FACULTY OF ENGINEERING AND ARCHITECTURE

DEPARTMENT OF MATERIALS, TEXTILES AND CHEMICAL ENGINEERING

SUSTAINABLE MATERIALS SCIENCE

CHARACTERISATION OF HYDROGEN-ASSISTED DEGRADATION OF A VINTAGE AND A MODERN PIPELINE STEEL

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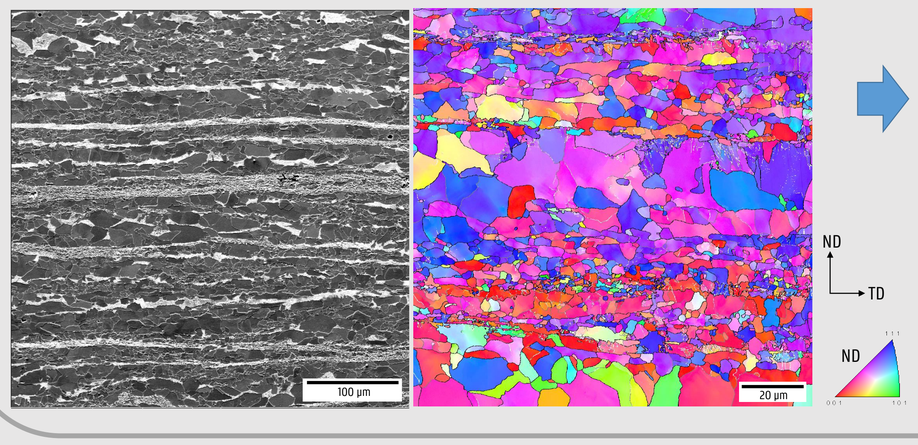
Introduction

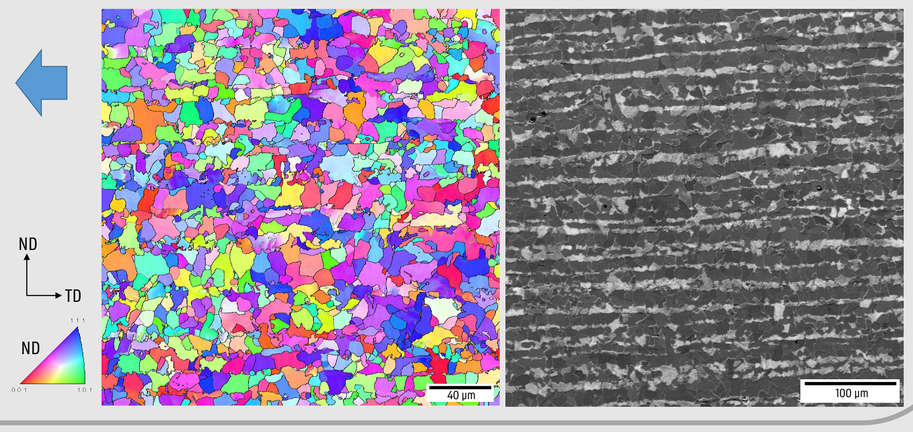
Hydrogen gas is a promising energy carrier in the transition to a low-carbon economy, with existing pipeline systems providing an economical means to store and transport H_2. However, atomic hydrogen is known to reduce toughness and promote cracking in steels. To evaluate mechanical degradation of pipeline steels by hydrogen, a series of tensile tests on smooth and double-notched round bar test specimens is performed.

