies typical of pipeline operations (~10 μHz) on the FCGR was evaluated at high values of ΔK. In addition to FCGR data, fracture toughness data was developed to understand the effect of geo technical hazards, as well as determine the end of life criteria. The data developed provides a framework in which fitness for service assessments for vintage pipeline steels for hydrogen transport can be performed.