LSI SUPPORT FOR PhD-STUDENTS IN APPLIED AREAS

# Using in-situ neutron imaging to better understand hydrogen embrittlement in modern high strength steels

**THE PURPOSE OF THE PHD PROJECT**

Hydrogen embrittlement is a phenomenon where mechanical toughness and strength of a metal are degraded by the presence of small amounts of hydrogen (H) in the atomic lattice. Most engineering alloys are susceptible to this form of degradation. The problem is accentuated in modern high-strength steels where it is a major limiting factor for usability and one of the main challenges for the development of next generation of high strength steels. It is an active R&D area for SSAB.


Dahlberg, Lindblom, Halilovic and Woracek (behind camera) at ILL in September 2021.

**USING A LARGE SCALE INFRASTRUCTURE**

Hydrogen embrittlement was first described over 150 years ago but is still poorly understood. The main issue is that H atoms are small, light, mobile, have a small electron and x-ray cross section, and diffuse easily. This means that they cannot be seen by either standard imaging or diffraction techniques, and that they are easily provoked into moving around and leaving or entering a sample. Therefore direct evidence of how H distribute or interacts to cause the degradation is lacking.

Contrary to x-rays and electrons, neutrons will interact strongly with H. The attenuation from H is about 4 times more than from Fe, thereby enabling spatially resolved neutron transmission imaging of H in steel. Since any local concentration of H is believed to be very small, we needed to use a facility where we would get the best signal-to-noise ratio and a large flux of neutrons.

We got 72 hours of beamtime at the experimental station for Neutron and X-ray Tomography (NeXT) of Institut Laue Langevin (ILL) in Grenoble.

**RESULTS AND IMPACT**

We got spatially and temporally resolved imaging data of our specimens under mechanical load at different levels of embrittlement. We also imaged and quantified intermittent crack propagation under static load. This is direct, and quantitative, evidence for so called delayed hydrogen cracking and also indirect data for the dynamics of H redistribution. Additionally, we observed a small region with slightly larger attenuation that could correspond to a local H concentration in front of the crack tip. The analysis is however complicated by an unusual crack propagation path and further experiments will be required to make a definitive conclusion regarding that signal. One important outcome was that we now know much better the conditions and limitations of our experimental setup. This will allow us to improve and optimize it for our planned future experiments. The PhD students got valuable know-how regarding neutron imaging techniques, how to write beamtime proposals and how it is to do experiments at an LSI.

Experiment setup at NeXT. Specimen is under mechanical load during electrochemical charging before neutron imaging.

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