Environmental Assisted Cracking of pipeline steels in CO_2 containing environment

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Buried pipelines are susceptible to Environmental Assisted Cracking (EAC) in three different conditions: Stress Corrosion Cracking in the presence of Carbonate-Bicarbonate (CB-SCC), Near Neutral Stress Corrosion Cracking (NN-SCC) and Hydrogen Embrittlement (HE). Both CB-SCC and NN-SCC involve in their mechanism the presence of CO_2 and/or its dissociated species dissolved in moisture under the coating, while the generic term of HE refers to the phenomena of brittle fracture taking place for entry of atomic hydrogen inside the metal lattice, owing to the applied cathodic protection.

Historically the CB-SCC was the first established form of stress corrosion on pipelines in the 60s, while Trans Canada Pipeline published in 1985-86 the first case of NN-SCC. The initiation conditions and the mechanism of propagation of CB-SCC were well established by means of the works of Parkins in 70ths. Many studies were carried out on NN-SCC, but actually there is not an exhaustive understanding of the problem.

This paper summarizes the results obtained by authors on pipeline steels in NN-SCC promoting environments. Constant load, constant deformation, slow strain rate, slow bending and corrosion fatigue tests were executed on different grades of pipeline steels. The obtained results pointed out the effect of continuously plastic deformation to observe the propagation of NN-SCC cracks. NN-SCC cracks are preferentially nucleated from localized attacks. Inside the pits, the decreasing of pH enhances the hydrogen ions reduction. The results of slow strain rate tests are in agreement with a hydrogen embrittlement mechanism for the NN-SCC cracks propagation.

Electrochemical tests, potentiodynamic and cyclic voltammetry were also carried out in order to analyze the effect of temperature, pH, CO_2 and bicarbonate concentration on the pitting initiation.

A pre-corrosion procedure, using a solution with high concentration of bicarbonate ions saturated with CO_2 and a great number of voltammetry cycles was developed to obtain localized attacks on the specimen surface, similar than those observed in the failure analysis of the cracked pipelines. The SSR and slow bending tests carried out on these pre-corroded specimens evidenced presence of cracks with the same morphology of NN-SCC.

Finally some corrosion-fatigue tests carried out on linear elastic fracture mechanics specimens (Single Edge Notch three four point Bending specimens) evidenced the increasing of fatigue propagation crack growth in NN-SCC environment.

In the range of traditional and innovative pipeline steels, the mechanical properties (ultimate tensile strength and yield strength) seem do not influence their NN-SCC resistance.