Study of hydrogen embrittlement of steels using ultrasonic methods

Hydrogen embrittlement is a degradation mechanism involving the penetration of hydrogen into steel that can reduce ductility and load-bearing capacity, leading to brittle cracks and fractures at stresses below the yield strength of steel materials [1-2].

Various non-destructive testing (NDT) methods exist to monitor the integrity of structures during use. The propagation of acoustic and elastic waves in a finite medium with low attenuation gives rise to complex signals containing quantitative and qualitative information on the properties of the medium. Consequently, appropriate data extraction techniques can be advantageously exploited for structural characterization.

This internship aims to study the mechanism of hydrogen embrittlement in steels. The aim will be to demonstrate that ultrasonic methods [3] offer a relevant means of highlighting a change in the structural properties of steels linked to the presence of hydrogen. The work will be carried out in collaboration with the MATEIS Laboratory at INSA Lyon and the ELyTMaX Laboratory at Tohoku University in Japan, who will produce the samples and contribute with their expertise on hydrogen diffusion mechanisms in steels.

The proposed work will be organized according to the tasks defined below:
First,

- A study and analysis of the bibliography and existing methods.
- Typical samples will be of the order of a millimeter thick and a few centimeters square. The aim will be to develop and/or adapt existing ultrasonic wave transmission/reflection devices for measuring the velocity and attenuation of longitudinal ultrasonic waves. It may also be possible to examine the transverse component of ultrasonic waves.
- Working on several reference samples with the same characteristics will enable us to assess measurement variability, as well as the accuracy of the methods used.
- Once the system has been set up, characterizations will be carried out on healthy steel samples whose hydrogen exposure rate has been controlled. Eventually, polymeric materials may also be characterized as part of this work.
- The results will be discussed and analyzed, particularly regarding the sensitivity to variations in hydrogen loading. They should enable us to examine structure-property relationships and propose an ad hoc model assessing steels' structural transformation rate as a function of hydrogen loading duration.

In the second phase, if the tools put in place validate the ultrasound methods. The aim will be to develop an imaging system based on a 64-channel open ultrasound scanner, as well as :
- get to grips with the imaging system

- develop an imaging module for steels, including beam-forming aspects
- Carry out the test on various reference and degraded samples.

Location :
The internship will occur at the GREMAN acoustics and piezoelectricity laboratory at INSA Centre Val de Loire in Blois. More details on the laboratory: https://greman.univ-tours.fr

Beginning of the internship: Feb/march 2024, duration 4 to 6 months. The intern will receive a grant of approximately 550€ per month.

Profile.

This internship is intended for a Master 2 student (Engineering School or University), with a background in acoustics, Applied Physics/Electronics or Instrumentation. Skills in signal processing, wave physics and programming will be appreciated.

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References :

1. Fan, Y.H.; Zhang, B.; Yi, H.L.; Hao, G.S.; Sun, Y.Y.; Wang, J.Q.; Han, E.-H.; Ke, W. (2017). The role of reversed austenite in hydrogen embrittlement fracture of S41500 martensitic stainless steel. Acta Materialia, (), S1359645417306547–. doi:10.1016/j.actamat.2017.08.011
2. Dwaipayan MALLICK Hydrogen Behavior in First and Second Generation of Advanced High Strength Steels THESE de DOCTORAT DE L'UNIVERSITE DE LYON 2020.
3. R. J. Kažys, L. Mažeika, V. Samaitis, R. Šliteris, P. Merck, and Ž. Viliūnas, "Comparative Analysis of Ultrasonic NDT Techniques for the Detection and Characterisation of Hydrogen-Induced Cracking," Materials, vol. 15, no. 13, p. 4551, Jun. 2022, doi: 10.3390/ma15134551.