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Hydrogen Embrittlement in a Fe-Mn-C Based Austenitic Steels

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Fe-Mn-C based austenitic steels show excellent combination of tensile strength (>1 GPa) and ductility (>60%) due to high strain hardening rate associated with deformation twinning of a face centered cubic (FCC) structure, microstructural interactions during plastic deformation and dynamic strain aging. Having FCC crystal provides large solubility and low diffusion coefficient of hydrogen. Therefore, they are potential materials for hydrogen-related infrastructure (i.e, storage, transportation, energy conversion). However, it has been observed that they are also susceptible to catastrophic hydrogen-related failure, often called as hydrogen embrittlement (HE) or hydrogen-delayed fracture (HDF). Therefore, better understanding of the mechanism of HE in Fe-Mn-C based austenitic steels is of utmost importance to use them in hydrogen-related infrastructures safely. The main factors, responsible for susceptibility of materials for HE, are 1) Mechanical (HE is linearly proportional to strength of material), Material (Microstructure, crystal structure, etc) and Environmental (Pressure, temperature, exposure time, etc).
In this study, the effects of strain rate on the HE susceptibility of twinning induced plasticity (TWIP) steel, a kind of Fe-Mn-C based austenitic steel, were investigated by tensile testing at room temperature and microstructural characterization. Hydrogen was introduced into the specimens by electrochemical hydrogen charging. Microstructural investigations were conducted using in-situ scanning electron microscopy, transmission electron microscopy and electron backscatter diffraction to observe the effects of hydrogen on microstructure during deformation. It was observed that hydrogen enhanced the microstructural interactions and slip localization during plastic deformation and HE is more pronounced at low strain rates. In addition, hydrogen charging did not change the average dislocation density considerably but changed the average twin thickness and fracture mode from ductile to quasi-cleavage at a low strain rate. Consequently, new HE mechanism was proposed based on these observations.

References:

[1] B. Bal, M. Koyama, G. Gerstein, H.J. Maier, K. Tsuzaki, Int. J. Hydrog. Energy 41 (34) (2016) 15362–15372.

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Born in 1989 in Kayseri, Turkey. He received his B.Sc. degree in Mechanical Engineering from the Middle East Technical University (METU) in 2011 with a second rank. Then he got full scholarship and stipend for Ph.D. studies from the Koç University, where he obtained his PhD degree in 2015 as a youngest Ph.D. graduate. He conducted three postdoctoral activities in Purdue University (US), Kyushu University (Japan), University of California - Los Angeles (UCLA, US), respectively and joined the academia as an assistant professor in Abdullah Gul University. His current scientific interests include mechanical property-microstructure relationships, multi-physics and multi-scale experimental and computational mechanics of materials, materials under extreme conditions and fracture.