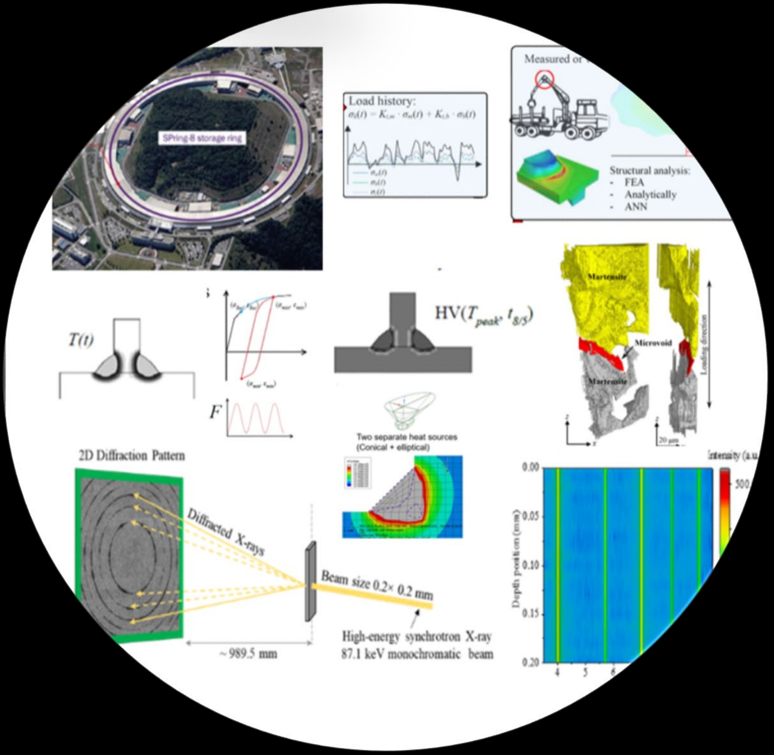

LUT University
LAND OF THE CURIOUS



Strategic insights into CO2 interactions with metallic components and energy infrastructure

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Department of Mechanical Engineering
School of Energy Systems
Lappeenranta-Lahti University of Technology
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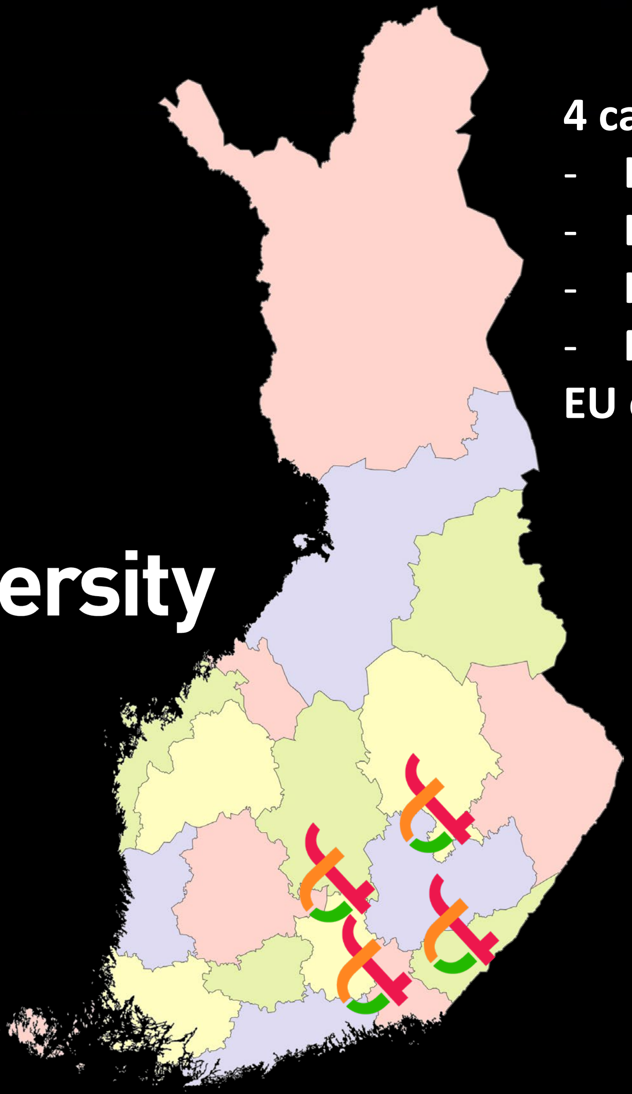
LUT University

SYSTEM
EARTH
AIR
From emissions to opportunities
BUSINESS AND SOCIETY
Sustainable renewal of business, industry and society
WATER
Complex water adequacy and water treatment needs
ENERGY
Transition to carbon neutrality
TRAILBLAZERS – Science with a Purpose
LUT UNIVERSITY STRATEGY 2030

About LUT

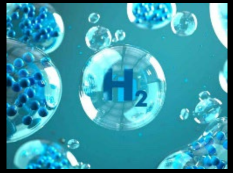
LUT University

LUT University



4 campuses in Finland
- Lappeenranta
- Lahti
- Kouvola
- Mikkeli

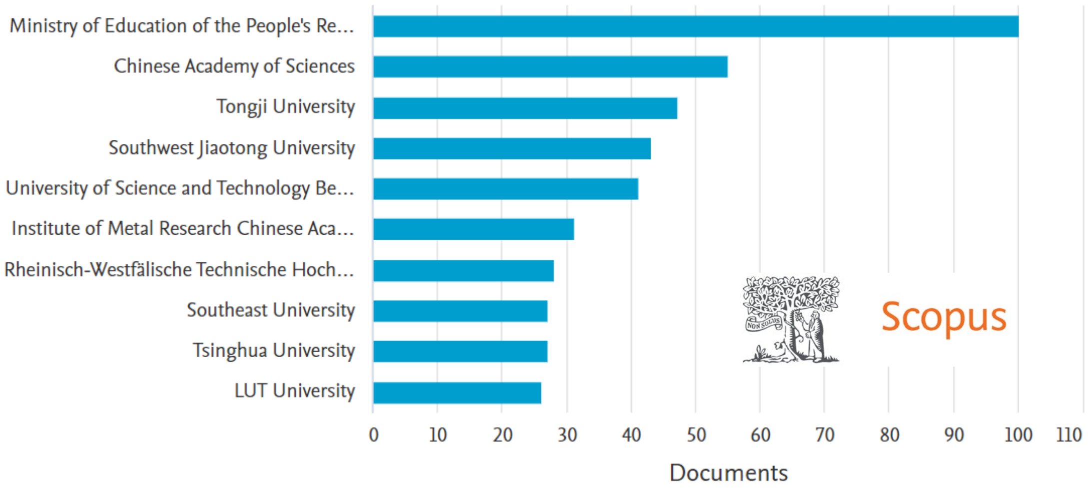
EU office in Brussel



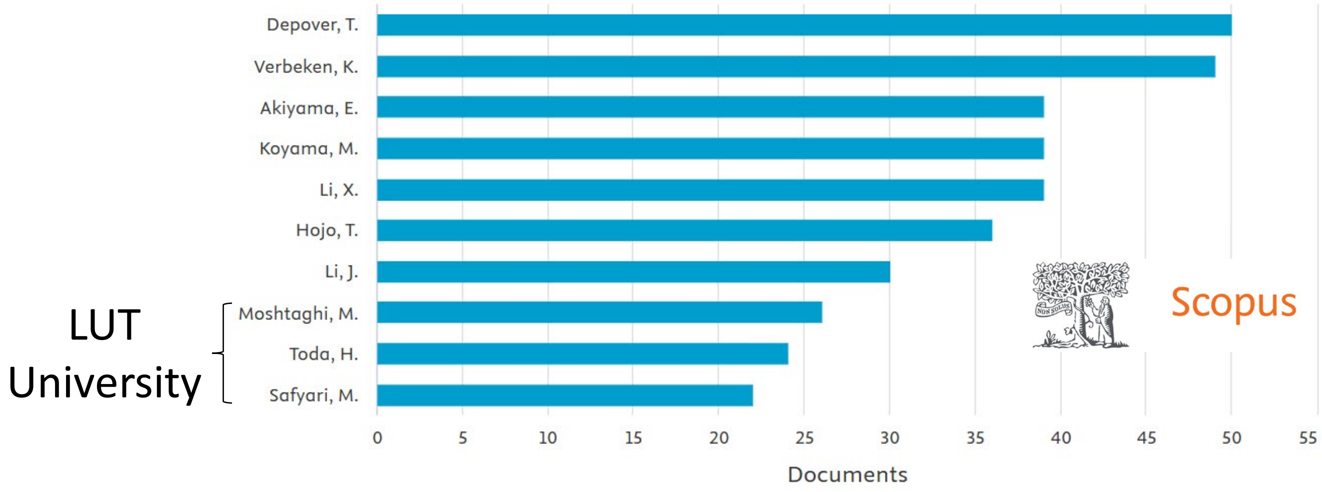
Hydrogen Europe

LUT Mechanics of Materials in the top 10 of the world (2021-2025)

Fatigue of high-strength steels



Energy infrastructures such as hydrogen, CO_2, methanol, ammonia, etc.



LUT Mechanics of Materials in the top 5 of the world (2021-2025)

LUT University

Hydrogen embrittlement
Prior 5 Years

ScholarGPS®
POWERING SCHOLARLY ANALYTICS

All Active

#1 **Michihiko Nagumo**
Waseda University, Japan
Field: Engineering and Computer Science
Discipline: Materials Science and Engineering

#2 **Mahdieh Safyari**
Field: Engineering and Computer Science
Discipline: Mechanical Engineering

LUT Mechanics of Materials

#3 **Eiji Akiyama**
Tohoku University, Japan
Field: Engineering and Computer Science
Discipline: Materials Science and Engineering

#4 **Milos B. Djukic**
University of Belgrade, Serbia
Field: Engineering and Computer Science
Discipline: Mechanical Engineering

#5 **Masoud Moshtaghi**
Field: Engineering and Computer Science
Discipline: Mechanical Engineering

LUT Mechanics of Materials

Industrial collaboration partners and funding agencies

ABB

GASGRID

SSAB

FWF

DELTAMARIN®

UPM

BUSINESS FINLAND

voestalpine
ONE STEP AHEAD.

