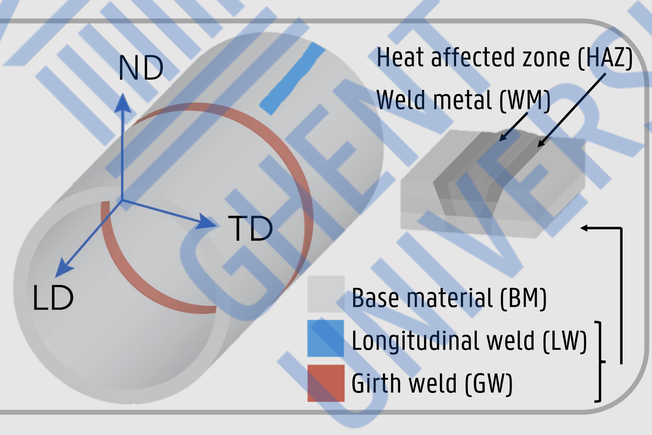
FACULTY OF ENGINEERING AND ARCHITECTURE
DEPARTMENT OF MATERIALS, TEXTILES AND CHEMICAL ENGINEERING
DEPARTMENT OF ELECTROMECHANICAL SYSTEMS AND METALS ENGINEERING
SUSTAINABLE MATERIALS SCIENCE
SOETE LABORATORY

FRACTOGRAPHY STUDY FOR SCREENING THE HYDROGEN COMPATIBILITY OF X70 PIPELINE STEELS AND WELDS

Lisa Claeys, Jubica, Laura De Pue, Stijn Hertelé, Wim De Waele, Tom Depover and Kim Verbeken

Introduction

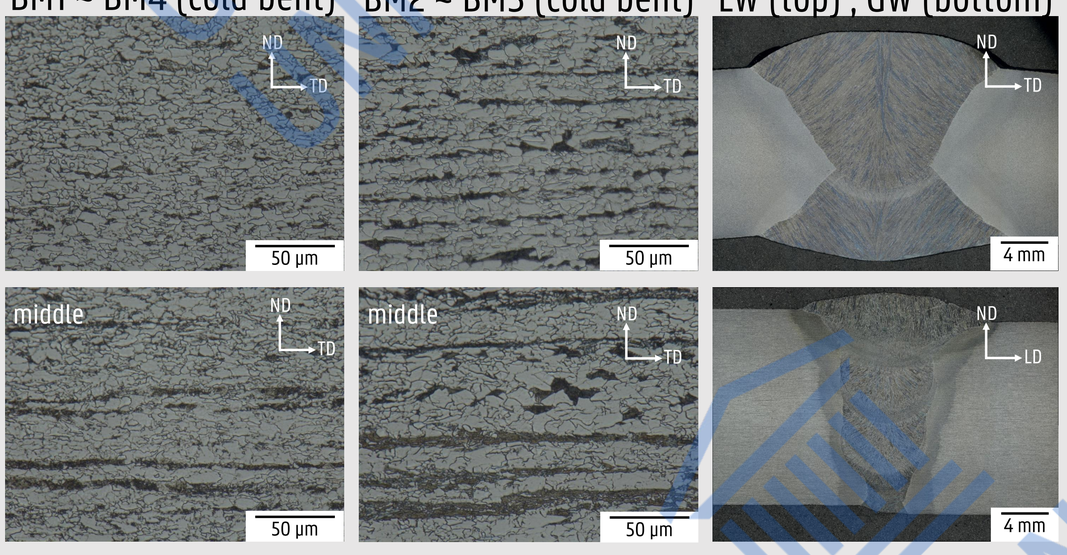
The natural gas **pipeline grid** that is currently in use will be partly **repurposed for transport of hydrogen** to decarbonize the energy landscape. Despite its necessity, evaluating fracture toughness and fatigue properties of pipeline steels in gaseous hydrogen at high pressures is very time consuming, needs to follow strict safety regulations and is thus expensive. Therefore, a **screening methodology** using **quasi-static tensile testing** is considered to evaluate the hydrogen embrittlement sensitivity of different X70 base materials and their welds in a relatively fast and less expensive way. **Fractography** analysis is an important asset with respect to the interpretation of the screening results.



