cbecimat26
26° Congresso Brasileiro de Engenharia e Ciência dos Materiais
22 a 26 de novembro de 2026
Costão do Santinho
Florianópolis-SC

Mechanical Characterization of Carbon Steels for Seasonal Underground Storage of Green Hydrogen

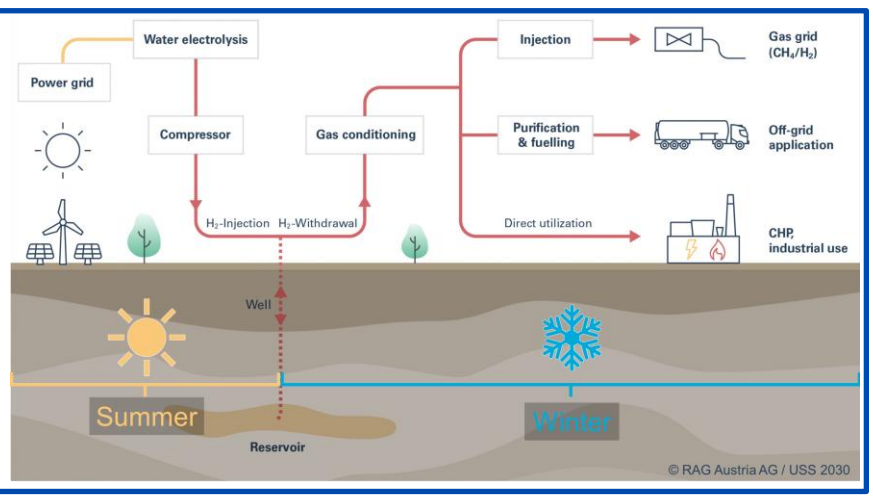
Luisa Bastos-Mateus[1], Gerald Sam[2], Benedikt Hasibar[2], David Fernández-Toledano[3], Santiago Ledesma-Mateo[3], Lajos Erdelyi[4], Julia van Winden[5], Gregor Mori[1]

1. Chair of General and Analytical Chemistry, Montanuniversität Leoben, Leoben/Austria, 2. RAG Austria, Vienna/Austria, 3. Trinity Energy Storage, Madrid/Spain, 4. Hungarian Gas Storage Ltd., Budapest/Hungary, 5. Shell Global Solutions International B.V., The Hague/The Netherlands

Motivation

Seasonal underground hydrogen storage (UHS) in depleted natural gas reservoirs offers a way to balance renewable energy supply and demand [1]. However, existing pipeline and storage materials were not originally designed for hydrogen service and may suffer from hydrogen embrittlement (HE) [2].

Aim: Evaluate the hydrogen embrittlement susceptibility of carbon steels considered for UHS applications.



Materials and Methods

Steel	YS [MPa]	UTS [MPa]	A [%]	Microstructure
A105	279	445	27.3	Ferrite/Pearlite
A52 K	270	446	28.4	Ferrite/Pearlite + MnS inclusions
P355 NH	355	509	27.9	Ferrite/Pearlite
T95	656	756	15.9	Martensitic
P110	896	984	12.5	Martensitic

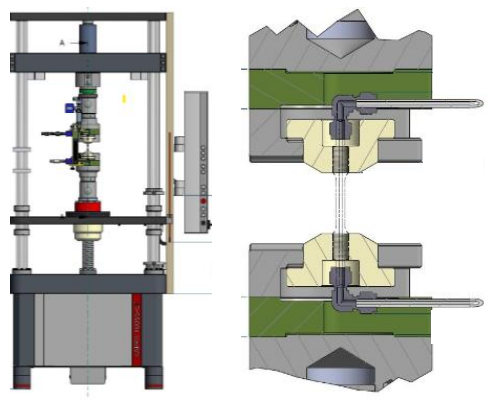
Strength ↓

Constant Load Tests (CLT):

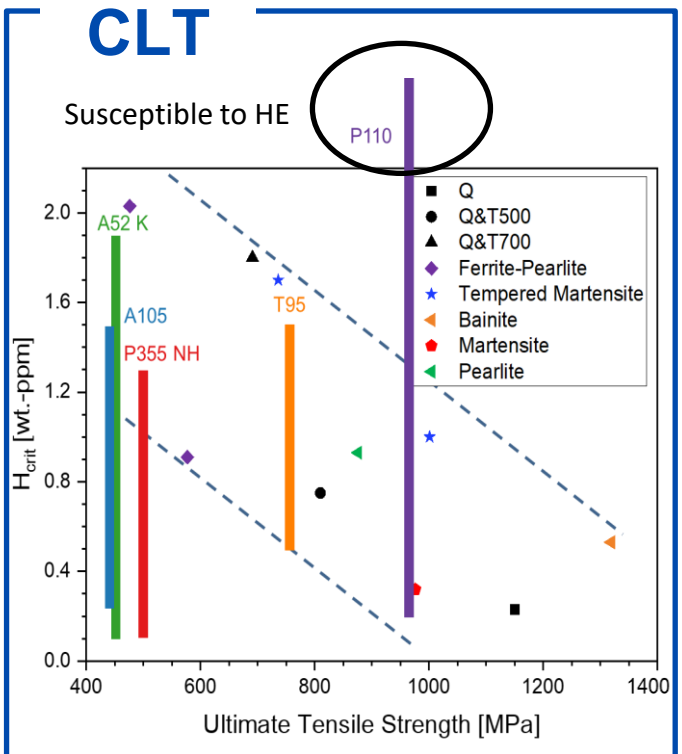
- 100% YS + H coupon
- 218 bar H_2 or 210 bar H_2 + 8 bar CO_2 + 0.1 bar H_2S
- RT/80 °C
- Dry/brine (5% NaCl)
- 4 weeks
- Results: Pass/Fail
- H uptake



Hollow-probe testing:
1000 bar Ar and H_2 Int. pressure
SSRT: strain rate: 10^{-6} s^{-1}
RLT: 500 cycles.