Sumitomo
SHI/FW

stresstech

OMV

horizon europe

fluxys

JSPS

Selected publications

LUT University

BUSINESS FINLAND · SHY FSF · horizon europe · SSAB · iiw · Sumitomo SHI FW · voestalpine ONE STEP AHEAD. · FWF

Acta Materialia
Available online 15 January 2025, 120749
In Press, Journal Pre-proof

Hydrogen decelerates fatigue induced grain boundary migration in nanostructured iron

M.W. Kapp[1], M. Zawodzki[1], M. Antoni[1], D. Zwittnig[2], M. Tkadletz[4], M. Moshtaghi[2,3], G. Mori[2], J. Eckert[1,4], O. Renk[1,4]

Welding in the World
https://doi.org/10.1007/s40194-024-01919-x
RESEARCH PAPER

Fatigue assessment of as-welded and HFMI-treated high-strength steel joints under variable amplitude loading using local approaches

Antti Ahola[2] · Martin Leitner[1,2] · Kiia Grönlund[2] · Peter Brunnhofer[1] · Christian Buzzi[1] · Masoud Moshtaghi[2] · Timo Björk[2]

Engineering Failure Analysis 163 (2024) 108560

Capacity of hydrogen traps affects H-assisted crack initiation and propagation mechanisms in martensitic steels

Mahdieh Safyari[a], Saurabh Bhosale[b], Masoud Moshtaghi[a,*]

Procedia Structural Integrity 54 (2024) 123–134
International Conference on Structural Integrity 2023 (ICSI 2023)

Influence of Mo content on susceptibility of medium-carbon martensitic high-strength steels to hydrogen embrittlement: single and double Q&T

International Journal of Hydrogen Energy 53 (2024) 434–440

Hydrogen-enhanced entropy (HEENT): A concept for hydrogen embrittlement prediction

Masoud Moshtaghi[a,b,c,*], Mahdieh Safyari[d], M.M. Khonsari[b]

Materials & Design 234 (2023) 112323

Design of high-strength martensitic steels by novel mixed-metal nanoprecipitates for high toughness and suppressed hydrogen embrittlement

Masoud Moshtaghi[a,*], Emad Maawad[b], Artenis Bendo[c], Andreas Krause[e], Juraj Todt[e,f], Jozef Keckes[e,f], Mahdieh Safyari[g,h]

Engineering Failure Analysis 163 (2024) 108562

Influence of Mo carbides and two-stage tempering methodology on the susceptibility of medium carbon martensitic steel to hydrogen embrittlement

Magdalena Eškinja[a,*], Gerald Winter[b], Holger Schnideritsch[b], Jürgen Klarner[b], Vsevold Razumovskiy[c], Masoud Moshtaghi[a,d], Gregor Mori[a]

Presentation

Hydrogen embrittlement susceptibility of X52 pipelines in different hydrogen environments under varied constant loads

March 2024
Conference: AMPP Annual Conference + Expo 2024 · At: New Orleans, United States
Ahmed Hamed · Matthias Eichinger · Masoud Moshtaghi · Gregor Mori

Materials Letters 340 (2023) 134149

Dependence of the mechanical properties of a metastable austenitic stainless steel in high-pressure hydrogen gas on machining-induced defects

Mahdieh Safyari[a,b], Masoud Moshtaghi[b,*]

J Mater Sci (2023) 58:13460–13475
Metals & corrosion

Inhibition of grain growth by pearlite improves hydrogen embrittlement susceptibility of the ultra-low carbon ferritic steel: the influence of H-assisted crack initiation and propagation mechanisms

Stefanie Pichler[1], Artenis Bendo[2], Gregor Mori[1], Mahdieh Safyari[3,4], and Masoud Moshtaghi[1,*]

DE GRUYTER — Int. J. Mater. Res. 2023; 114(6): 439–452

Mathias Truschner*, Johann Pengg, Bernd Loder, Hubert Köberl, Peter Gruber, Masoud Moshtaghi and Gregor Mori

Hydrogen resistance and trapping behaviour of a cold-drawn ferritic–pearlitic steel wire

International Journal of Hydrogen Energy 48 (2023) 27408–27415
Short Communication

Different augmentations of absorbed hydrogen under elastic straining in high-pressure gaseous hydrogen environment by as-quenched and as-tempered martensitic steels: combined experimental and simulation study

Masoud Moshtaghi[a,*], Mahdieh Safyari[b]

Corrosion Science 217 (2023) 111118

The effect of HPAM polymer for enhanced oil recovery on corrosion behaviour of a carbon steel and interaction with the inhibitor under simulated brine conditions

Masoud Moshtaghi[a,*], Magdalena Eškinja[a], Gregor Mori[a], Thomas Griesser[b], Mahdieh Safyari[a,c], Ivan Cole[d]

Corrosion Science 194 (2022) 109895

Mechanisms of hydrogen embrittlement in high-strength aluminum alloys containing coherent or incoherent dispersoids

Mahdieh Safyari[a,*], Masoud Moshtaghi[c,*], Tomohiko Hojo[a], Eiji Akiyama[a]

International Journal of Hydrogen Energy 47 (2022) 20676–20683
Short Communication

Hydrogen trapping and desorption affected by ferrite grain boundary types in shielded metal and flux-cored arc weldments with Ni addition

Masoud Moshtaghi[a,*], Bernd Loder[a], Mahdieh Safyari[b], Thomas Willidal[c], Tomohiko Hojo[b], Gregor Mori[a]

Electrochemistry Communications 134 (2022) 107169
Full Communication

Hydrogen absorption rate and hydrogen diffusion in a ferritic steel coated with a micro- or nanostructured ZnNi coating

Masoud Moshtaghi[a,*], Mahdieh Safyari[b], Gregor Mori[a]

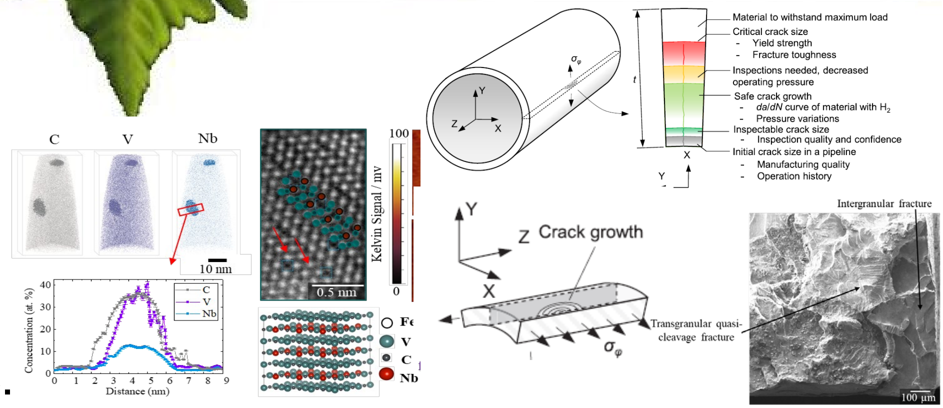
Hydrogen trapping at micro/nano-sized secondary hardening precipitates in high-strength martensitic stainless steels

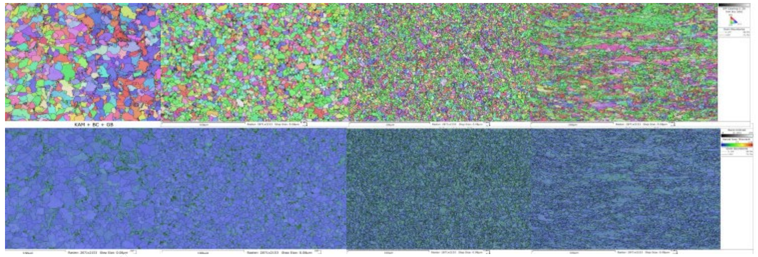
Stefanie Pichler, Gregor Karl Mori, Mahdieh Safyari, Masoud Moshtaghi

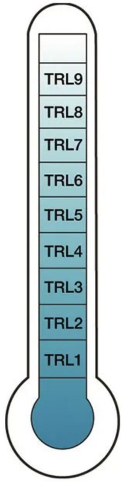
Overview of activities of LUT Mechanics of Materials

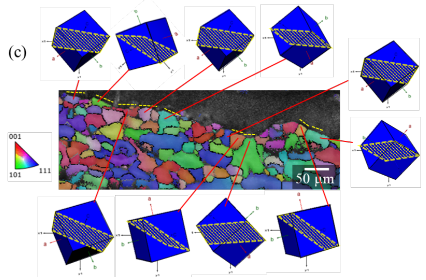
LUT University

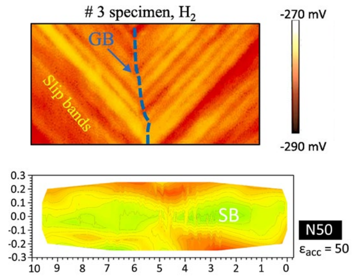
- **CO_2 interaction with metals,Hydrogen Embrittlement & Hydrogen-Assisted Fatigue**
- **Design and testing materials and structures for hydrogen pipelines, underground storage, storage tanks, etc.**
- **Steel Structures for Hydrogen Energy:** Applications and innovations.
- **Energy applications**: Hydrogen, ammonia, methane, methanol, CO_2, etc.
- **Fatigue Assessment:** Methods for life prediction and analysis.
- **Strength of Welded Joints:** Static and fatigue performance.
- **High-Strength Steels (HSS & UHSS):** Applications and advancements.
- **Fatigue Behavior:** High-cycle and low-cycle effects linked to microstructure.
- **Microstructure-Property Relationships:** Impact on mechanical performance.
- **Structural Quality:** Performance of high-strength steels.
- **Enhancing Welded Joints:** Techniques for improving fatigue strength.
- **Numerical Analysis:** Stress and welding simulations for structures.
- **Thin-Walled Products:** Stability and distortion challenges.
- **Steel Performance in Extreme Conditions:** Subzero temperature applications.
- **Additive Manufacturing (AM):** Structural performance of AM components.

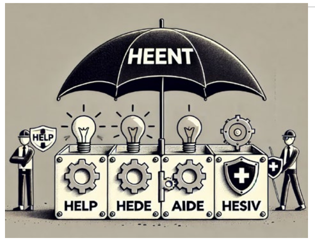


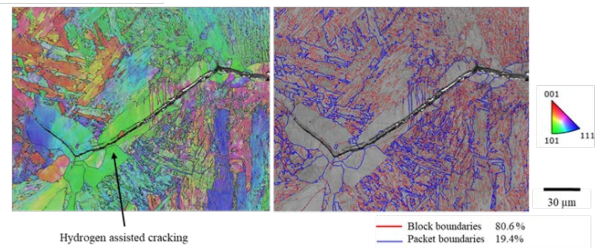












Facilities

LUT University

Mechanical Testing and Fatigue Life evaluation

- High Cycle and Low Cyclic Fatigue Test with various test capacities
- Stress corrosion cracking testing in CO2 environment
- Fatigue testing at different pressures up to 500 bar
- Mechanical testing in different sizes and shapes
- Mechanical testing of the specimens in different environments
- Fracture mechanics testing approach, CT specimen
- Micro-Hardness Testing
- Slow Strain Rate Testing
- Finite Element Modelling and Machine Learning

Mechanical testing

Analytical Characterisation

- Hydrogen Mapping by Hydrogen Microprint Technique/ Silver Decoration
- Thermal Desorption Spectroscopy (TDS)
- Hydrogen Hot/Melt Extraction
- Hydrogen Electrochemical Permeation Tests
- Hydrogen Diffusion & Profile in Metals by finite element analysis
- Hydrogen Mapping by SKPFM
- X-ray photoelectron spectroscopy
- Electrochemical corrosion tests
- Hydrogen Mapping by NanoSIMS*

Hydrogen characterisation

Tools & Methods

Microstructural Observation

Microstructural Observation

- SEM/EDS
- Optical Microscopy
- 3D Surface Measurement Device
- SEM/EBSD/FIB
- TEM
- HRTEM
- Atom Probe Tomography *

Quantum beams

Quantum beam evaluation of the stressed specimen

- X-ray diffraction
- X-ray synchrotron diffraction
- Neutron diffraction

Facilities

LUT University

Mechanical Testing and Fatigue Life evaluation

Mechanical testing

- High Cycle and Low Cyclic Fatigue Test with various test capacities
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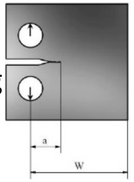
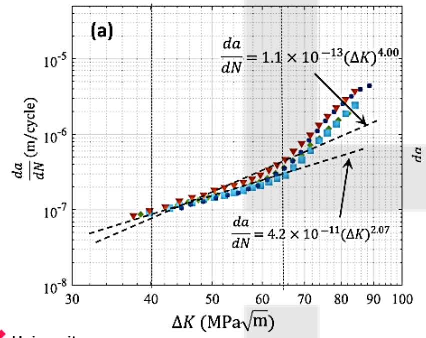


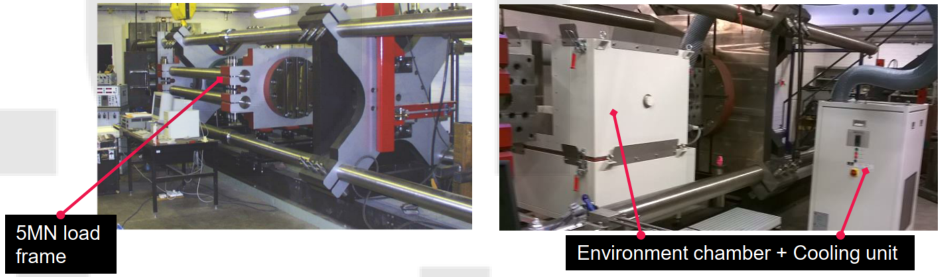


Fatigue crack growth behaviour by linear elastic fracture mechanics (LEFM)

MATERIAL TESTING MACHINES (LOAD FRAMES)

LUT University

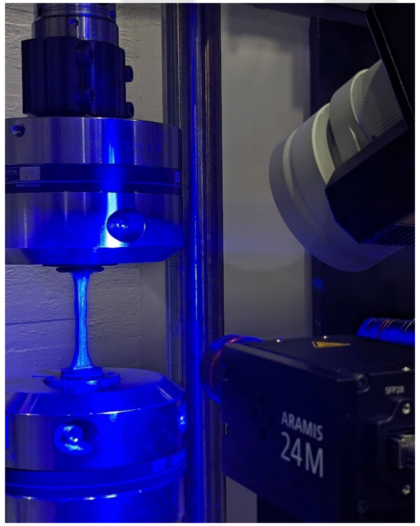
- Laboratory have ten (10) servo hydraulic load frames for dynamic and static loading test set-ups.
- Biggest test rig in Finland for dynamic testing up to 5 MN compression and tension loading.
  - Equipped with movable environment chamber down to -60°C to determinate material and connections behaviour at sub zero temperatures.
  - Full-scale tests of components made of high- and ultra-high-strength steels (S700-S1100).

