SEMINAR SERIES

Hydrogen Accelerated Fatigue Crack Growth of Pipeline Steels and Welds

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JOSEPH RONEVICH
SANDIA NATIONAL LABORATORIES

Joe Ronevich received his PhD from the Advanced Steel Processing and Products Research Center (ASPPRC) at Colorado School of Mines in 2012. He has been working at Sandia National Laboratories in Livermore, CA since this time with a focus on hydrogen compatibility of structural materials ranging from pipeline steels, stainless steels, and aluminum alloys.

Steel pipelines represent a cost effective means of transporting gaseous hydrogen over long distances from centralized production facilities to end uses. However, steel pipelines have been shown to be susceptible to hydrogen embrittlement. In a pipeline subjected to pressure cycling, degradation is manifested through accelerated fatigue crack growth in hydrogen as compared to in air. Pressure cycling represents one of the key differences in operating conditions between current hydrogen pipelines (e.g. low strength pipelines typically operated under constant pressure) and those anticipated in a nationwide hydrogen delivery infrastructure. Although the performance of steel pipelines is reduced by hydrogen, use of steel pipelines is not precluded but necessitates a stronger understanding of performance in cyclic environments to ensure proper design and reliability. Of particular interest is performance of the welds due to challenges in testing and therefore lack of significant data. It is the goal of this work to enable the deployment of higher strength steel pipelines for the future hydrogen infrastructure. Currently, restrictions or thickness premiums are required for higher strength pipeline steels in the design code (ASME B31.12). Beneficial cost savings are diminished by requirements to use thicker-walled pipes on higher strength steels.

To address this concern, fatigue crack growth rate (da/dN) versus stress intensity factor range (ΔK) relationships were measured on X52, X65, and X100 welded steel pipe test coupons in high-pressure hydrogen gas (21 MPa). Tests were performed at a load ratio (R) of 0.5, frequency of 1 Hz, and at a temperature of 293 K. In high pressure hydrogen gas, the fatigue crack growth rates accelerated to over an order of magnitude greater than tests performed in air. Despite significant differences in the specified minimum yield strengths (SMYS) of the pipes examined (e.g. 358 to 689 MPa), fatigue performance in high pressure hydrogen did not vary considerably, which suggests higher strength pipes could be implemented and cost-savings could be realized without compromising integrity. The X100 weld exhibited higher crack growth rates compared to the X52 and X65 welds. Residual stresses were measured in the X100 welds and the effects of residual stress on the da/dN vs. ΔK curves are discussed. Future work is focused on identifying microstructures relationships with fatigue crack growth rates.

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