# HYDROGEN EMBRITTLEMENT EVALUATION OF HSLA STEELS USING SMALL PUNCH AND SLOW STRAIN RATE TESTS

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The evaluation of hydrogen embrittlement susceptibility of high strength steels for application in subsea components subjected to cathodic protection for corrosion control is of fundamental importance. This assessment can help decisions and materials qualification to avoid failures that cause environmental and economic damages, as well as loss of human lives. Therefore, this study evaluates an AISI 4340 steel with 32, 36 and 40 HRC, by means of two methodologies: slow strain rate test (SSRT) and small punch test (SPT). The tests were carried out at two cathodic protection levels (-950 mV and -1100 mV using Ag|AgCl reference electrode) in an aqueous solution with 3.5 % wt of NaCl. The post-test fracture surfaces were also evaluated via scanning electron microscopy. The test results indicated: (i) that the hydrogen embrittlement index (HI) is greater the higher is the material hardness and level of cathodic protection applied and (ii) a relationship between HI and the degree of intergranular fracture in the specimens. It was observed that the most affected parameters due to hydrogen effect were the ones related with the material toughness: elongation and area reduction in the SSRT and maximum displacement in the SPT. In the hardness range and environmental conditions used, it was not observed a significant difference related to yield and tensile stress. The specimens, when tested in air, presented the discontinuous yielding phenomenon, however, when tested under cathodic protection, there was a change in this behavior, with hydrogen being responsible for reducing or eliminating it. For a better comparison of the hardness effect on HE susceptibility, the area reduction parameter, AR, proved to be more effective in differentiate the aggressiveness conditions than the elongation parameter, AL. Therefore, the condition with the lowest HIAR value was 36 HRC – 950 mV, while the most severe condition was 40 HRC – 1100 mV, reaching HI values of 70.9% and 88.3%, in relation to AL and AR, respectively, showing the greater susceptibility of this material at high hardness and higher cathodic potential applied. Through the fracture surface evaluation of the SSRT specimens, it was possible to observe that the fractures in hydrogenated environment started on the specimen surface, with crack propagation until the final failure, unlike the test in air, which presented the characteristic cup-cone fracture mode, with coalescence of microcavities in the center of the specimen, followed by unstable crack propagation. It was possible to determine a relationship between the fracture micromechanisms and the HIAR. Therefore, both techniques have potential for comparing susceptibility to hydrogen embrittlement between materials and application environment