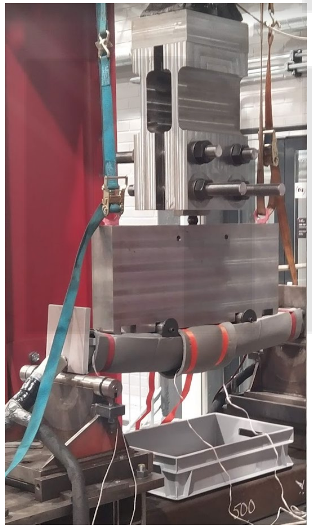


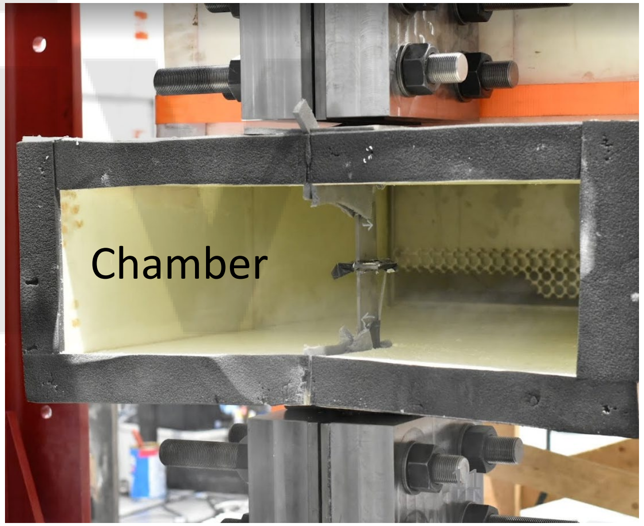
MATERIAL TESTING MACHINES (LOAD FRAMES)

University

- RUMUL Vibroforte 700 high frequency testing machine, April/2022
- 5 MN for static and dynamic loading
- 1200 kN and 750 kN for dynamic and static loading
- 400 kN for dynamic and static loading
- Hz1 and Hz2 frames for 150 kN dynamic and static loading
- 150 kN for dynamic and static loading
- 1 MN compression up to 7 m length columns and beams
- Drop weight testing machine for impact tests





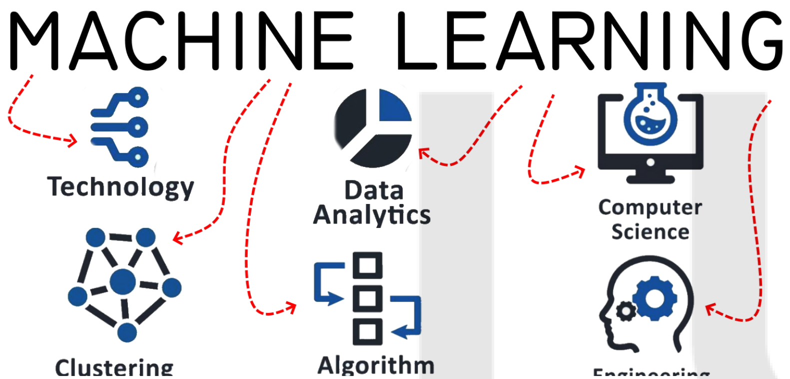


FEM and Machine Learning

LUT University

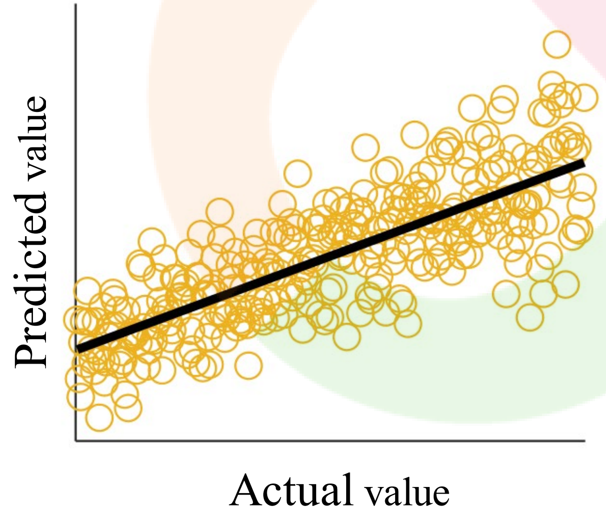
Methodology

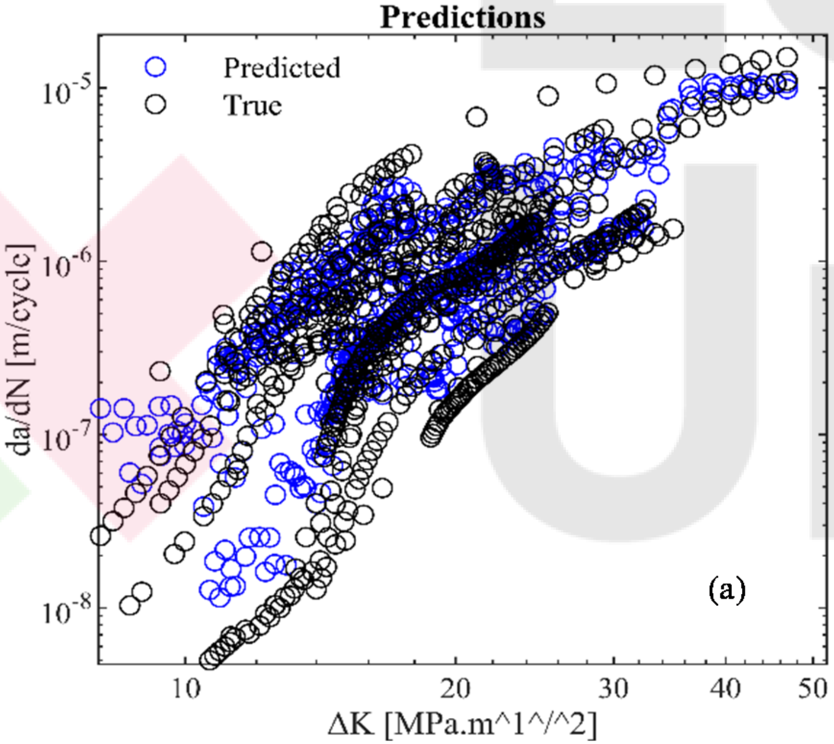
Data Analytics

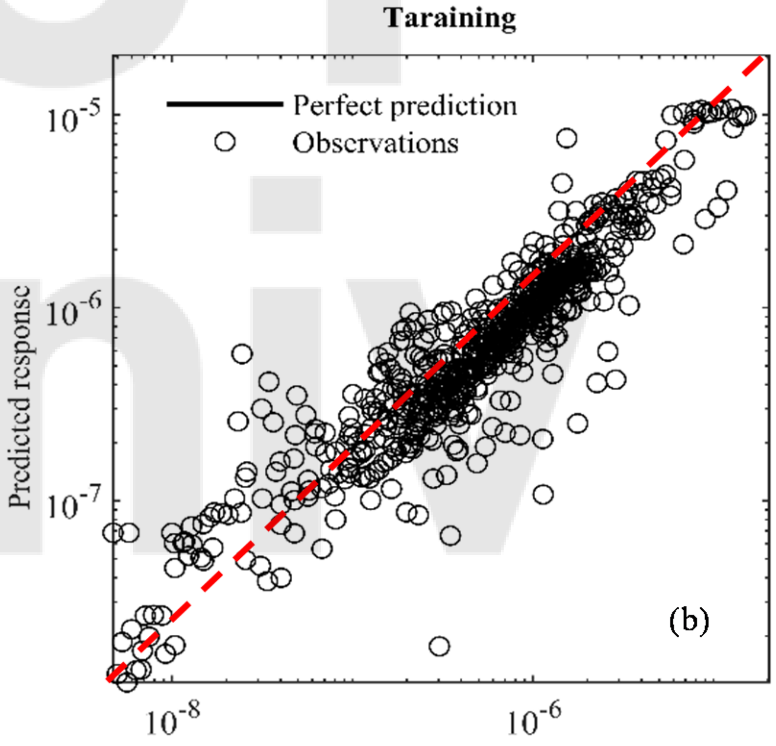


Application of Machine Learning

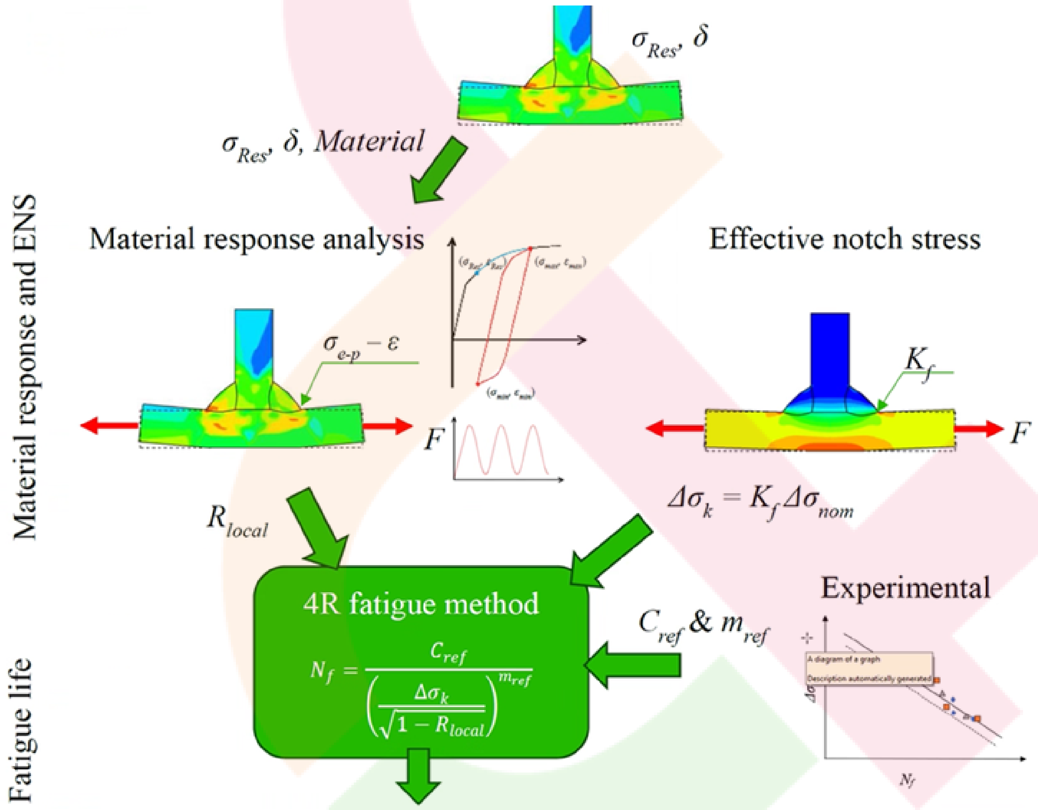
- Development of predictive models
- Assessment of various models
- Verification of developed model