Screening method

1. X70 base materials and welds

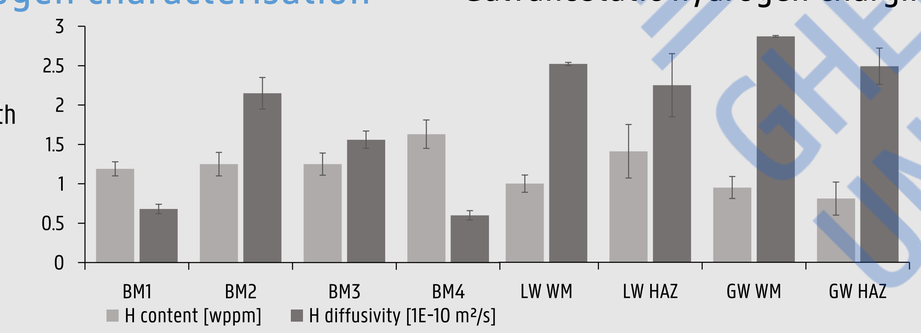
BM1 ≈ BM4 (cold bent) | BM2 ≈ BM3 (cold bent) | LW (top) ; GW (bottom)



2. Hydrogen characterisation

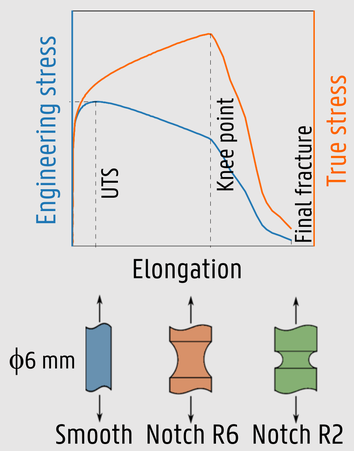
Galvanostatic hydrogen charging

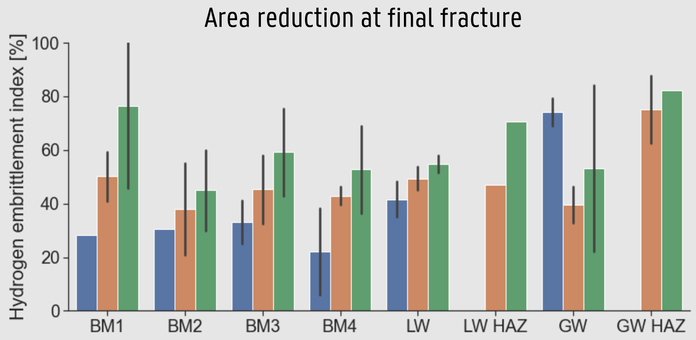
H content:
0.5M H_2SO_4 with
1 g/l thiourea
H diffusivity:
0.1M NaOH



3. Mechanical characterisation

Ex-situ quasi static tensile testing
0.5M H_2SO_4 with1 g/l thiourea

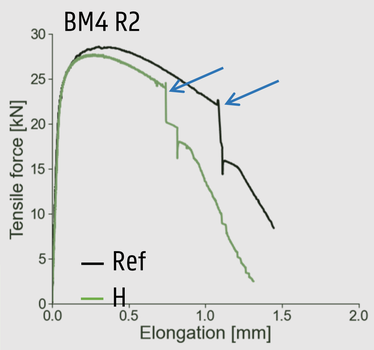


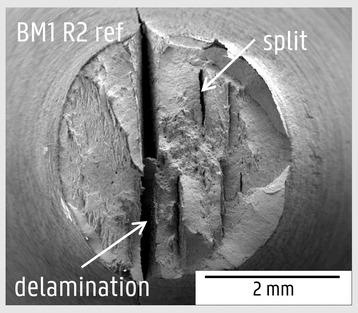


4. Database creation

Fractography analysis

General trends

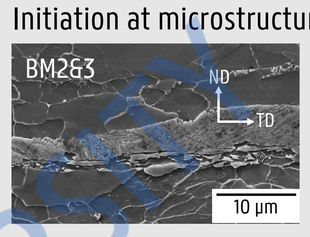


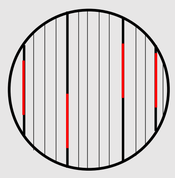


no splits or delaminations
few splits (<10)
many splits (>=10)
delaminations
splits and delaminations

