INSTITUT NATIONAL DES SCIENCES APPLIQUÉES CENTRE VAL DE LOIRE

GREMAN

Master 2 Internship

hydrogen embrittlement of steels using the ultrasonic method

The development of hydrogen is a major way of reducing CO2 emissions into the atmosphere. However, the development of this sector presents major technological challenges in terms of production methods, storage and transport. Hydrogen is stored or transported in steel tanks or pipes, which are subject to specific constraints due to the very nature of hydrogen. Placed in such an environment, steel undergoes an embrittlement and degradation mechanism linked to the absorption of hydrogen within it. This degradation results in a reduction in ductility and load-bearing capacity, which can lead to cracks or brittle fractures at stresses below the usual elasticity limits of steels. This is known as hydrogen embrittlement. Characterising this degradation is therefore a key factor in the safety and reliability of hydrogen storage and transport systems.

Given the significant industrial challenges, the study of hydrogen absorption in steels is widely researched. One method widely used to study this phenomenon is electrochemical charging. The application of a potential difference between the steel sample and a counter electrode promotes hydrogen adsorption by reduction, which then diffuses into the steel. After charging, the samples are characterized to highlight changes in mechanical and structural properties. However, as the samples quickly release hydrogen, some of it is desorbed between the end of the charging process and the characterization. Exploring the possibility of coupling the measurement of mechanical properties simultaneously with the charging process would add real value.

Among the possible methods for characterizing mechanical properties, ultrasonic methods, which involve sending a wave through the medium, are well-known and widely used in both industrial and laboratory settings. If hydrogen charging in steel modifies its structural properties, it is then possible to detect this charging by measuring the variation in the speed of ultrasound waves through the sample.

To our knowledge, no in-situ characterization during hydrogen charging has been performed to date. Our objective is therefore to couple ultrasonic and electrochemical measurements to monitor, in real time, the hydrogen absorption of steels and provide an in-situ indication of hydrogen charging. During a previous Master’s internship, we were able to set up instrumentation that allowed this simultaneous measurement over periods of 36 to 48 hours in a non-thermostated environment. We achieved a precision of less than 1 m/s in measuring the velocity of ultrasound waves in steel. However, given the absorption kinetics, which take about one to two weeks, we cannot guarantee that the velocity variations measured are representative of hydrogen absorption leading to changes in the acoustic properties of steel.

The goal of this internship is therefore to confirm these initial measurements by ensuring the reliability of all measurement protocols over these experimental durations and even over longer periods. The expected velocity variations are on the order of 0.1%, requiring precision metrology where all external parameters, particularly temperature, must be taken into account. This sensitivity will be evaluated.

The proposed work will be organized around the following tasks:

- Procure reference steel materials, reference electrodes, and counter-electrodes.

- Ensure the reliability and optimization of ultrasonic measurement protocols and hydrogen charging protocols. The design and construction of a thermostated tank will be considered.
- Develop a user interface for real-time measurements of acoustic properties, taking into account temperature effects.
- Conduct measurement campaigns over several days.
- Correlate the variations in ultrasonic properties with mechanical tests: tensile tests and hardness measurements.
- Compare the results obtained with hydrogen charging measurements conducted using eddy current control methods specifically developed at Tohoku University.

The work will be carried out in collaboration with the MATEIS Laboratory at INSA Lyon and the ELyTMaX Laboratory at Tohoku University in Japan, which will produce the samples and provide their expertise on hydrogen diffusion mechanisms in steels.

Required profile: Master's level (Engineering School or University), background in Applied Physics/Electronics, Instrumentation, skills in signal processing, wave physics, and programming.

Application: send a detailed CV and covering letter by email.

Beginning of the internship : Feb/march 2025

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