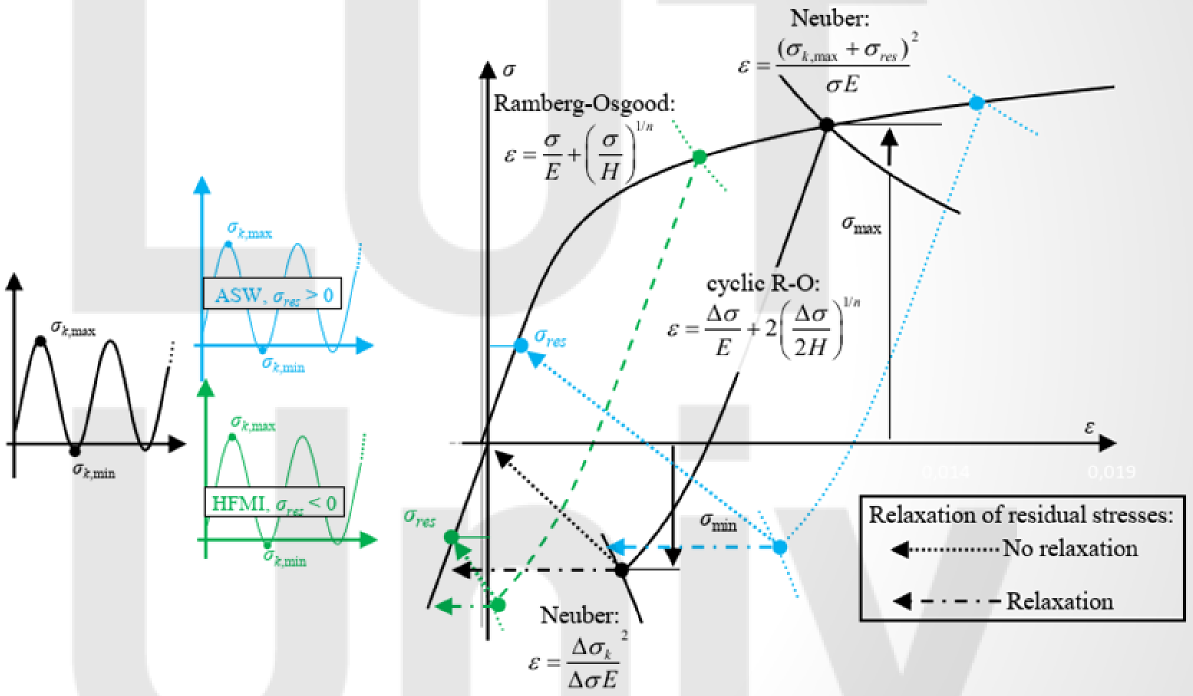






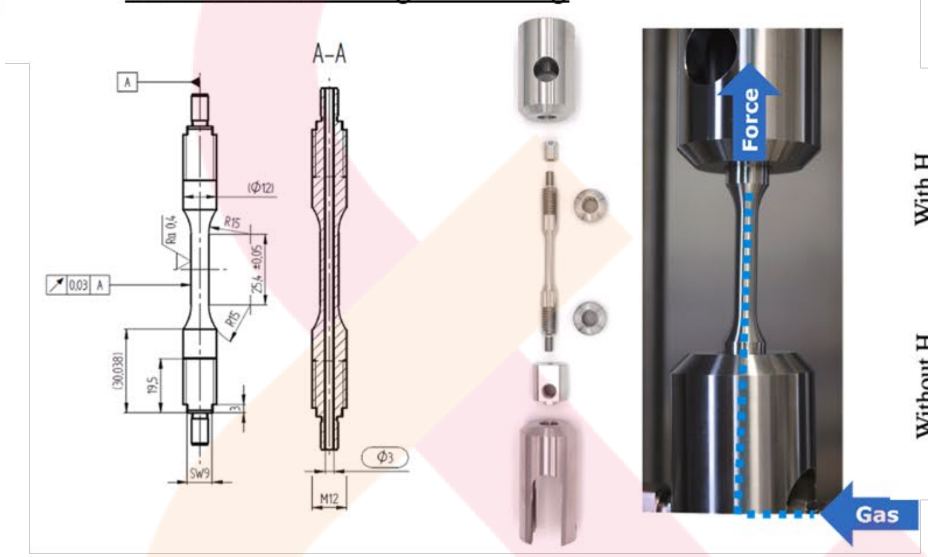
Finite element simulation & Fatigue life prediction



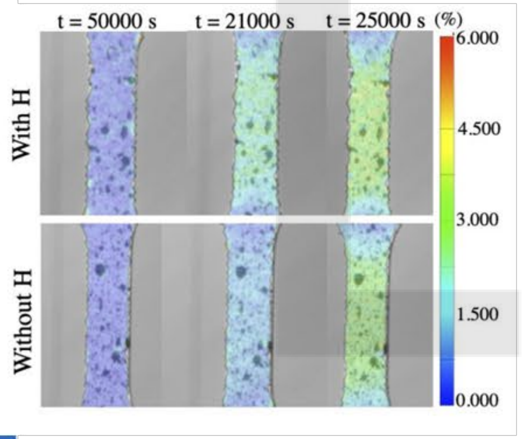


Facilities

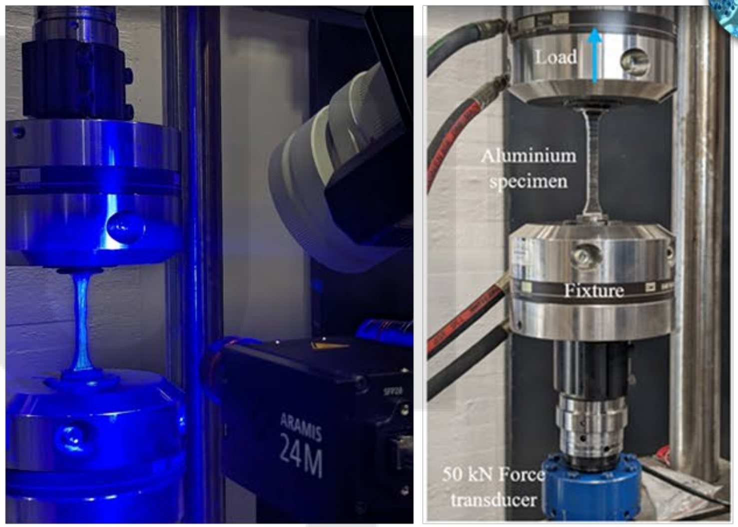
Hollow-Probe Fatigue Testing

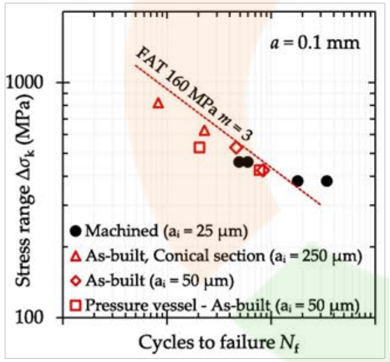


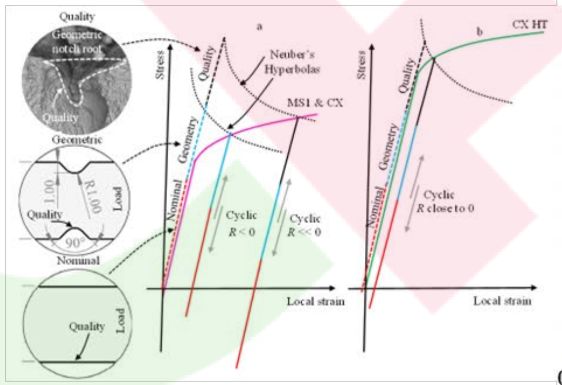
Digital Image Correlation

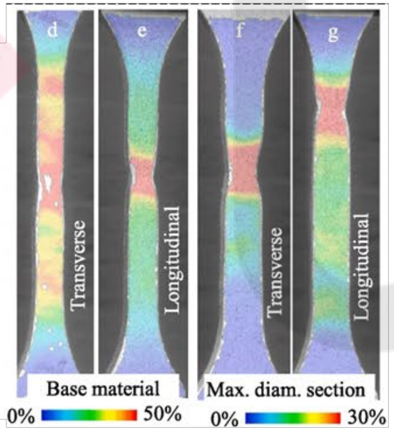


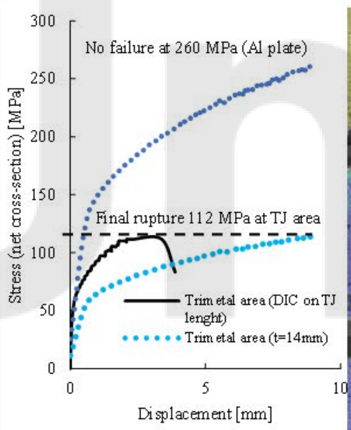
Fatigue & mechanical testing

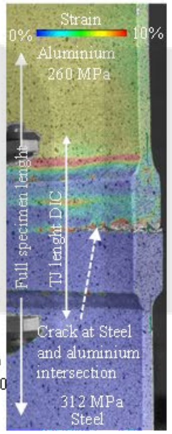


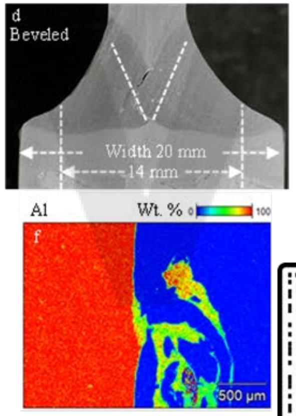






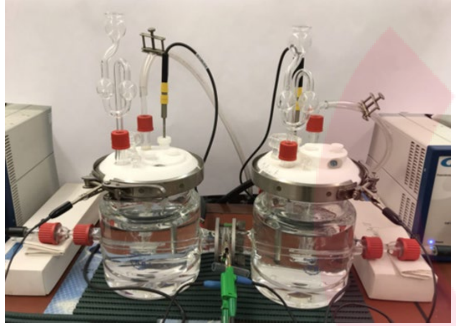




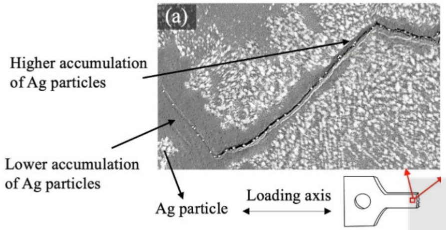


Facilities

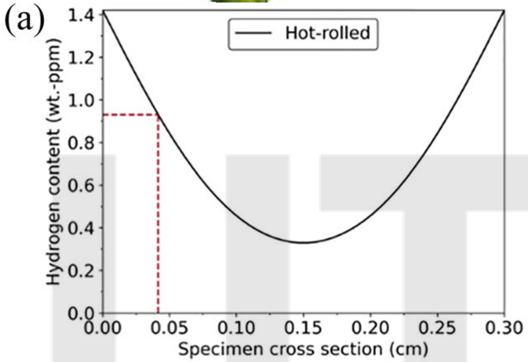
LUT University



Hydrogen Electrochemical Permeation Tests



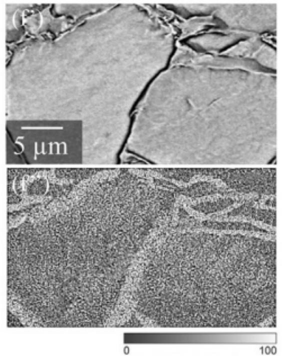
Hydrogen Microprint Technique



$$C_{tot} = \frac{C_0}{r}\left(\mathrm{rerfc}\left(\frac{x}{\bar{x}}\right)\right) - \frac{\bar{x}}{\sqrt{\pi}} e^{\left(\frac{-r}{\bar{x}}\right)^2} + \frac{\bar{x}}{\sqrt{\pi}} \text{ where}$$