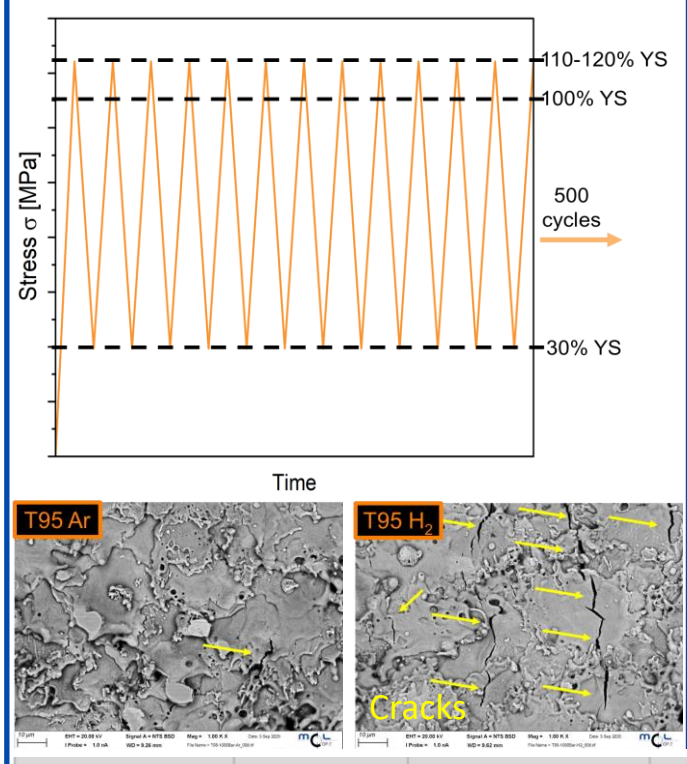
CLT



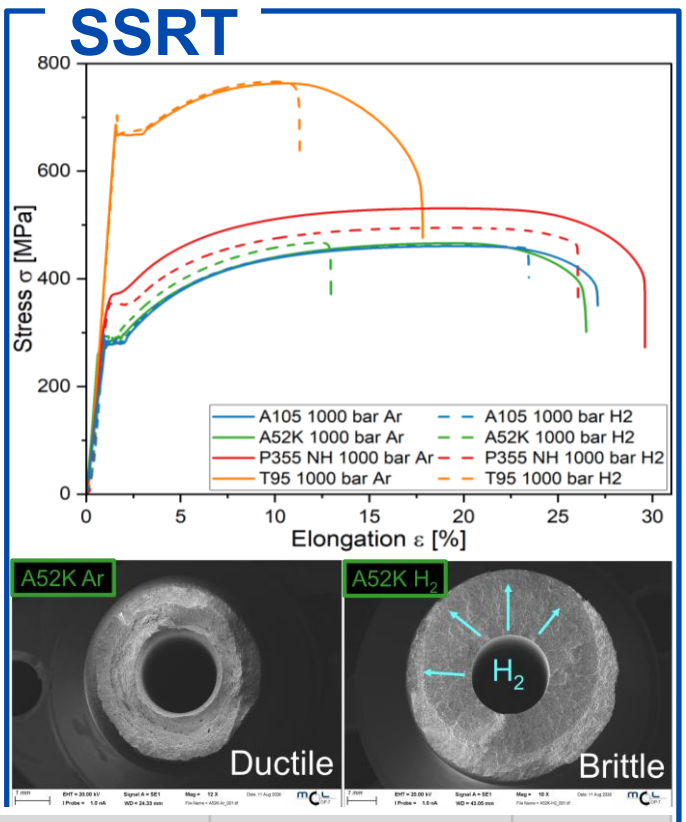
Adapted from[3]

Critical hydrogen content (H_{crit})
The hydrogen content above which embrittlement becomes possible under sufficient stress [3].

RLT



SSRT



Steel	CLT	RLT range	RLT	HE index SSRT	Cause
A105	Pass	30-120%YS	Pass	12.8%	
A52 K	Pass	30-120%YS	Voids	51.2%	→ MnS Inclusions Higher UTS
P355 NH	Pass	30-120%YS	Pass	12.9%	
T95	Pass	30-110%YS	Microcracks	41.0%	→ MnS Inclusions Higher UTS

Conclusions

A105, and P355 NH : $H_{uptake} \leq H_{critic}$
Low HE indices
Compatible with UHS under tested conditions ✓

A52 K, and T95: $H_{uptake} \leq H_{critic}$
High HE indices
Suitable under tested conditions; Potential HE risk at higher pressures !

P110:
$H_{uptake} > H_{critic}$
Can lead to HE under tested conditions ✗

References and funding

[1] **TARKOWSKI, R.** Underground hydrogen storage: characteristics and prospects. *Renewable and Sustainable Energy Reviews*, v. 105, p. 86–94, 2019.
[2] **FERNANDEZ, D. M. et al.** A holistic review on wellbore integrity challenges associated with underground hydrogen storage. *Int. J. of Hydrogen Energy*, v. 57, p. 240–262, 2024.
[3] **ZWITTNING, M. et al.** Hydrogen effects on the mechanical properties of pipeline steels. International Journal of Hydrogen Energy, v. 50, p. 123–130, 2025.

Co-funded by the European Union
This project is supported by the Clean Hydrogen Partnership and its members.