IS MICROSTRUCTURAL HOMOGENEITY THE ANSWER TO HYDROGEN EMBRITTLEMENT RESISTANCE?

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Hydrogen transportation by pipelines (whether 100% pure H2 gas or blended with natural gas) is rapidly gaining traction as a critical component of a low carbon energy infrastructure. However, low-cost pipeline steels often perform poorly in the presence of hydrogen, particularly in fatigue due to pressure cycling. The large number of studies on pipeline steels do suggest some promising avenues for development. In particular, homogeneity of microstructure appears to produce higher resistance to hydrogen effects.

Mechanical tests, including fatigue crack growth and strain-life, were conducted on two X60 pipeline steel alloys. One alloy was processed to obtain a fine grain size and a homogeneous distribution of grain size. The other alloy had identical chemistry, and similar microstructure, but was processed to have a larger grain size and a heterogenous grain size distribution. Baseline tests were conducted in air, and those results were compared with tests conducted in pressurized hydrogen gas. Fatigue crack growth rate tests were performed at (load ratio) R = 0.5 and a frequency of 1 Hz and at a hydrogen gas pressure of 21 MPa. Strain-life tests were run at R=-1 and various strain amplitudes in 21 MPa hydrogen gas. The steel with the microstructure optimized for resistance to hydrogen gas showed lower fatigue crack growth rates and higher strain life than the non-optimized steel when tested in 21 MPa hydrogen gas.