# EFFECT OF MECHANICAL STRENGTH ON THE HYDROGEN EMBRITTLEMENT SUSCEPTIBILITY AND FRACTURE BEHAVIOR OF A MODIFIED AISI 4130 STEEL

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Hydrogen embrittlement (HE) is a phenomenon that affects many steels and other metallic alloys, drastically reducing their fracture strength. In particular, high-strength steels (HSS) are more prone to HE due to their low plastic deformation capacity. However, the demand for weight reduction and manufacturing costs of metallic structures and mechanical components has led to an increase in the use of HSS. Therefore, it is important to understand their behavior in hydrogenated environments to ensure a safe use in applications where HE may be a problem. The present work evaluates the effect of mechanical strength on HE susceptibility of a modified AISI 4130 (4130M) steel with different hardness levels (44 HRC, 40 HRC, 36 HRC and 32 HRC). To measure the fracture load in air ($P_{FFS}$) and in H+ rich environment ($P_{th}$), notched specimens were subjected to incremental step-loading (ISL) tests in air and with in-situ electrolytic hydrogen charging. The results showed a reduction of the AISI 4130M steel HE susceptibility with decreasing hardness, where the obtained $P_{th}$ was 15.0 %$P_{FFS}$, 22.0 %$P_{FFS}$, 60.0 %$P_{FFS}$ and 65.0 %$P_{FFS}$ for the specimens with 44 HRC, 40 HRC, 36 HRC and 32 HRC, respectively. The main reasons for this behavior were due to both: the hydrostatic stress field that develops under the notch root and the material plastic deformation capacity. Additionally, a trend of HE fracture threshold stress stabilization was observed from 36 HRC hardness value, indicating an optimum hardness level that balances high mechanical strength with high HE resistance. The fracture surfaces of the tested specimens were analyzed using a scanning electron microscope. For all hardness levels, the specimens tested in air presented a typical ductile fracture with the presence of dimples all over de fracture surface. On the other hand, the specimens tested under hydrogen charging presented brittle fracture characteristics and a transition from intergranular (IG) to quasi-cleavage (QC) was noticed. The 44 HCR presented a predominantly IG fracture, with small regions of QC, and as the hardness decreased, the QC regions became more evident until a complete QC fracture was observed for the 32 HRC. This behavior was mainly related to the microstructure and hydrogen traps presented by the AISI 4130M steel with different hardness levels. Harder specimens tend to present a high amount of hydrogen traps at the prior austenite grain (PAG) boundaries, which favors crack propagation trough the prior austenite grain (PAG) boundaries. On the other hand, softer specimens present a more homogeneous microstructure, less hydrogen traps at the PAG boundaries, and the plastic deformation favors the hydrogen concentration at the martensite blocks and packets boundaries, leading to QC fracture. The use of the in-situ ISL test allowed the analysis of the mechanical strength effect on the AISI 4130M steel HE susceptibility. The observed trend was a reduction in HE susceptibility with decreasing steel mechanical strength. This behavior was corroborated by the fracture surfaces observations.