HYDROGEN-INDUCED DEGRADATION OF MECHANICAL PROPERTIES DESPITE REDUCTION IN BRITTLE FRACTURE-FEATURES IN A 1.5 GPa DUAL-PHASE STEEL

Rama Srinivas Varanasi, Institute for Materials Research, Tohoku University, Aoba-ku, Japan.
rama.varanasi@tohoku.ac.jp
Motomichi Koyama, Institute for Materials Research, Tohoku University, Aoba-ku, Sendai, 980-8577 Japan.
Shuya Chiba, Institute for Materials Research, Tohoku University, Aoba-ku, Sendai, 980-8577 Japan; Graduate School of Engineering, Tohoku University, Aoba-ku, Sendai, Miyagi, 980-8579 Japan.
Eiji Akiyama, Institute for Materials Research, Tohoku University, Aoba-ku, Sendai, 980-8577 Japan.

The presence of hydrogen in steels has been shown to significantly increase the possibility of brittle fracture (such as an intergranular or quasi-cleavage fracture) [1]. Consequently, the increase in the brittle features has been used as a proxy to understand the severity of hydrogen embrittlement (HE). We investigate the HE mechanisms in a 1.5 GPa class dual-phase (DP) steel. It has been reported earlier that the 1.5 GPa DP steel undergoes brittle fracture in the absence of hydrogen [2]. In the presence of hydrogen, the fractographic analysis revealed an increase in ductile features such as dimples and/or voids. However, contrary to conventional wisdom, the increase in local ductile features was accompanied by drastic degradation of mechanical properties. The HE sensitivity increased with a decrease in strain rate, as summarized in table 1. The fractographic analysis revealed that the crack initiated at the edge of the specimen. The fracture surface morphology at the crack initiation region was distinct compared to the area away from the crack initiation site. To understand the origins of such a difference in fracture surface, we conducted transmission Kikuchi diffraction (TKD) and transmission electron microscopy (TEM) studies. We also conducted electron backscattered diffraction (EBSD) and electron channel contrast imaging (ECCI) investigations to explain the crack initiation and crack propagation behavior. In our study, in addition to the effect of macroscopic strain rate, we also discuss the role of microscopic strain rate during crack propagation arising due to the stress partitioning between martensite and ferrite. Finally, we compare the HE mechanisms observed in a uniaxial tensile test to those observed in a U-bend test [3].

Table 1 Summary of the tensile properties

Condition	Strain rate (s^{-1})	UTS (GPa)	Elongation (%)
Without Hydrogen	10^{-3}	1.5	5.2
Hydrogen Charged	10^{-3}	1.2	1.2
	10^{-4}	0.9	0.6

Acknowledgements
This work is based on results obtained from a project, JPNP14014, commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

References

[1] L. Cho, P.E. Bradley, D.S. Lauria, M.L. Martin, M.J. Connolly, J.T. Benzing, E.J. Seo, K.O. Findley, J.G. Speer, A.J. Slifka, Characteristics and mechanisms of hydrogen-induced quasi-cleavage fracture of lath martensitic steel, Acta Mater. 206 (2021) 116635. https://doi.org/10.1016/j.actamat.2021.116635.
[2] R.S. Varanasi, M. Koyama, Y. Shibayama, E. Akiyama, Mixed type brittle fracture in 1.5 GPa dual-phase steel via 100 ferrite cleavage cracking, Mater. Sci. Eng. A. (2022) 144021. https://doi.org/10.1016/j.msea.2022.144021.
[3] R.S. Varanasi, M. Koyama, Y. Shibayama, S. Chiba, S. Ajito, T. Hojo, E. Akiyama, Hydrogen-Induced Delayed Fracture in a 1.5 GPa Dual-Phase Steel Via Coalescence of Surface and Sub-Surface Cracks, (2022). https://doi.org/10.2139/ssrn.4266763.