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The synergistic action of HELP and HEDE mechanisms of hydrogen embrittlement in steels

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Abstract

Hydrogen effects and provoked degradation of mechanical properties are expressed in diverse and often in opposite ways depending on three main factors: material, mechanic, and environmental. The deleterious and often multifaceted effects of hydrogen on the mechanical properties of different metallic structural materials, including different grades of steel has been confirmed in numerous studies. Simultaneous action in a cooperative manner of the hydrogen-enhanced localized plasticity (HELP) and hydrogen-enhanced decohesion (HEDE) mechanisms (HELP+HEDE model) of hydrogen embrittlement (HE) were detected and fully confirmed experimentally to be active, depending on the local concentration of hydrogen in steel [1-3], and not only through simulation and modeling. However, critical evaluation and quantification of the synergy between the HELP and HEDE mechanisms, and their combined effects on various macromechanical properties, still does not exist. The recently proposed HELP+HEDE model of HE is based on the correlation of mechanical properties to SEM microscopy fractography analysis of fracture surfaces in the presence of simultaneous action in a cooperative manner of the HELP and HEDE mechanisms of HE depending on the local concentration of hydrogen [3]. Particular emphasis is given to the proposal of the novel and unified HELP + HEDE model based on the specific microstructural mapping of the dominant HE mechanisms with implications on the fracture process and resulting hydrogen-assisted fracture modes [3]. This presentation provides recent results and the current state of the art in understanding in overview-form of critical discussion about the synergistic action and interplay of HE mechanisms in steels and iron, experiments, and models. Also, the effect of hydrogen on the material mechanical properties and ductile to brittle fracture transition resulting from the concurrent and synergistic (HELP+HEDE) or due to the competing action of HELP and HEDE mechanisms is discussed. The proposed model should enable enhanced predictive maintenance of industrial component systems.

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[3] **M.B. Djukic**, V. Sijacki Zeravcic, G.M. Bakic, A. Sedmak, B. Rajicic, The synergistic action and interplay of hydrogen embrittlement mechanisms in steels and iron: Localized plasticity and decohesion, Engineering Fracture Mechanics **216** (2019), p. 106528.