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TOWARDS A BETTER UNDERSTANDING OF HYDROGEN EMBRITTLEMENT IN AUSTENITIC STEELS: THE ROLE OF HYDROGEN CHARACTERISTICS AND FRACTURE MECHANISMS

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Austenitic steels are frequently used materials that come into contact with hydrogen (H) both during production and while in service. Increasing our understanding of the interaction between their microstructure and H is therefore of utmost importance. Two different austenitic steel types are considered to elucidate the role of H on the active deformation mechanism, i.e. 304L austenitic stainless steel (ASS) and twinning-induced plasticity (TWIP) steels.

Firstly, the influence of H on the mechanical properties of 304L ASS is studied at different strain rates. A substantial ductility loss of about 30% is observed when H is electrochemically charged into the steel. A decrease in work hardening rate is observed as well. However, above a strain rate of 10^{-2} s^{-1}, H has limited influence on the macroscopic stress-strain behaviour although clear influences on the fracture surface are noticeable and H-assisted cracks are observed. At these high strain rates, H is thus not able to play its detrimental role and cause macroscopic embrittlement. A dedicated study of the deformation-induced martensitic transformations is performed by EBSD. This reveals that this martensitic transformation is enhanced when H is present and adiabatic heating is controlled. Finally, the interaction between H-assisted cracks and deformation-induced martensite is evaluated as well.

Secondly, the role of stacking fault energy (SFE) in the HE sensitivity of TWIP steels is studied. Aluminium (Al) addition is claimed to improve the HE resistance of these steels. The associated increase in SFE is one of the proposed mechanisms. A lower SFE increases twinning and reduces dislocation cross-slip. Twinning induces large stress concentrations that attract H and as such become prone to cracking. To further elucidate the mechanism, an Fe-18Mn-0.6C TWIP steel is, at first, compared to Fe-18Mn-0.6C-1.5Al to evaluate the addition of Al. To separate the effect of Al from the effect of the SFE, a third TWIP steel with equal SFE as the Al added variant is produced as well by increasing the manganese (Mn) content (Fe-24.5Mn-0.6C). The H concentration increases with the Al and Mn additions after electrochemical charging. TDS is used to evaluate the H diffusion properties since H diffusion is the rate-determining step in the desorption for FCC steels. It is found that Al addition decreases the H diffusivity. Ex-situ constant extension rate tensile tests with and without electrochemical H precharging are done to quantify the amount of embrittlement and to assess post-mortem the fracture behaviour by SEM-EBSD. Al addition clearly results in a reduced HE degree, confirming previous literature results. Mn addition, however, increases the HE sensitivity. A comparative study of the fracture surface and deformation mechanisms suggests that the SFE is not the main factor controlling the HE sensitivity. The resistance to intergranular cracking determines the ranking of the HE sensitivities. A TEM study reveals C and Mn segregation at grain boundaries, i.e. as $(Fe,Mn)_3C$. The beneficial role of Al is proposed to be related to the reduced H diffusivity and the increased grain boundary cohesive strength.