STRAIN LOCALIZATION AND HYDROGEN-RELATED FRACTURE IN MARTENSITIC STEELS INVESTIGATED BY COMBINED DIGITAL IMAGE CORRELATION AND ELECTRON BACKSCATTER DIFFRACTION

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The multi-scale complexity of martensitic microstructures makes it difficult to understand the relationship between hydrogen-related fracture and martensitic microstructures. Intensive studies have shown that typical modes of hydrogen-related fracture in martensitic steels are quasi-cleavage and intergranular. Several models have been proposed to account for hydrogen-related fracture. However, the underlying mechanisms for hydrogen-related fracture have not been elucidated conclusively. Hydrogen-related quasi-cleavage fracture is confirmed to be closely related to plastic deformation on {011} slip planes in steels having BCC phases [1]. Regarding intergranular fracture, it has been reported that a small change in grain boundary cohesive energy induced by segregated solute atoms results in several orders of magnitude more energy loss in fracture toughness [2]. One important factor to bridge this gap is energy dissipation by plastic deformation. This study aims to extend the understanding on the local deformation behavior in lath martensite, both with and without hydrogen pre-charging. The relationship between cracking, microstructure, and local plasticity can be tracked to extract quantitative information about how hydrogen-related fracture takes place. In this study, the local plasticity accompanying hydrogen-related fracture in a low-carbon (Fe-0.2wt.%C) martensitic steel was investigated by correlative analysis combining digital image correlation (DIC) and electron backscatter diffraction (EBSD). The DIC strain distribution maps were analyzed in connection to the EBSD maps to investigate whether any microstructural features correspond to the preferentially deformed regions. Figure 1 shows the meso-scale strain distribution map that covers multiple prior austenite grains in the hydrogen-charged specimen. It shows that martensitic steel was deformed in a highly heterogeneous manner. Upon deformation, strain localization appeared in the bulk of martensite blocks and at some prior austenite grain boundaries (PAGB). Such heterogeneity in local strain evolution would in turn lead to a spatially heterogeneous hydrogen accumulation and hydrogen-related cracking, and thus, play an important role in the process of fracture. One can easily find that there is a distinct correlation between the cracking sites and the highly deformed regions. The comparative study of specimens with and without hydrogen pre-charging revealed that hydrogen enhanced strain localization during deformation and facilitated the nucleation and propagation of cracks. The quasi-cleavage cracking was closely related to the local plastic deformation and increasing hydrogen content decreased the local strain level for quasi-cleavage cracking. It is also found that strain localization appeared around the intergranular cracking, which suggests that strain localization is also involved in the sequence of hydrogen-assisted intergranular cracking.

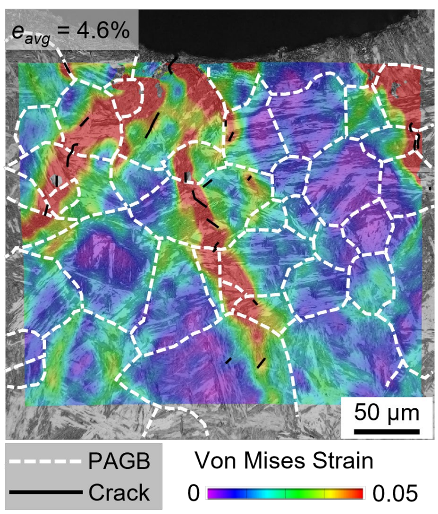

Figure 1 Local strain distribution map of the hydrogen-charged specimen (e = 0.89%, H_D = 5.18 wt. ppm)

References
[1] A. Shibata et al, Acta Materialia, 210 (2021) 116828.
[2] M. Yamaguchi et al. Philosophical Magazine, 94 (2014) 2131.