Materials Characterisation

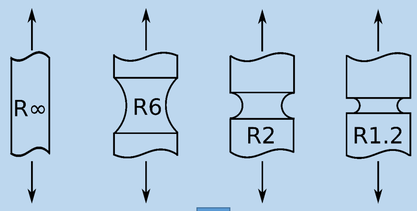
API 5L X70



API 5L X56



Electrochemical H precharging
+
Notched round bars with different notch radii



Loss of ductility

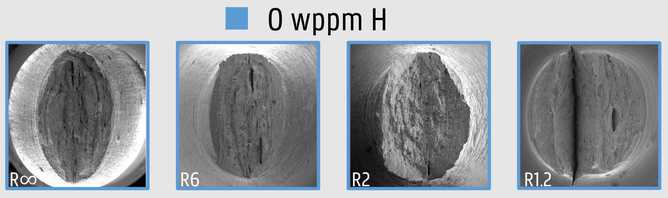
Quantified by Embrittlement Index

$$\frac{RA\%_{air} - RA\%_{hydrogen}}{RA\%_{air}} \cdot 100$$

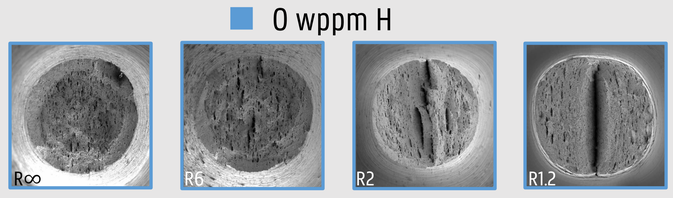
Tensile tests with ex-situ H charging

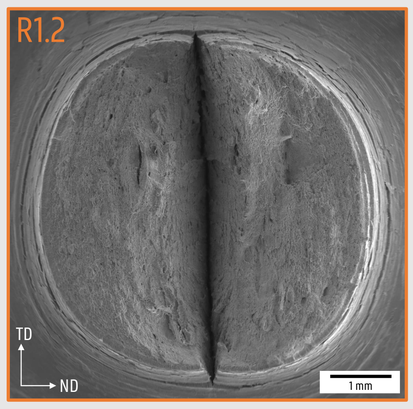
■ 0 wppm H

X70



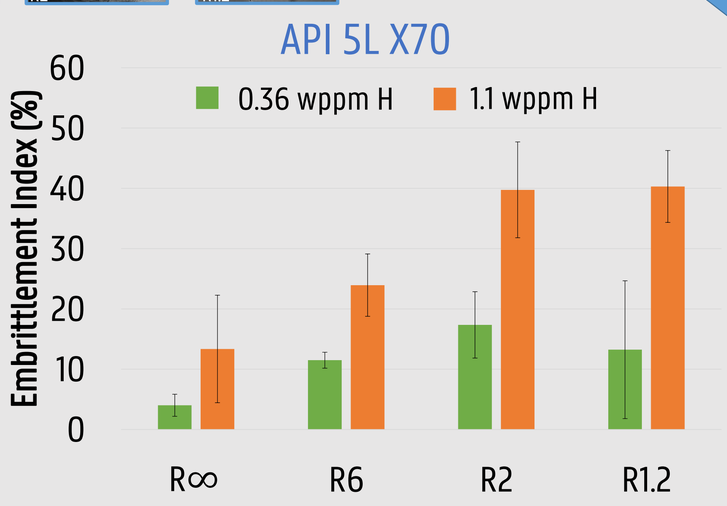
X56

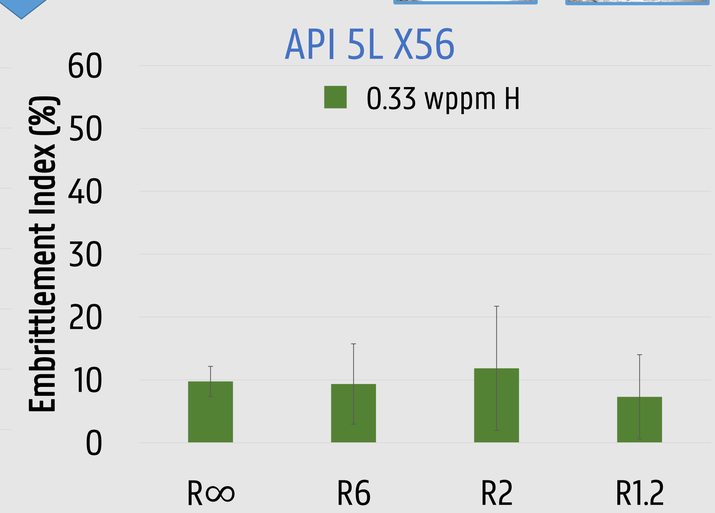


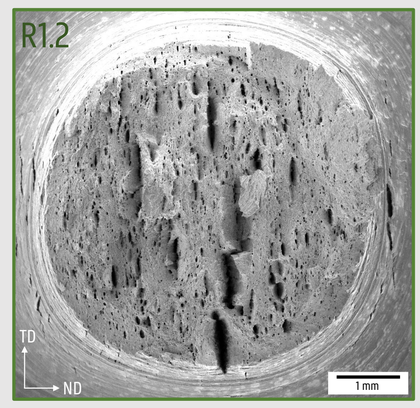


Delamination for R1.2

Delamination chance ↑ when H charged

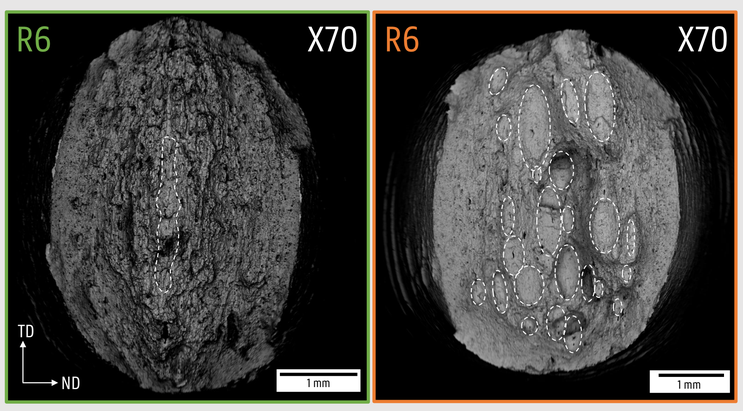




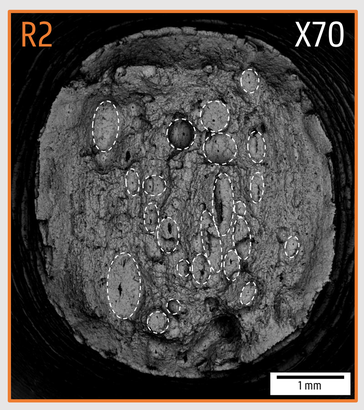


Necklace coalescence

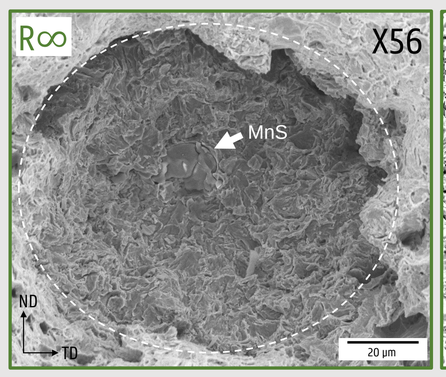
