EXTERNAL HYDROGEN EMBRITTLEMENT ASSESSMENT OF PIPELINE BASE METAL AND HEAT AFFECTED ZONE THROUGH SLOW STRAIN RATE TENSILE TESTING

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Hydrogen as an energy carrier can play a key role in the transition from fossil fuel to renewable energy. This shift can be promoted by reuse of existing natural gas subsea pipelines for large scale hydrogen gas transport, ensuring sustainable development of the energy system and positive economic impact. To enable safe and efficient hydrogen transport, safe operating limits and countermeasures against hydrogen embrittlement need to be established, ensuring pipeline integrity. This work presents the results from a material test program of three vintage pipeline steels and two modern pipeline steels, strength classes X65 and X70, with the aim of building a knowledge base for establishing safe operation limits. A combined nano to macro scale experimental approach is conducted, investigating both the base metal and the weld simulated heat affected zone of each pipeline steel material. The aim is to provide an overall indication of the hydrogen embrittlement susceptibility of the various pipeline steels.

Microstructural characterization and slow strain rate tensile testing in air and under in-situ electrochemical hydrogen charging conditions are performed. The susceptibility of the various materials to hydrogen degradation is quantitatively assessed through the embrittlement index, reflecting the degree of embrittlement. Post-mortem analysis of the fracture surfaces is carried out to relate the overall degree of hydrogen embrittlement susceptibility of the materials to the hydrogen-induced degradation mechanisms. Nanoindentation and micromechanical testing are performed to in-situ unveil the hydrogen influence on the deformation behavior, local mechanical properties, and crack initiation and propagation mechanisms. Finally, electrochemical permeation measurements are performed to characterize the hydrogen permeation properties of the various pipeline steels in terms microstructure.

All materials revealed a loss in ductility when tested under electrochemically hydrogen charging condition as compared to testing in air. Negligible effect of hydrogen on strength was revealed. The modern steels were found the least affected by hydrogen exposure, as compared to the vintage steels. This is attributed to the presence of a higher number of impurities and the pearlitic-bainitic banding of the vintage pipeline steels compared to the more homogenous microstructure of the modern materials. Further, the modern steels revealed the highest diffusion coefficients and lowest trapping capabilities.