PAVING THE PATH FOR A SAFE HYDROGEN ECONOMY: UNDERSTANDING HYDROGEN'S IMPACT ON MATERIALS INTEGRITY THROUGH CRITICAL EXPERIMENTS

Afrooz Barnoush[1], Qingyang Liu[2], Tarlan Hajilou[3], Yun Deng[3], Bjørn Rune Rogne[4], Iman Taji[5], [6]Shabnam Karimi[6]
[1] SLB, Midstream Production System, Bergen, Norway
[2] Qatar Environment Energy Research Institute, HBKU, Qatar
[3]DNV, Norway
[4]Mantena Nordic, Trondheim, Norway
[5]ArcelorMittal Global R&D Gent, OCAS NV, Belgium
[6]Østfold University College, Fredrikstad, Norway

Corresponding author's e-mail address: abarnoush@slb.com

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ABSTRACT

Due to its small size, hydrogen exhibits high mobility at room temperature in metals and alloys. The hydrogen mobility is also affected by the local stress field in the material. On the other hand, hydrogen can interact and trap in different crystal defects in alloys. The hydrogen trapping energy depends on the type of the defect. This can result in a non-uniform distribution of hydrogen within the microstructure and its local enrichment. Further, during the mechanical loading of metallic components in contact with hydrogen or hydrogen sources, the stress distribution in the lattice becomes a driving force for the redistribution of the hydrogen in the microstructure. Further, the stress fields affect the dynamics of the crystal defects, i.e., generation and mobility of the defects, and cause hydrogen to dynamically redistribute and concentrate at specific locations, creating hot spots with high hydrogen concentrations. These hot spots are formed spatiotemporally within the microstructure, leading to cracks when hydrogen concentration and stress levels become high enough. Conventional macroscopic mechanical tests cannot accurately reflect these distributed hot spots and cracks, as they only measure the cumulative impact over time, which manifests as a loss of ductility. To better understand the hydrogen effect on mechanical properties, it is necessary to isolate and study these hot spots at various length scales by critical experiments. To achieve this, we developed mechanical testing methods that examine the interaction of hydrogen with different types of defects and their behavior under hydrogen influence. We have made a comprehensive overview of the work done in the past 20 years to gain insight into the hydrogen effect on mechanical properties at various length scales. This has been only half of the challenge in the quest for deciphering the hydrogen embrittlement mystery. The other half is to detect and measure the hydrogen quickly and reliably to avoid any interaction of the hydrogen dynamic in the metal with the hydrogen measurement. To realize this we recently developed methods based on Glow Discharge Optical Emission Spectroscopy (GDOES) for rapid, reliable quantification of hydrogen in the microstructure, which will be presented in this talk.