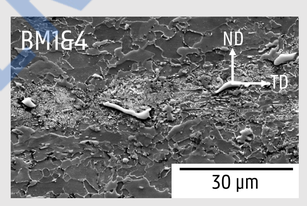
Splits and delaminations

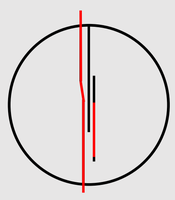
Initiation at microstructural bands (absent in weld)



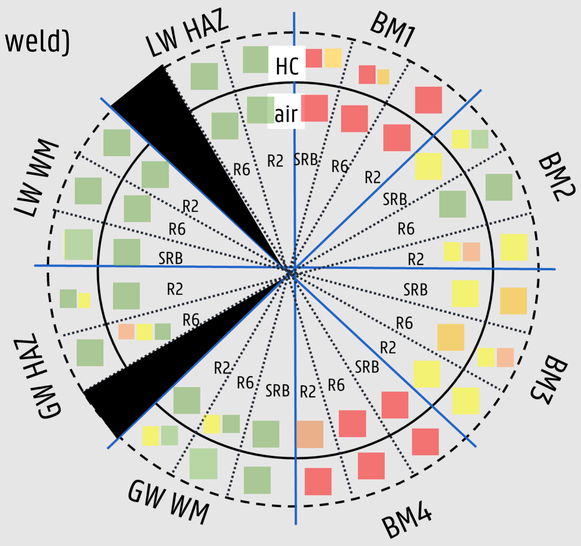


Hard bands all over thickness

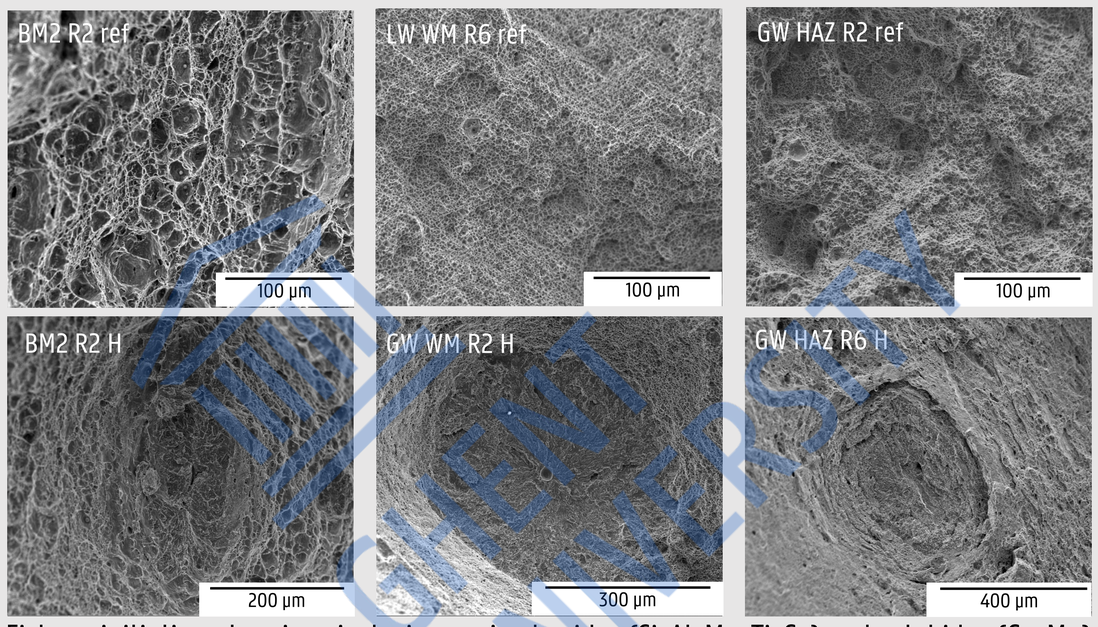




Segregation bands only in center



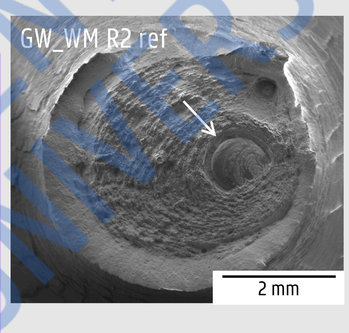
Dimples → dimples + fisheyes with quasi-cleavage (QC)

