HYSCORE - Hydrogen Storage and Carriage as Opportunity for Renewable Energy Transition

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Motivation

To decrease Europe-wide CO_2 emissions and reduce reliance on fossil fuels, we need to replace current energy sources with renewable alternatives. Hydrogen is a promising option for widespread energy production, but its use requires a secure infrastructure for transport and storage. The existing European pipeline network, designed for gases and liquids, can be adapted for hydrogen transport.

Efficient distribution is crucial for hydrogen as an energy carrier. While steel pipelines are economical and reliable, transporting hydrogen through them poses challenges like embrittlement due to atomic hydrogen diffusion. This project aims to create a simulation-based framework for a comprehensive safety assessment of steel pipelines under hydrogen loading, addressing issues such as pressure variations based on gas energy density. This framework is expected to benefit future steel developments resistant to hydrogen-induced failure.

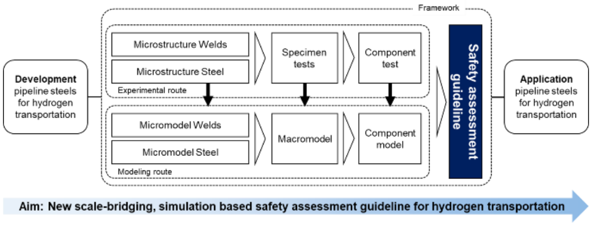

Figure 1: Project framework.

Objectives

The results obtained in this project will be used to screen the suitability of established guidelines (in absence of hydrogen) for weld defect acceptance on the one hand, and crack initiation and arrest on the other hand. Particularly, predictions from the parametric studies conducted using the probabilistic safety concept will be compared against existing guidelines. These will elucidate the potentially detrimental role of hydrogen on the structural integrity of (welded) pipelines. Adaptations to existing guidelines will be proposed, in which the effect of hydrogen is covered by well-chosen and well-dimensioned (on the basis of all results obtained) correction factors to either the input or the output of those guidelines. Finally, our recommendations will be translated into a report, which is the basis for further discussions with relevant standardisation workgroups.

Tasks

Within this project, Soete Laboratory is coordinator of two main work packages, (WP).

WP8: Development of approaches for scale bridging

This WP aims at extension and implementation of material model developed in previous work packages to a finite element (FE) model of a pipeline section containing a defected girth weld, with attention for the description of heterogeneous weld, Heat Affected Zone (HAZ) properties in terms of mechanical properties and hydrogen embrittlement sensitivity.

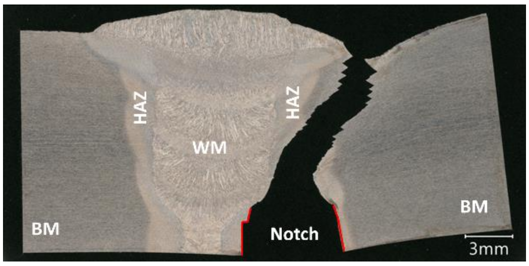

Figure 2: Defected girth weld, notch located at HAZ.

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Furthermore, it deals with optimization of the balance between computational time and accuracy for numerical predictions of hydrogen assisted damage in large pipeline sections.

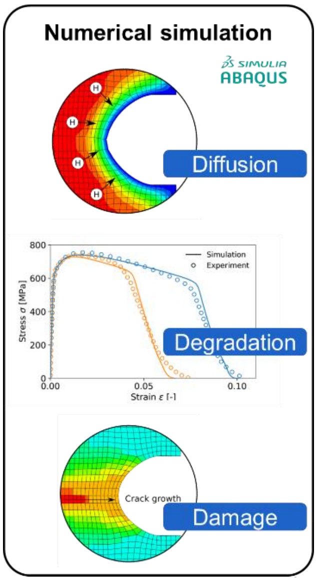

Figure 3: Damage model on hydrogen embrittlement, WP8.

WP 10: Transfer to safety assessment guidelines

Creating a deterministic guideline for weld defect acceptability is the primary focus, leveraging the probabilistic safety concept established in previous WPs. Likewise, within this WP, it aims to develop a deterministic guideline for crack initiation/arrest, utilizing the insights gained from the probabilistic safety concept developed in previous WPs.

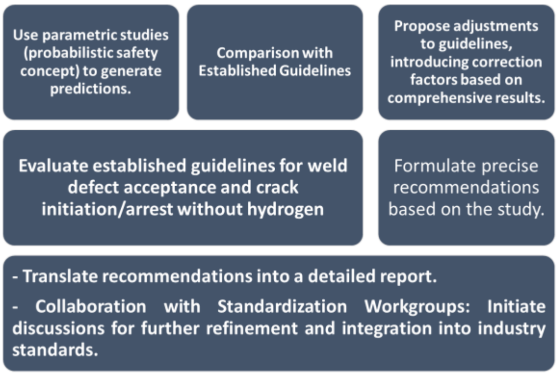

Figure 4: Strategy to approach WP10.

APPROACH

Hydrogen induced damage of welds containing potentially local brittle zones will be enabled by developing a hydrogen level dependent criterion for brittle fracture through FE simulations. The simultaneous implementation of this criterion and the model developed in previous WPs will allow to describe transitional failure, and the detrimental effect of hydrogen thereon.

Cohesive zone modelling (CZM)

The CZM is used relying on the mode-I crack tip loading to describe the brittle aspect of transitional fracture.

In this project, since the aim is to achieve a more accurate representation of transitional fracture behaviour, thus, it will be accomplished through the implementation of a semi-empirical procedure, grounded in calibration testing conducted at different hydrogen levels.

Calibration and Validation

Then, the FE model will be applied to girth welded connections. This will encompass the development of a component scale FE model in which the elements within and near the weldment are assigned specific material properties according to their location. Doing so allows to simulate the effects of weld heterogeneity (in terms of strength, toughness, hydrogen diffusivity and/or hydrogen embrittlement sensitivity) on defect tolerance. The model will be calibrated for various microstructures of the HAZ.

For the calibration purpose of crack initiation/propagation model, a set of experimental tensile tests will be performed on different specimens including Notched Round Bar (NRB) specimens. The calibrated model will be validated on the basis of lab scale and full scale component tests. Hence, welded compact tension (CT) specimens will be tested in air and pressurized gaseous hydrogen, to screen the ability of the model to predict weld fracture in absence and presence of hydrogen embrittlement.

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