MM 19: Topical Session: Hydrogen in Materials: from Storage to Embrittlement II

Time: Tuesday 10:15–11:30 Location: C 130

Topical Talk MM 19.1 Tue 10:15 C 130

Hydrogen-Induced Fracture Behavior in Cr-Mo Low Alloy Steel: In-situ ETEM Insights on Crack Propagation — •Lin Tian[1], Masanobu Kubota[2], Petros Sofronis[2,3], Reiner Kirchheim[1,2,4], and Cynthia A. Volkert[1,2,5] — [1]Institute of Materials Physics, University of Göttingen, Göttingen, Germany — [2]International Institute for Carbon Neutral Energy Research, Kyushu University, Fukuoka Japan — [3]Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, Urbana, USA — [4]Max-Planck-Institute for Iron Research, Duesseldorf, Germany — [5]The International Center for Advanced Studies of Energy Conversion (ICASEC), University of Göttingen, Göttingen, Germany

Taking advantage of an in-situ fracture test method inside an environmental transmission electron microscope (ETEM), the fracture behavior of a Cr-Mo low alloy steel is examined. Through controlled gas environments, we compared the fracture behavior of samples in vacuum and in hydrogen gas. In vacuum, the sample fractures by void nucleation and coalescence showing typical ductile fracture behavior. It is found that the ferrite matrix is the major void initiation site due to the low stress triaxiality in the thin sample. However, in the presence of hydrogen gas in the TEM chamber, clear evidence of hydrogen embrittlement is observed. The crack tip in hydrogen gas remains sharp and propagates by the formation and linking up of staircase-shape micro-cracks, without much associated plasticity. We will discuss possible contributions to embrittlement from the effect of hydrogen on (i) dislocation formation and mobility, and (ii) lattice decohesion.

MM 19.2 Tue 10:45 C 130

Microstructure-based modeling of fatigue damage of ferritic steel in hydrogen environments using crystal-plasticity-FEM simulation — •Alexandra Stark[1], Wolfgang Verestek[1], Petra Sonnweber-Ribic[1], and Christian Elsässer[2] — [1]Robert Bosch GmbH, CR, Renningen — [2]Fraunhofer IWM, 79108 Freiburg

Hydrogen Embrittlement (HE) of ferritic steels is a long and well-known phenomenon. Depending on its environment the material may be prone to a premature mechanical failure. In real world service, steel components are frequently exposed to cyclic loading. Therefore, with increasing relevance of hydrogen-related technologies, handling the influence of hydrogen on the fatigue behavior of steel is of growing interest.In the complex phenomenon of metal fatigue, one of the main factors that determine the lifetime is attributed to the microstructure of the metal. A well established approach to describe microstructural influences on the mechanical behavior of metals is the crystal plasticity (CP) theory [1]. CP finite element methods (CP-FEM) are useful to investigate fatigue damage in the material by a microstructure-sensitive modeling. In the present work, a diffusion coupled crystal plasticity model is used to investigate the influence of hydrogen on the fatigue behavior of a ferritic steel. Within this model the mechanical properties of the material are characterized by local hydrogen concentrations based on proposed HE-failure mechanisms. The study addresses the impact of environmental conditions and internal hydrogen concentrations on HE and investigates the influence on the prediction of fatigue damage. [1] F. Roters et al. Acta mater 58.4 (2010): 1152-1211

MM 19.3 Tue 11:00 C 130

Effect of retained austenite volume fraction on the hydrogen uptake and hydrogen embrittlement susceptibility of high-strength steels. — •Eric A.K. Fangnon and Yuriy Yagodzinskyy — Department of Mechanical Engineering, School of Engineering, Aalto University, P.O Box 11000, FI-00076, Espoo, Finland

Retained austenite (RA) is known for playing a dual role in the way hydrogen interacts with steels affecting their resistance or susceptibility to HE. In this study, we investigate the performance of five distinct high-strength steels with varying volume fractions of RA (0 - 35%) obtained from different alloying and heat-treatment processes. Electrochemical hydrogen charging under monotonic and cyclic loading modes was used to evaluate the steel's performance in hydrogenated conditions. In addition, the effect of RA on hydrogen uptake and phase transformation under load was investigated by thermal desorption spectroscopy, X-ray diffraction, and electron backscatter diffraction analysis. The Results show that there is a threshold at which the benefits of RA exist. After which the steels manifest severe susceptibility to HE as a function of RA volume fraction Via intergranular fracture modes for steels with higher contents of RA. Different hydrogen uptake and trapping were observed for the steels as a function of RA volume fraction, Load magnitude, and time. On phase transformation under load and continuous hydrogen charging, local variations in the measured RA that can be associated with the loading mode and hydrogen concentration were observed. γ-Fe into α-Fe may be specifically localized near the crack tips requiring further studies.

MM 19.4 Tue 11:15 C 130

Hydrogen Effect on the Activation Enthalpy of Plastic Deformation — •Florian Schaefer, Rouven Schneider, Lukas Hasenfratz, and Christian Motz — Materials Science and Methods, Saarland University, Campus D2 3, 66123 Saarbruecken, Germany

The strain rate sensitivity of a material arises from a thermally activated contribution to the rate-determining deformation process, e.g. to dislocation slip or dislocation grain boundary interaction. For instance, nanocrystalline f.c.c. metals exhibit an increased strain rate sensitivity compared to a coarse-grained equivalent due to the constraints on dislocation plasticity caused by the multitude of grain boundaries. In this study, the extent to which hydrogen affects thermally activated dislocation mobility and thus the strain rate sensitivity was investigated. For this purpose, specimens were charged in situ, both cathodically and by low-pressure hydrogen plasma, and subjected to nanoindentation, micropillar compression, and strain-rate jump macro-tensile tests, and the results were contrasted. Hydrogen is shown to increase the strain rate sensitivity of f.c.c. nickel but not in a b.c.c structural steel. The temperature was then varied to the cryogenic level. For this purpose, the macro strain rate jump tests were carried out in a bath cryostat combined with ex situ charging. The low temperature prevents from outgassing. The activation volume for plastic deformation in a head-to-head comparison between nanocrystalline and coarsely grained f.c.c. nickel as well as the b.c.c. structural steel shows that the rate-determining deformation mechanism seems to change for f.c.c. but not for the b.c.c. material.