1st Biennial ESIS-CSIC Conference on Structural Integrity
(BECCSI 2025)

November 25-28, 2025, Metropol Palace, Belgrade, Serbia

HYDROGEN EMBRITTLEMENT MECHANISMS IN METALS: NEW INSIGHTS

Milos B. Djukic[1,*]

[1] University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, Belgrade 11120, Serbia
*mdjukic@mas.bg.ac.rs

Abstract

The unified HELP+HEDE model is a comprehensive concept that explains the synergy of hydrogen embrittlement (HE) mechanisms in metallic materials. This model involves the interplay and competence between two groups of HE mechanisms: HELP and/or other plasticity-mediated HE mechanisms, and the HEDE mechanism. The confirmed competition and transition in dominance between hydrogen provoked localized plasticity, i.e., hydrogen-induced dislocation activity (HIDA), HE mechanisms (HELP and others), and HEDE, depending on the global/local hydrogen (H) concentration and distribution, microstructural characteristics, and stress state, are of utmost importance to achieve a unified model for HE in metals. The recently updated unified HELP+HEDE model introduced the novel concept of "local HEDE micro-incidents," which refers to the appearance of discrete micro-scale incidents, i.e., hydrogen-induced crack initiation, at a high local H concentration above the critical one, particularly at "HEDE-prone H traps" within the microstructure. For the shift from HELP to HEDE macroscopic predominance, followed by a sharp drop in ductility, the necessary prerequisite is the macro-volume appearance of "local HEDE micro-incidents". In that case, the degree of activity of the HELP mechanism and other plasticity-mediated (HIDA-type) HE mechanisms can become negligible. This talk presents new insights into the unified HELP+HEDE model, including the innovative concepts of "local HEDE micro-incidents" and "HEDE-prone H traps", which highlight its significance in the fundamental understanding of HE phenomena in metals.

Keywords
Hydrogen embrittlement; Metallic materials; HELP; HEDE, Hydrogen-induced crack initiation