$$\bar{x} = 2\sqrt{D_{\text{eff}} t}$$

Hydrogen Diffusion & Profile in Metals by Finite Element Analysis



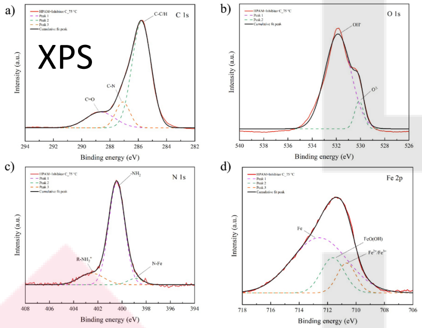
Nano SIMS

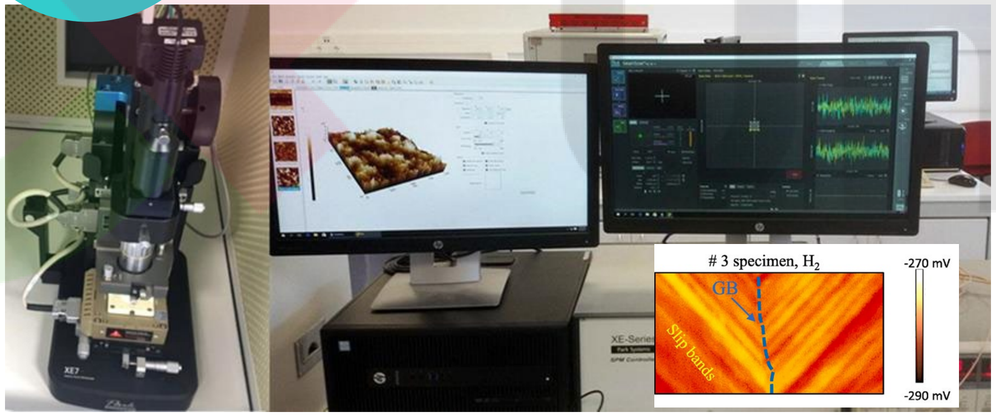
TDS at LUT

Analytical Characterisation

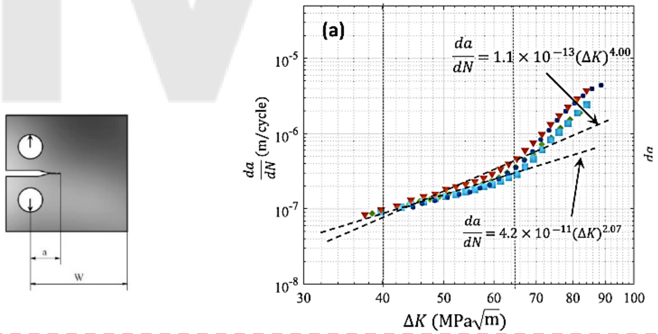
- Hydrogen Mapping by Hydrogen Microprint Technique/ Silver Decoration
- Thermal Desorption Spectroscopy (TDS)
- Hydrogen Hot/Melt Extraction
- Hydrogen Electrochemical Permeation Tests
- Hydrogen Diffusion & Profile in Metals by finite element analysis
- Hydrogen Mapping by SKPFM
- X-ray photoelectron spectroscopy (XPS)
- Electrochemical corrosion tests
- Hydrogen Mapping by NanoSIMS*

Hydrogen characterisation





Hydrogen Mapping by SKPFM at LUT



Fatigue crack growth rate at LUT

Facilities

Scanning electron microscopy (SEM) at LUT

Transmission electron microscopy (SEM) at LUT

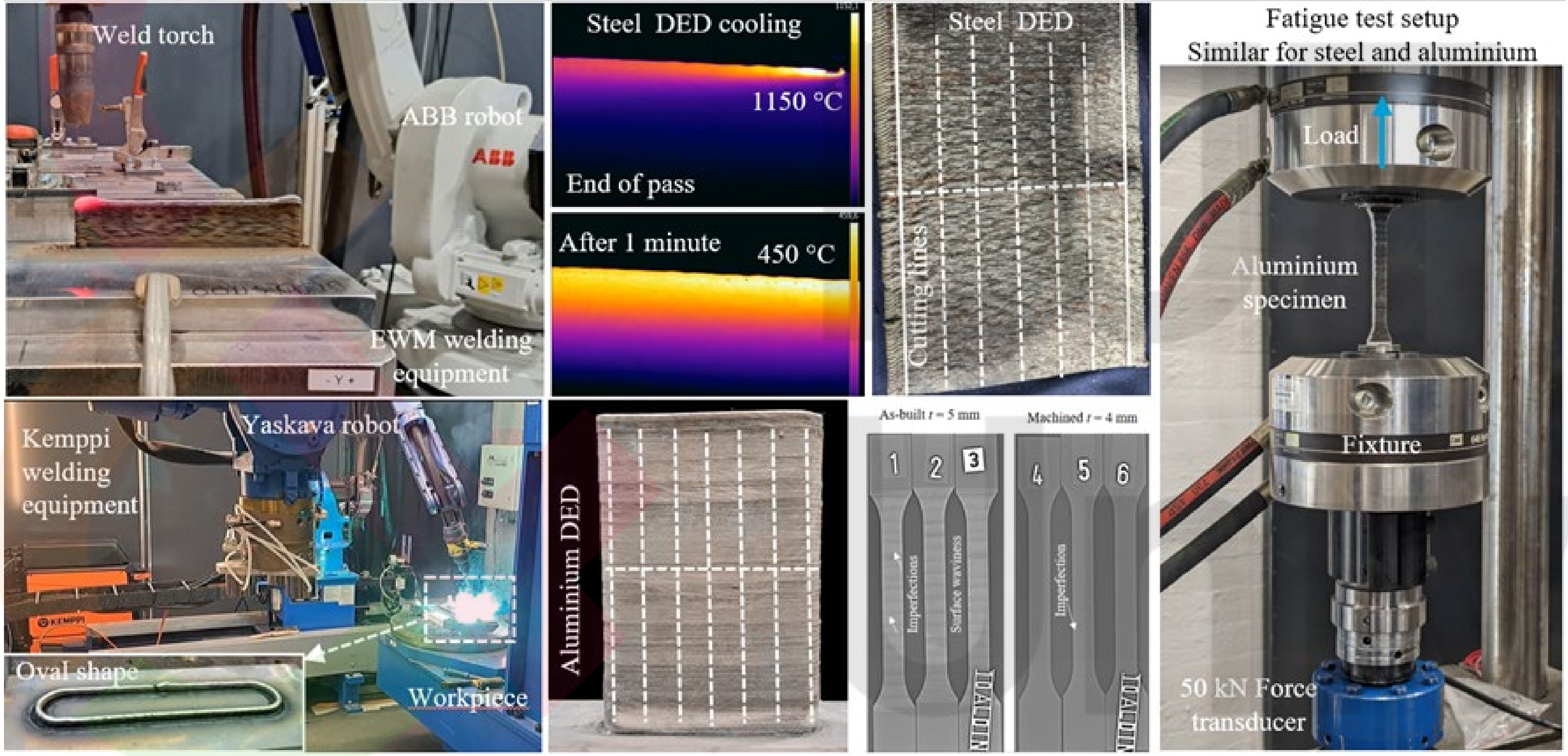
Atom Probe Tomography, MUL

Microstructural Observation

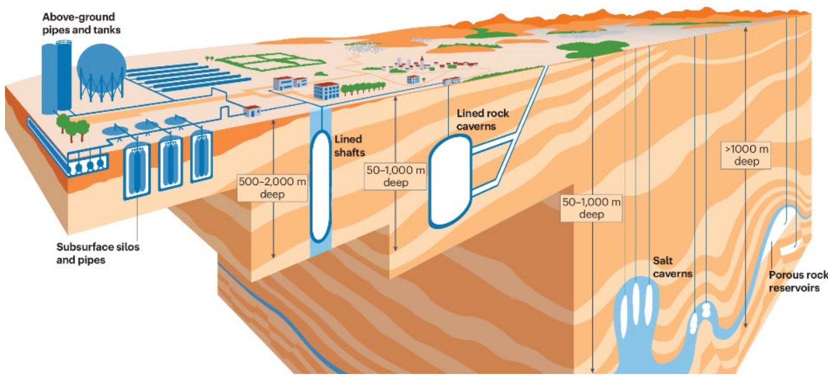
Microstructural Observation

- Optical Microscopy
- 3D Surface Measurement Device
- SEM/EDS/EBSD
- TEM
- Atom Probe Tomography * (Montanuniversitaet Leoben)

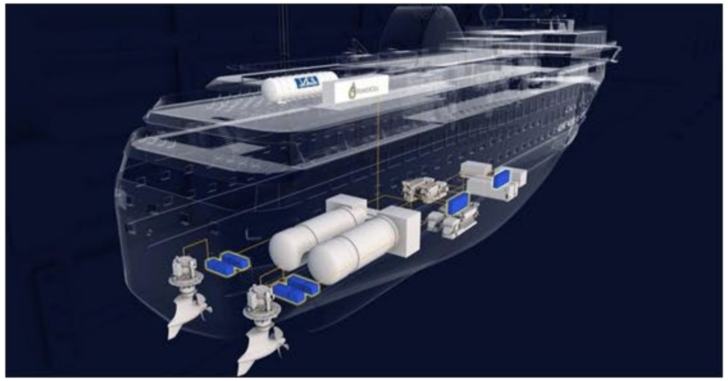
Additive manufacturing in LUT University



