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Exploring Hydrogen Embrittlement and Fatigue Crack Growth in API 5L X52 Steel Pipeline Under Cyclic Internal Pressure

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Abstract : Transporting hydrogen gas through the existing natural gas pipeline network offers an efficient solution for energy storage and conveyance. Hydrogen generated from excess renewable electricity can be conveyed through the API 5L steel-made pipelines that already exist. In recent years, there has been a growing demand for the transportation of hydrogen through existing gas pipelines. Therefore, numerical and experimental tests are required to verify and ensure the mechanical integrity of the API 5L steel pipelines that will be used for pressurized hydrogen transportation. Internal pressure loading is likely to accelerate hydrogen diffusion through the internal pipe wall and consequently accentuate the hydrogen embrittlement of steel pipelines. Furthermore, pre-cracked pipelines are susceptible to quick failure, mainly under a time-dependent cyclic pressure loading that drives fatigue crack propagation. Meanwhile, after several loading cycles, the initial cracks will propagate to a critical size. At this point, the remaining service life of the pipeline can be estimated, and inspection intervals can be determined. This paper focuses on the hydrogen embrittlement of API 5L steel-made pipeline under cyclic pressure loading. Pressurized hydrogen gas is transported through a network of pipelines where demands at consumption nodes vary periodically. The resulting pressure profile over time is considered a cyclic loading on the internal wall of a pre-cracked pipeline made of API 5L steel-grade material. Numerical modeling has allowed the prediction of fatigue crack evolution and estimation of the remaining service life of the pipeline. The developed methodology in this paper is based on the ASME B31.12 standard, which outlines the guidelines for hydrogen pipelines.

Keywords : hydrogen embrittlement, pipelines, transient flow, cyclic pressure, fatigue crack growth
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