INDUSTRIAL PILOT PROJECT

Characterisation of hydrogen and strain interactions in the microstructure of duplex stainless steel using x-ray diffraction

THE INDUSTRIAL CHALLENGE

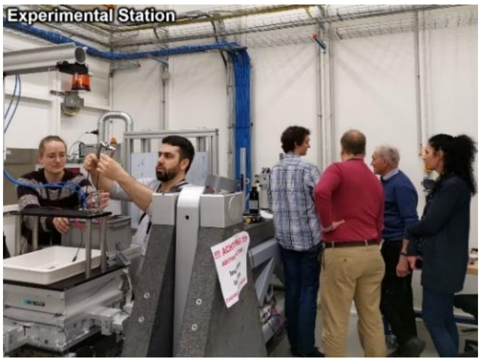
Duplex stainless steels have experienced some failures in subsea applications when subjected to cathodic protection. This is due to hydrogen-induced stress cracking, a type of hydrogen embrittlement failure. Since only large components such as forgings have had failures, but not smaller components such as seamless tubes, this has been linked to the coarseness of the microstructure. Understanding the effect of hydrogen on microstructural degradation of advanced stainless steels has however remained challenging.

WHY USING A LARGE SCALE FACILITY?

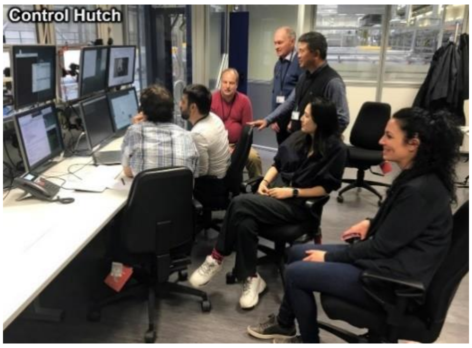
The strains in the microstructure associated with hydrogen infusion are very small (sub-Ångstrom metre) which require ultra-high-spatial-resolution measurement of the lattice parameters (sub-Ångstrom). Hydrogen mobility in microstructures is ultra-high, and to study hydrogen-metal require rapid testing while the material of interest is under mechanical loading. While the use of more traditional experimental techniques can't provide sufficient knowledge, synchrotrons enables x-ray diffraction measurements with ultra-high spatial and temporal resolution.

HOW THE WORK WAS DONE

The investigation of the early stages of hydrogen-induced material degradation on commercial duplex stainless steel was carried out with high energy XRD with low angels for surface characterization as well as layer by layer for effects of hydrogen ingress and strains through the material.



This was done under in operando conditions. The Swedish beamline P21.2 at the German synchrotron Petra III (DESY) in Hamburg was used. The conditions were strained material in sodium chloride with a cathodic protection potential imposed. The work was performed by the partners and beamline scientists at DESY (Dr Timo Müller and Dr Ulrich Lienert) present.



The results were correlated with data obtained from various laboratory techniques (EIS, AFM and SKPFM).

THE RESULTS AND EXPECTED IMPACT

The main results were the development of an experimental method and adjustments of an in-situ cell for the P21.2 beamline. Obtained data indicate that this method is promising to for investigation of microstructural influence on hydrogen degradation. The results showed that hydrogen leads to the development of tensile strains in the microstructure and that most strain evolution were concentrated on the surface region where hydrogen first entered the material. More strains were developed in the austenite phase than the ferrite phase during hydrogen charging. The outcome has improved our understanding of material degradation in earliest stages due to hydrogen infusion in stainless steel. The collaboration has set up a network with multi-disciplinary focus on material research for tomorrow's materials. The collaboration has further enabled access to large-scale synchrotron facilities with a special focus to meet industrial demands, which will be utilized for further experiments.

Contacts: Ulf Kivisäkk – Sandvik Materials Technology, ulf.kivisakk@sandvik.com
Jinshan Pan – KTH Royal Institute of Technology, jinshanp@kth.se

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