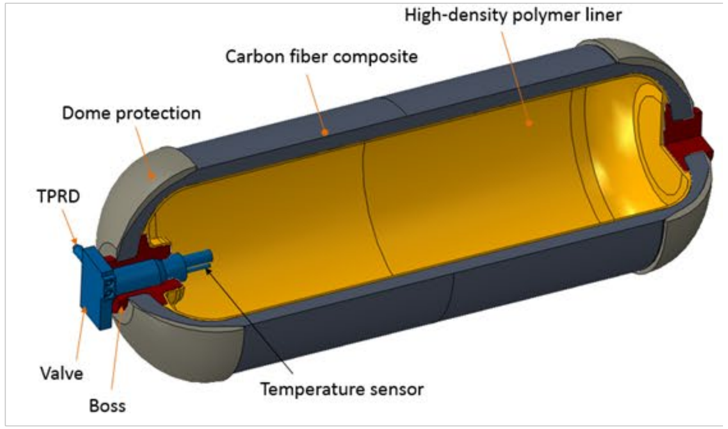
Hydrogen energy applications



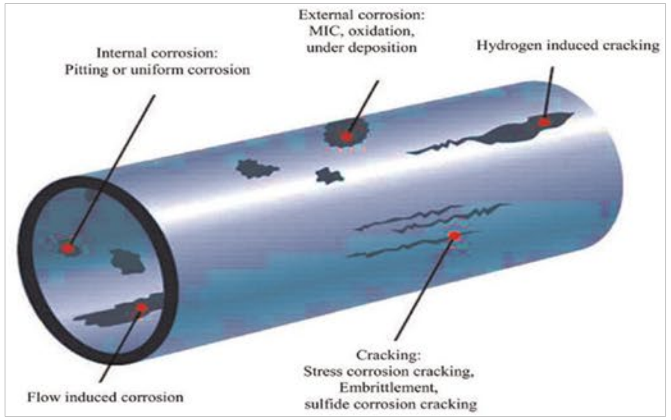
Steel design for underground storage



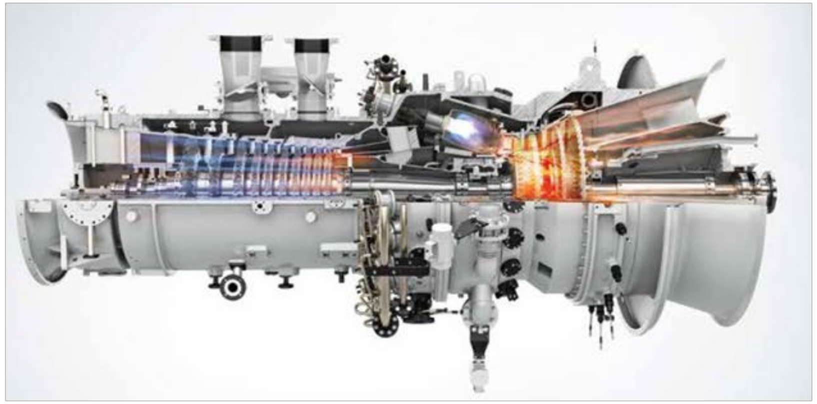
Ship design and fatigue design



Design of hydrogen storage tanks under fatigue and vibration condition

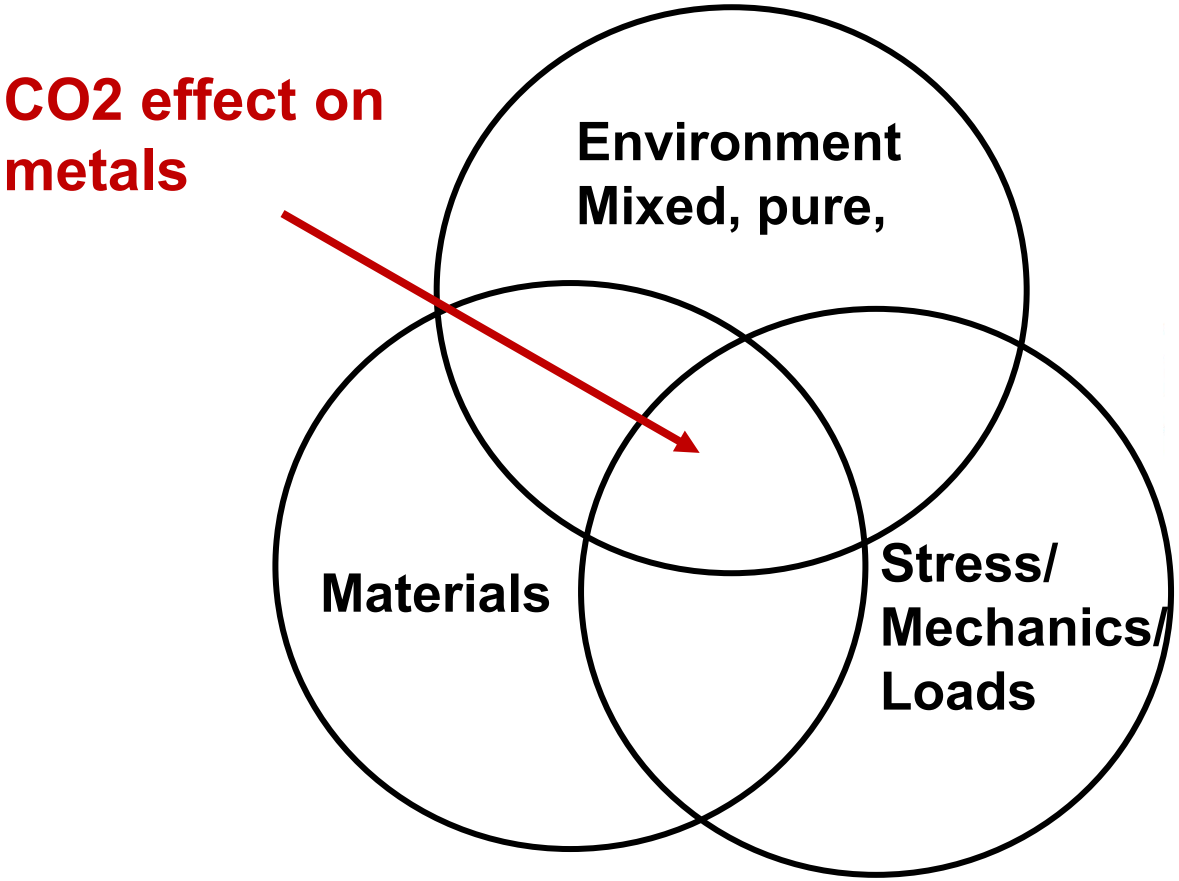


Design of welded pipeline steels



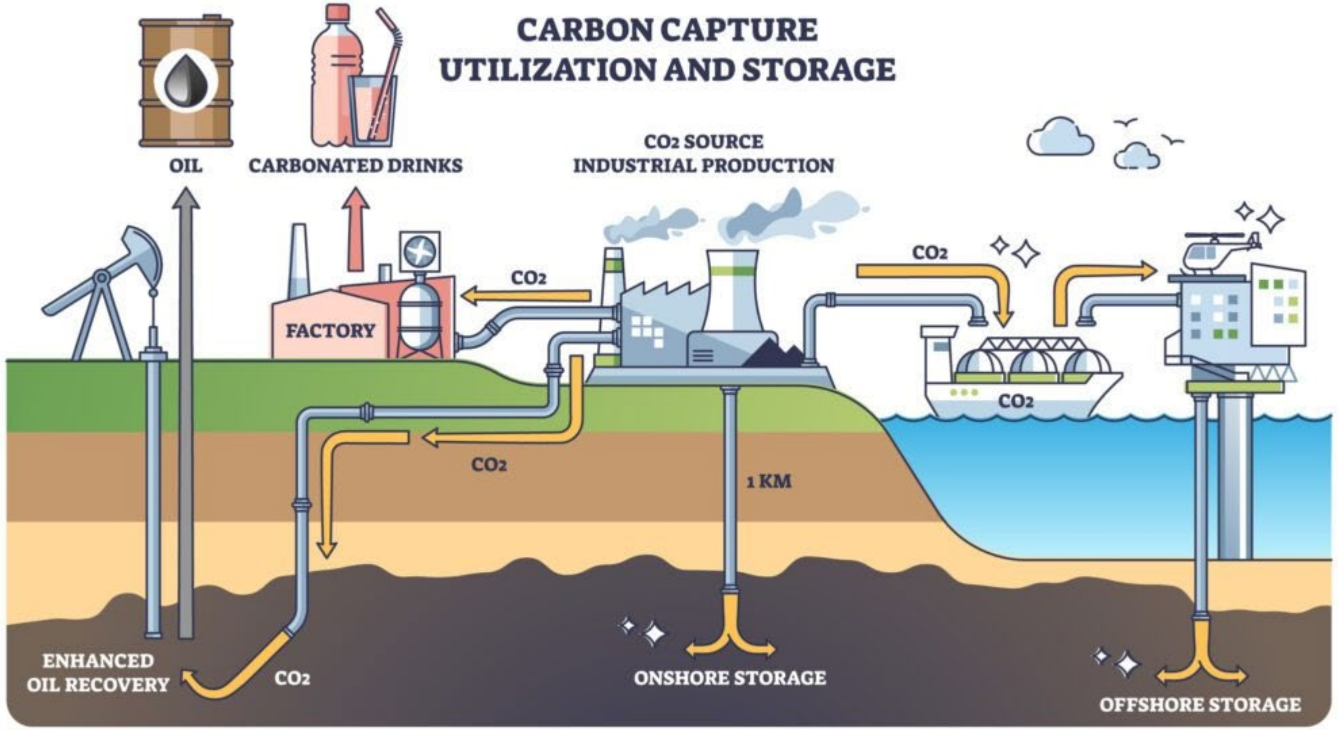
Compressors and gas turbines

Interaction of CO2 with the energy infrastructure

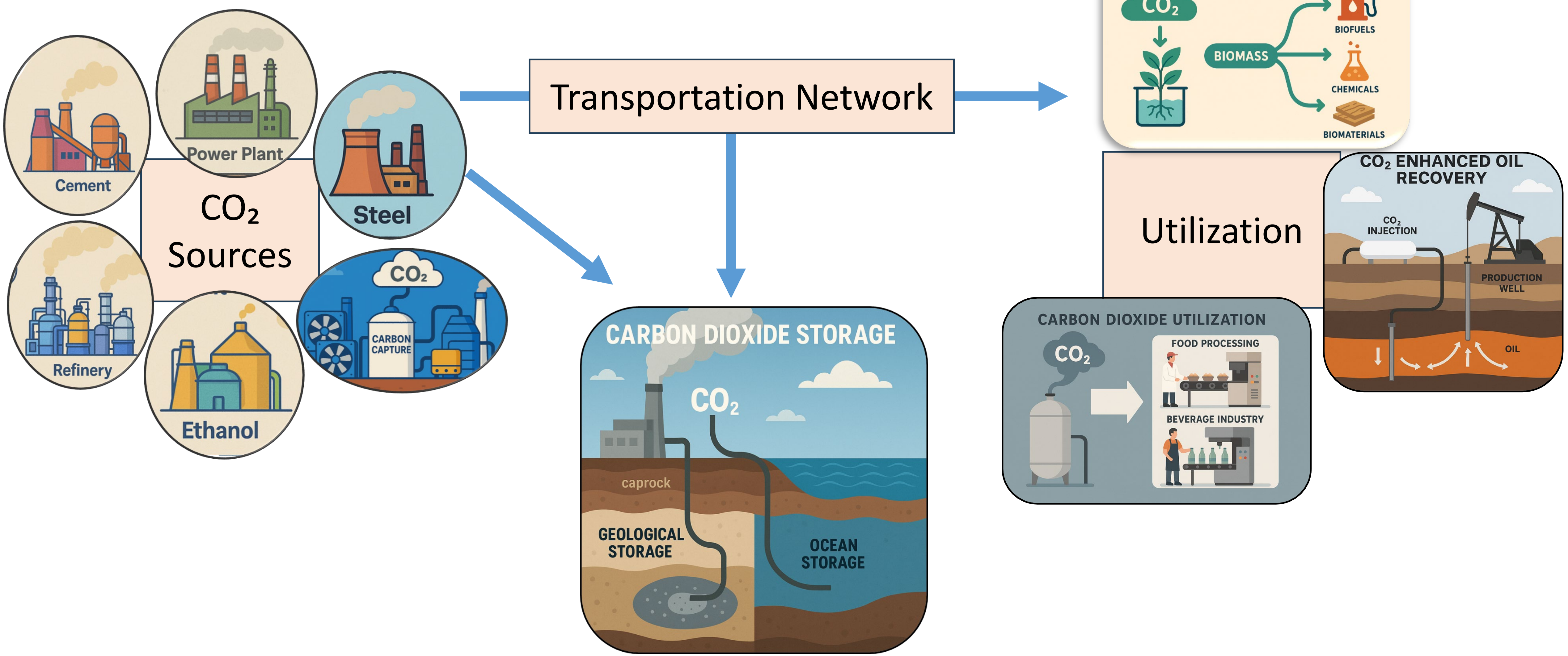


Carbon Capture, utilization, and storage (CCUS)

- Net-zero emission goal is possible by CCUS
- Capturing CO_2 from different sources
- CO_2 transportation
- Utilization of CO_2 for enhanced oil recovery (EOR)
- Storage of CO_2 in onshore or offshore



Carbon Capture, utilization, and storage (CCUS)



CO_2 Transportation

- It is important to safely transport captured CO_2 with a reliable and economic transportation system.
- It can be done by using tankers, pipelines, and ships in various CO_2 phases.