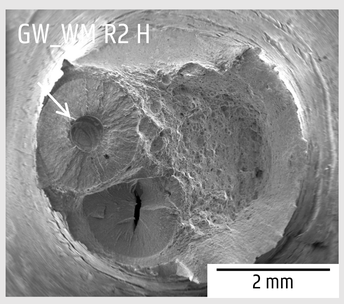


Fisheye initiation at various inclusions: mixed oxides (Si, Al, Mg, Ti, Ca) and sulphides (Ca, Mn)

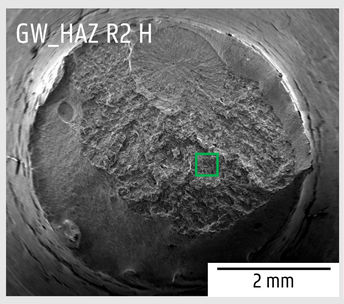
Weld-specific behaviour

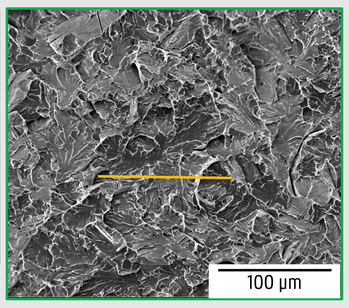
Weld flaw → pineapple slice with QC

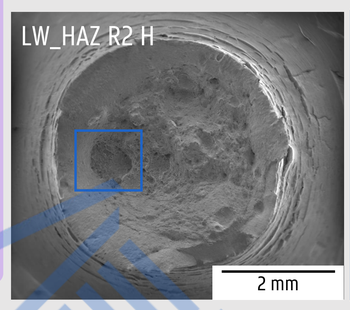


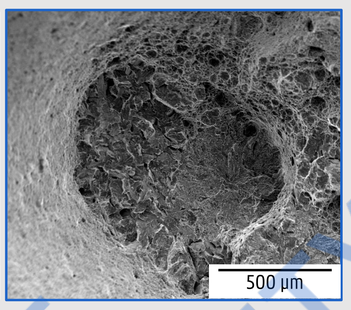


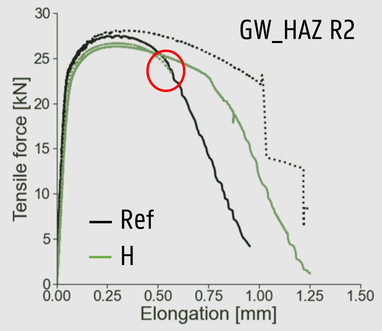
HAZ ustructure transgranular cleavage

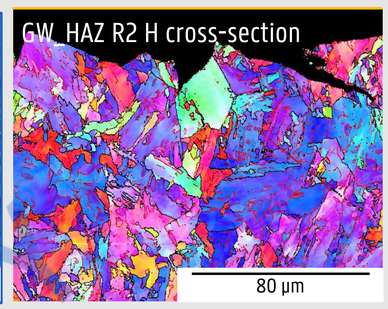












Conclusions

- The natural gas pipeline grid is characterized by a variety of pipeline steel and weld microstructures showing different responses to hydrogen exposure.
- Inclusions, segregation and hard bands, weld flaws and specific HAZ microstructures determine the fracture mechanism as revealed by the fracture surfaces after straining in hydrogen.
- Applicability of the screening method needs to be verified with gaseous hydrogen results. Most suitable EI could as such be defined.

GHENT UNIVERSITY
fluxys
economie

Contact:
Lisa.Claeys@ugent.be;
Tom.Depover@ugent.be;
Kim.Verbeken@ugent.be