EVALUATION OF THE "NICKEL EFFECT" IN SULFIDE STRESS CRACKING OF LOW ALLOY STEELS USING THIOSULFATE AS AN ALTERNATIVE TO H_2S-CONTAINING ENVIRONMENTS

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Sulfide Stress Cracking (SSC) of Low Alloy Steels (LAS) is widely accepted as a case of hydrogen embrittlement. H_2S is a poison for the hydrogen recombination reaction that enhances the absorption of this element into the steels. Susceptibility to SSC increases with the improvement of the mechanical resistance of the steels. The standard ISO 15156-2 details the requirements for LAS components for the oil and gas production industry used in H_2S-containing environments.[1] While the hardness of these steels is restricted to 22 HRC, the chemical composition is limited to a maximum of 1 wt.% Ni.[1] This restriction in the chemical composition, also known as the "Ni effect", is controversial since Ni is a desired alloying element in the steels because it improves hardenability, mechanical resistance, and fracture toughness, and decreases the ductile-to-brittle transition temperature without affecting negatively the weldability.

In this research, a set of five Ni-containing steels with tempered martensite microstructure and a hardness below or equal to 22 HRC was fabricated to evaluate the effect of Ni independently of other alloying elements. The effect of Ni on SSC was evaluated using thiosulfate additions as a surrogate to H_2S bubbling in acid brines. The electrochemical behavior at the open circuit potential (OCP), and at more anodic and cathodic potentials was evaluated after slow strain rate tests and in absence of tensile stress. Gaseous hydrogen permeation tests were conducted to evaluate the effect of Ni on the solubility and effective diffusivity of hydrogen on the steels.

The obtained results indicate that Ni influences sulfide stress cracking initiation at OCP due to the formation of trenches, even at Ni contents below the 1 wt.% limit established in ISO 15156-2. Trenches are deep-elongated pits that nucleate at a certain level of stress in H_2S-containing environments, denominated in this work as σ_{trench}. Anodic potentials promoted trenches and cathodic potentials suppressed them. These findings were consistent with those reported by other authors[2–5], validating the use of thiosulfate additions as an alternative to H_2S-containing environments. Additionally, a slight decrease on the hydrogen permeability was observed due to the increase of Ni content in the steels. This effect was related to a decreasing lattice hydrogen solubility. The role of Ni on trapping was quantified and it was concluded that its effect is modest in comparison with other common alloying elements.

References

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