Four different CO_2 transportations

- Gaseous
- Liquid
- Dens-phase
- Supercritical

(Mandra, 2023)

(“CO2 transport infrastructure,” 2025)

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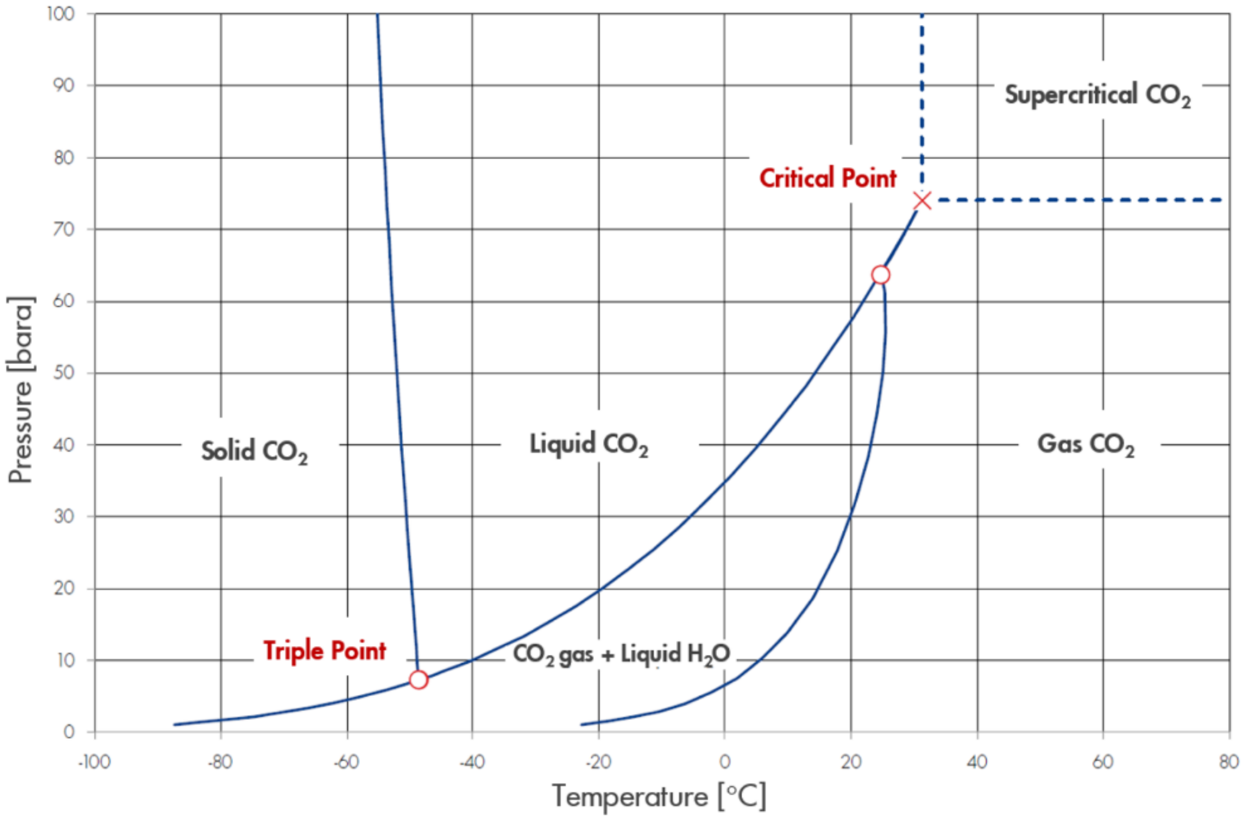
➢ Suitable for short-distance pipelines

- Gas
- Liquid

➢ Suitable for long-distance pipelines and economically better

- Dense phase
- Supercritical

Critical point: 31 °C, 74 bar



(Sonke et al., 2022)

- In the presence of liquid water, carbon dioxide hydration occurs.

Bulk Solution Reactions

$$CO_{2\,(aq)} + H_2O_{(l)} = H_2CO_{3\,(aq)} \quad (1)$$

$$H_2CO_{3\,(aq)} = HCO_{3\,(aq)}^{-} + H^{+}_{(aq)} \quad (2)$$

$$HCO_{3\,(aq)}^{-} = CO_{3\,(aq)}^{2-} + H^{+}_{(aq)} \quad (3)$$

Anodic Reaction

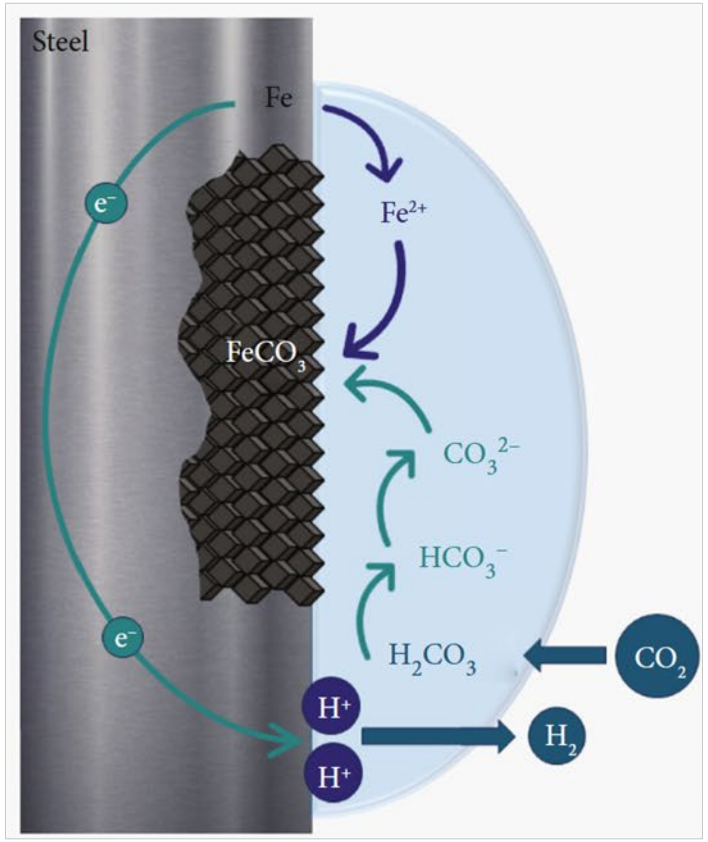
$$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^{-} \quad (4)$$

Cathodic Reactions

$$2H^{+}_{(aq)} + 2e^{-} \rightarrow H_{2\,(g)} \quad (5)$$

$$2HCO_3^{-} + 2e^{-} \rightarrow 2CO_3^{2-} + H_{2\,(g)} \quad (6)$$

$$H_2CO_3 + 2e^{-} \rightarrow 2HCO_3^{-} + H_{2\,(g)} \quad (7)$$



Methodology

➢ Material

- Carbon steel grade C1020 with ferritic microstructure is studied.

Elements	C	Mn	S	P	Fe
Content	0.205	0.45	0.025	0.02	Bal.

➢ Solution

- Deionized water saturated with CO_2 and 1.5 wt. % NaCl.
- Solution temperature is set at 25, 30, 60, 75, 90 °C.
- Polymer and Inhibitor concentrations were 0-10000 ppm HPAM and 0-200 ppm Inhibitor C.

➢ Electrochemical tests

- Linear polarization resistance (LPR)
- Polarization ±10 mV vs. OCP and 0.125 mV/s scan rate.

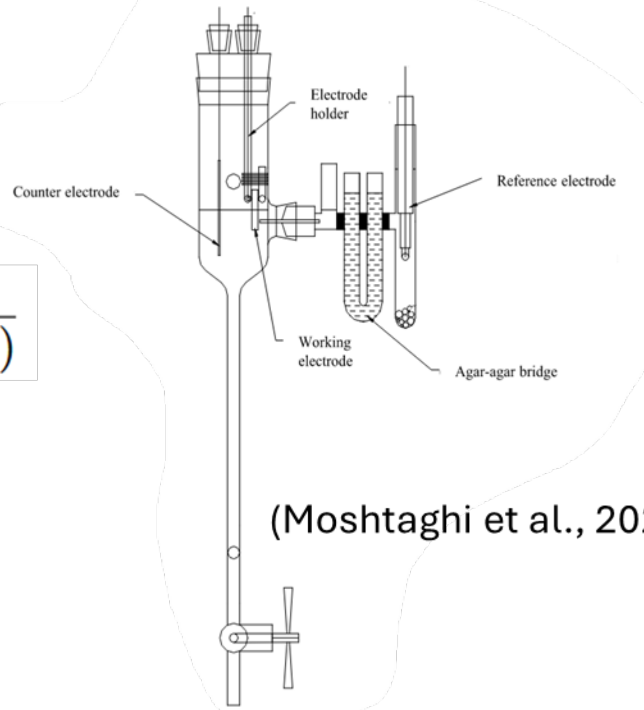
$$R_p = \frac{\Delta E}{\Delta i}$$

$$i_{corr} = \frac{b_a b_c}{2.303 R_p (b_a b_c)}$$

$$CR = \frac{0.13 i_{corr} EW}{d}$$

➢ Surface analysis

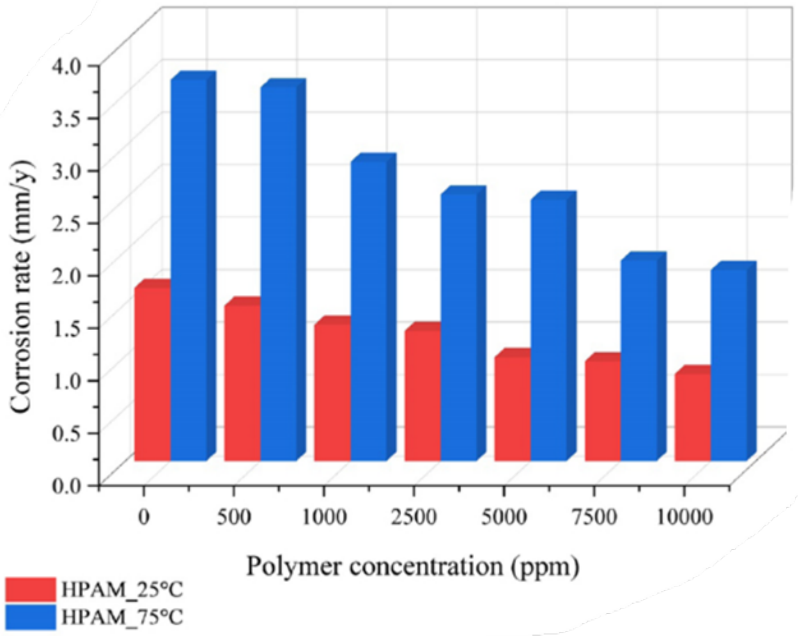
- Scanning electron microscopy (SEM) equipped with an EDS.
- X-ray photoelectron spectroscopy.
- X-ray diffraction analysis



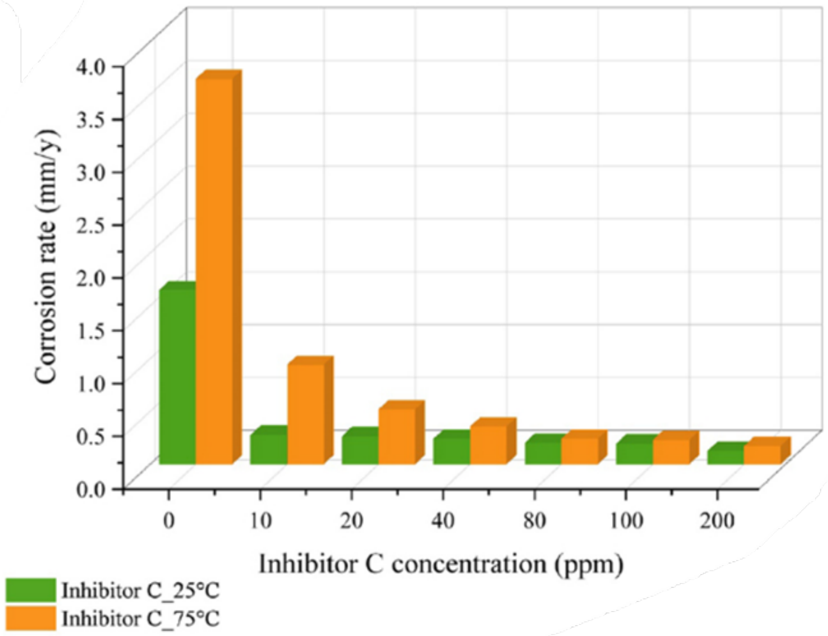
(Moshtaghi et al., 2023)

