MM 25: Hydrogen in Metals V: H in Steels

Time: Tuesday 11:45–13:15 Location: TC 006

Topical Talk MM 25.1 Tue 11:45 TC 006

An Industrial Perspective on Materials Design for Reduced Sensitivity to Hydrogen-Embrittlement — •Richard G. Thiessen and Oliver Rott — ThyssenKrupp Steel Europe AG, Duisburg, Germany

In order to improve efficiency, performance and safety in the automobile and transportation sector, manufacturers require materials with higher strengths while maintaining or improving their ductility. These demands are being met with extremely complex steels which exploit thermodynamically meta-stable phases to expand the property combinations. The resulting microstructures are challenging to characterize with even the most advanced techniques, let alone the investigation towards their interaction with hydrogen. Nevertheless, advances have been made in recent years in linking details in the microstructure to the behavior of hydrogen in these microstructures. The presented research aims to show some typical demands of modern advanced high strength steels, illustrate typical setups for the testing and measurement of hydrogen, and to correlate trends in the testing results with features in the microstructure. Furthermore, some suggestions and considerations will be given for the development of new steels with a reduced sensitivity to hydrogen-embrittlement.

MM 25.2 Tue 12:15 TC 006

Influence of hydrogen on the fatigue strength of ferritic stainless steel — •Andrej Turk[1], Georg Schauer[2], and Ferdinand Haider[3] — [1]Technische Universität München — [2]Robert Bosch GmbH — [3]Universität Augsburg

In this work the fatigue behaviour of 1.4005IA stainless ferritic steel is investigated. Stress S-N and strain S-N curves are obtained with respect to two parameters: load ratio R and surface residual stresses. Air-tested specimens are compared to specimens electrochemically precharged with hydrogen and tested in a gaseous hydrogen atmosphere of 10 bar. The fracture surfaces of broken specimens are analysed to determine the nature of the failure, its point of origin and how the surface is related to the experimental parameters. While such observations have been reported for a variety of high-strength steels and austenitic steels, little information on ferritic stainless steels is available to date. Additionally, TDS measurements of precharged specimens are carried out to investigate hydrogen distribution in the microstructure and hydrogen saturation kinetics. A review of hydrogen embrittlement mechanisms under static loading is given and used to evaluate the experimental results. The applicability of these mechanisms to cyclic loading conditions is discussed as well as their likelihood in this particular case.

MM 25.3 Tue 12:30 TC 006

Eigenschaftsdegradation durch H in schweißgeeigneten höherfesten Feinkornbaustählen unterschiedlicher Herstellungsverfahren — •Enrico Steppan, Arne Kromm und Thomas Kannengiesser — Bundesanstalt für Materialforschung und -prüfung

Der Einsatz schweißge. höherfester FKB ist aus wirtschaftlichen Gründen & dem Streben nach konstruktivem Leichtbau in vielen Industriezweigen unabdingbar. Das Potential einer Sensibilität gegenüber H-bedingter Eigenschaftsdeg. ist jedoch signifikant erhöht. Die mech.-technolog. Gütewerte moderner niedriglegierter höherfester FKB werden maßgeblich durch Ihre chem. Zus. und dem Herstellungsprozess beeinflusst. Hierdurch leiten sich mikrostrukturelle Unterschiede (Korngröße, Ausscheidungen, Versetzungen) ab. Aufgrund dessen wurden 2 höherf. FKB gleicher Festigkeitsklasse, jedoch unterschiedlicher Herstellung (vergütet Q/thermomechanisch MC), untersucht. Neben den makroskopisch beobachtbaren Merkmalen (Streckgrenzenerhöhung, Abnahme wahre Bruchdehnung und Bruchfläche) wurde das lokale Verhalten unter H in den Stählen mit Synchrotronstrahlung am HZB untersucht. Anhand H-beladener Zugproben wurde die Wechselwirkung des H mit dem Gitter untersucht. Hierzu wurden entsprechende Messungen während des Zugversuches im elast., elast./plast. und plast. Bereich vorgenommen. Grundlegende Unterschiede zwischen den verwendeten Stahlgüten bezüglich der H-degradation ließen sich somit anhand makroskopischer als auch mikroskopischer Merkmale erstmals belegen. Die erlaubt schließlich Rückschlüsse auf die grundlegenden Mechanismen der Eigenschaftsdeg. durch H.

MM 25.4 Tue 12:45 TC 006

The impact of carbides on the hydrogen trapping and embrittlement of Fe-C-X quenched and tempered alloys — •Tom Depover[1], Elien Wallaert[1], Zinedine Zermout[2], and Kim Verbeken[1] — [1]Department of Materials Science and Engineering, Ghent University, Belgium — [2]ArcelorMittal Global R&D Ghent, Zelzate, Belgium

The present work evaluates hydrogen trapping and embrittlement of different laboratory cast Fe-C-X alloys with various carbide forming elements (=X). Tempering generated X-based precipitates. The materials were examined under two conditions, as quenched and quenched and tempered. The hydrogen trapping capacity of the precipitates was investigated by thermal desorption spectroscopy, while melt extraction allowed to determine the hydrogen content after cathodic charging. In-situ hydrogen pre-charged tensile tests were performed to evaluate the hydrogen embrittlement susceptibility. The different carbides exhibited a variable effect on the hydrogen embrittlement behavior. For example, the Fe-C-Ti material embrittled the most and tempering even increased its susceptibility, whereas the opposite tendency was observed for the Fe-C-Cr grade. On the contrary, the resistance against embrittlement was good for all Fe-C-Mo alloys. Other carbide forming elements such as V, Nb and W were evaluated as well. All observations were correlated with thermal desorption spectroscopy and melt extraction results. It was also demonstrated that, by modifying the tempering treatment, the Ea of the traps could be increased and hence the HE-resistance of the material was improved.

MM 25.5 Tue 13:00 TC 006

Die Bestimmung von Wasserstoffverteilungen in Eisen und Stahl mittels Neutronenradiographie und -tomographie — •Axel Griesche, Thomas Schaupp und Thomas Kannengiesser — BAM Federal Institute for Materials Research and Testing, Berlin, Germany

Wir zeigen die Ergebnisse von neutronentomographischen Messungen von Wasserstoffverteilungen in zentimeterdicken Stahl- und Eisenproben. Es gelang die Messung von Wasserstoffverteilungen an Rissflanken in wasserstoffversprödeten Eisenproben [1] mit einer Ortsauflösung in den rekonstruierten 3D-Modellen von ca. 25E-6 m. Dabei konnte auch erstmals gasförmiger Wasserstoff in den Hohlräumen der Risse nachgewiesen und dessen Druck bestimmt werden. Die verwendete Messmethode wird der häufig verwendeten Trägergas-Heißextraktion gegenüber gestellt [2]. Die Neutronenmessungen wurden an den Forschungsreaktoren BER II des HZB in Berlin und FRM II der Neutronenquelle Heinz Maier-Leibnitz in Garching durchgeführt.

[1] Griesche A, Dabah E, Kardjilov N, Hilger A, Manke I, Kannengiesser T, Three-dimensional imaging of hydrogen blister in iron with neutron tomography, Acta Mater 78 (2014) 14

[2] Griesche A, Solórzano E, Beyer K, Kannengiesser T, The advantage of using in-situ methods for studying hydrogen mass transport: Neutron radiography vs. carrier gas hot extraction, Int J Hydrogen Energy 38 (2013) 14725