H-assisted fisheyes

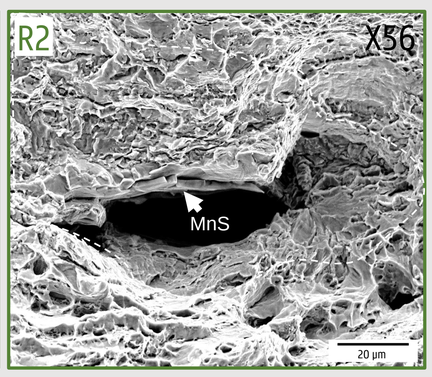


More fisheyes for H content ↑



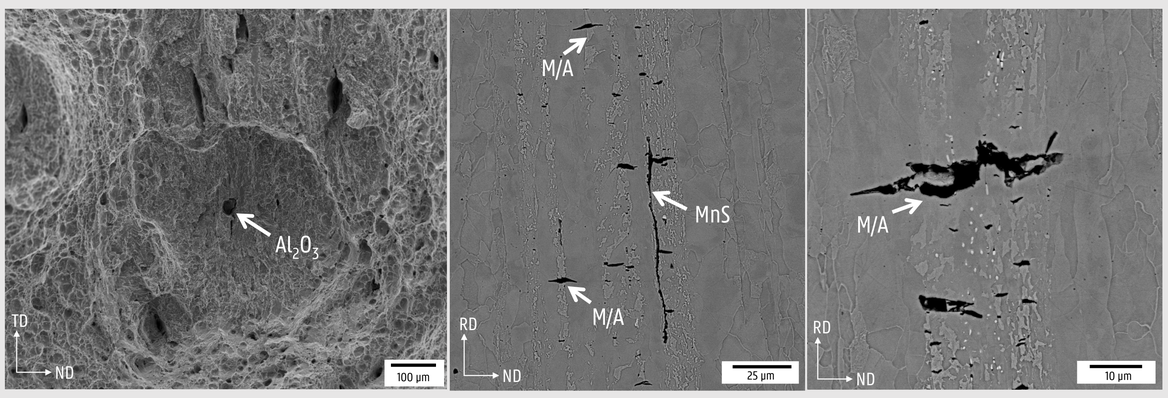
More fisheyes for notched samples





Fisheye shape ↔ inclusion shape

Fisheye initiation



Initiation at inclusions (Al_2O_3, MnS) & martensite islands (M/A)

Conclusions

- H charging causes loss of ductility + change in fracture mode from fully ductile to ductile with regions of quasi-cleavage (fisheyes)
- Notched specimens without delaminations show more fisheyes, indicating stress plays an important role in fisheye formation
- H charging allows for delaminations to occur at lower stress triaxialities
- Hydrogen content has a large impact on embrittlement & fisheye formation

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