PhD offer (2024-2027)

Title: Hydrogen - metallurgical defects interactions and their consequences on the diffusion and trapping processes of hydrogen in carbon steels

Supervising team:
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Start of the thesis: September-October 2024

The thesis is part of the project funded by the ANR (https://anr.fr/) entitled “Hydrogen in Steels – A scale transition problem - HYSTYLE” (consortium: GPM - Univ. Rouen, LaSIE – Univ La Rochelle, MATEIS – INSA Lyon, IJL – Lorraine, IM2NP – Aix Marseille) and dedicated to a better understanding of the influence of hydrogen on the behavior of steels.

Context

Metal alloys are essential materials at all levels for the production, storage or transport of hydrogen. The goal of this project is to enhance fundamental knowledge on the interactions at atomic scales between hydrogen and crystalline defects or carbides in steels. This is a topic with a high impact since it is linked to hydrogen embrittlement, a phenomenon with major industrial consequences. Several phenomenological models already exist, they are mainly based on these hydrogen/defect interactions. However, many unknowns remain about complex or dynamic configurations when other solutes are present (such as carbon in solid solution) or when dislocations interact with carbides.

Thesis objectives

As part of this thesis work, we will attempt to study the interactions between hydrogen, carbon and defects in martensitic steels, model microstructures often encountered in industry. The advantage of this structure is that we can vary the metallurgical states and the distribution of crystalline defects (solutes, dislocations, vacancies and austenitic grain boundaries) as well as carbides and precipitates by heat treatments. These states will be characterized by several techniques (in situ XRD-synchrotron, and ex-situ by laboratory techniques - XRD, EBSD, TEM, SEM-FIB-EDS), then we will evaluate the influence of these metallurgical heterogeneities on the solubility, diffusion and trapping of hydrogen using different experimental approaches (electrochemical permeation, charging, TDS dosage, SKPFM). Then, we will question the impact of these interactions on local mechanical properties with instrumented ex situ nanoindentation tests coupled with hydrogen charging tests. The expected results will be input data to model H-crystalline defect interactions with theoretical and numerical approaches at the atomic scale (ab initio, DFT, KMC), then converge to larger scales using simulation by finite elements.

Keywords: Martensitic steels, Hydrogen, Crystal defects, Segregation, Diffusion and trapping, Electron microscopy, electrochemical permeation, HEXRD, Structure/property relationships

Required profile

- Candidate with an engineering degree and/or a master's degree.
- Rigorous, conscientious, dynamic, curious, creative and cooperative, with a synthesis mind and a marked appetite for research.
- Solid knowledge in materials science and physical metallurgy (phase transformations and relationships between microstructure and mechanical properties).
- Experience in a project involving microstructural characterization, measurement of mechanical properties and a study of structure/property relationships in a metallic alloy would be highly appreciated.
- Good written and oral communication skills, and mastery of the English language.

Host laboratories

The thesis will be based at the Laboratory of Engineering Sciences for the Environment UMR CNRS 7356, located at La Rochelle University

Part of the thesis work will take place at the Jean Lamour Institute (IJL) - UMR CNRS 7198 located at the University of Lorraine in Nancy where various stays are planned.

As part of the "Hydrogen in steels – A problem of transition scales - HYSTYLE" project, travel for scientific meetings will also take place in the other laboratories of the consortium.

Contacts and application

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