Results

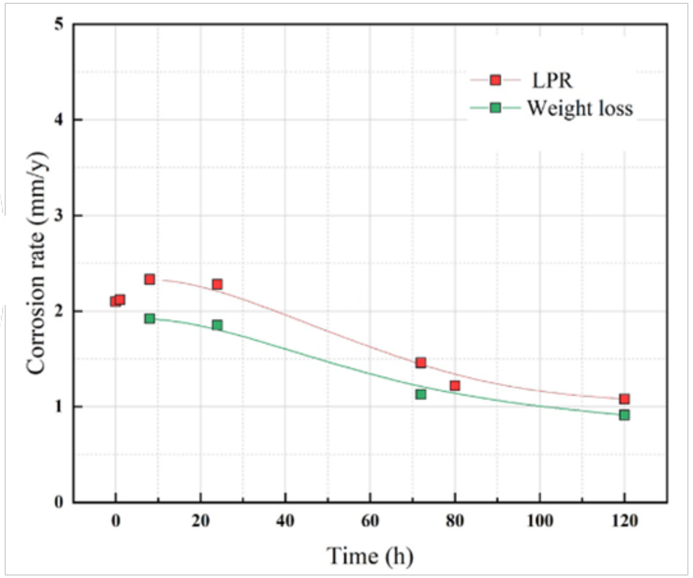
➢ Corrosion rate



(A)



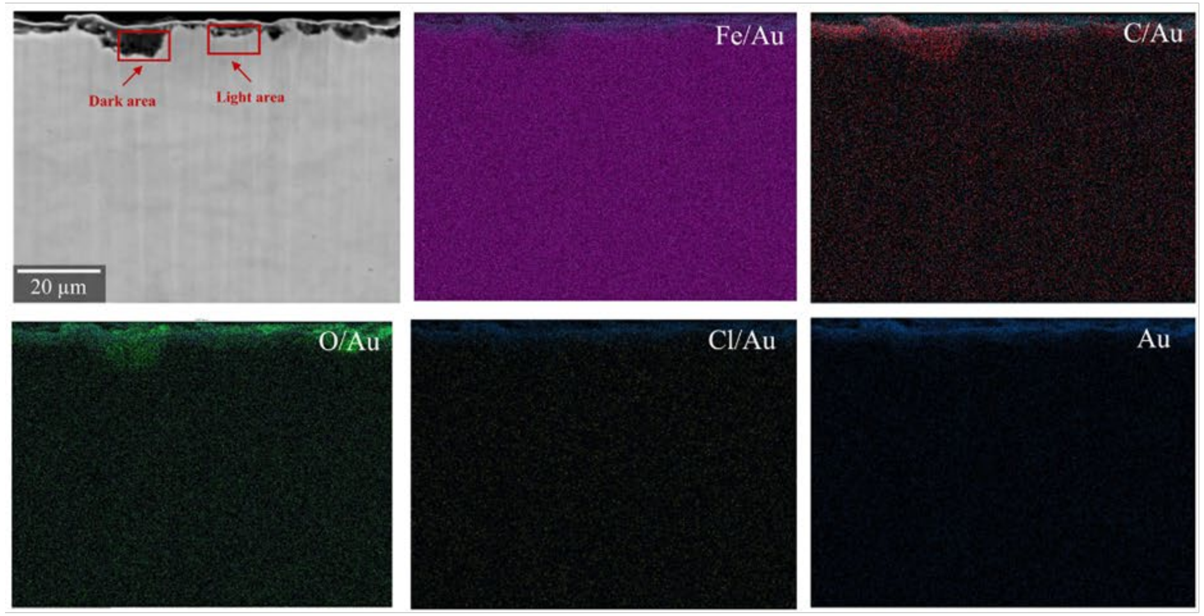
(B)



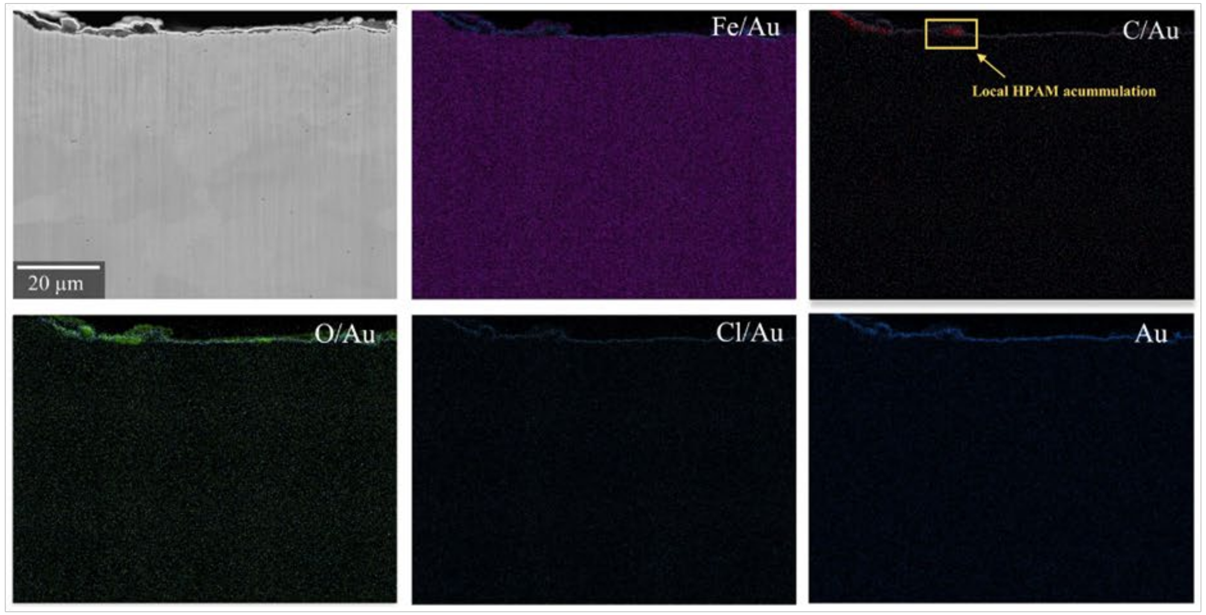
(C)

Results

➢ Surface analysis and corrosion products



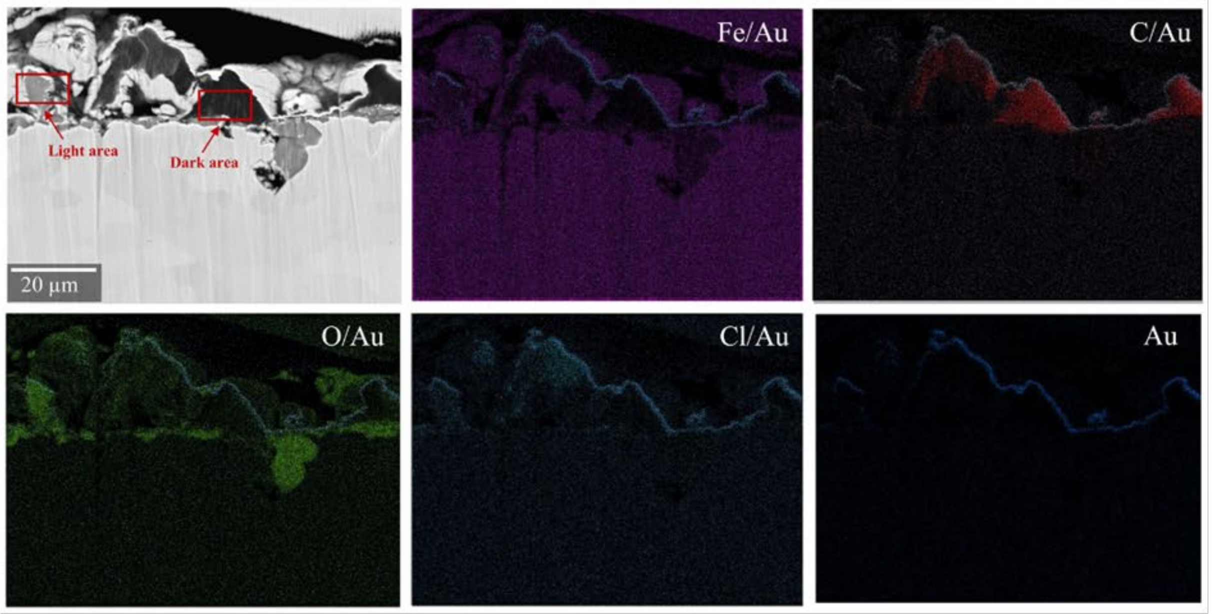
CO_2-saturated + 1.5 wt. % NaCl solution 120 h at 25 °C.



CO_2-saturated + 1.5 wt. % NaCl +1000 ppm HPAM solution 120 h at 25 °C.

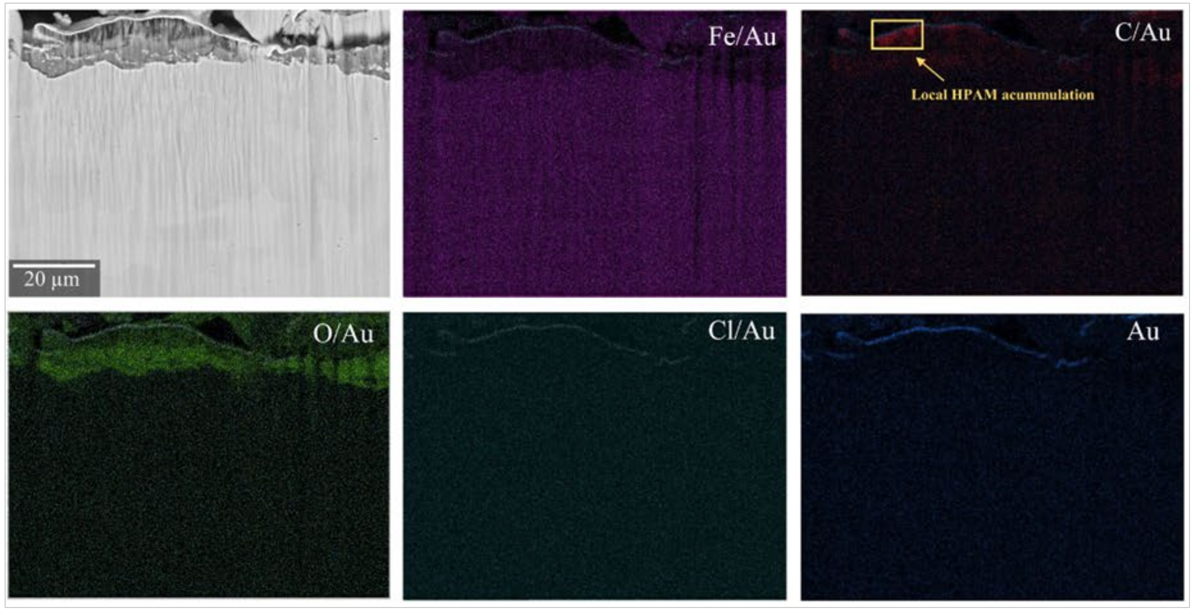
Results

➢ Surface analysis and corrosion products



CO_2-saturated + 1.5 wt. % NaCl solution

120 h at 75 °C.

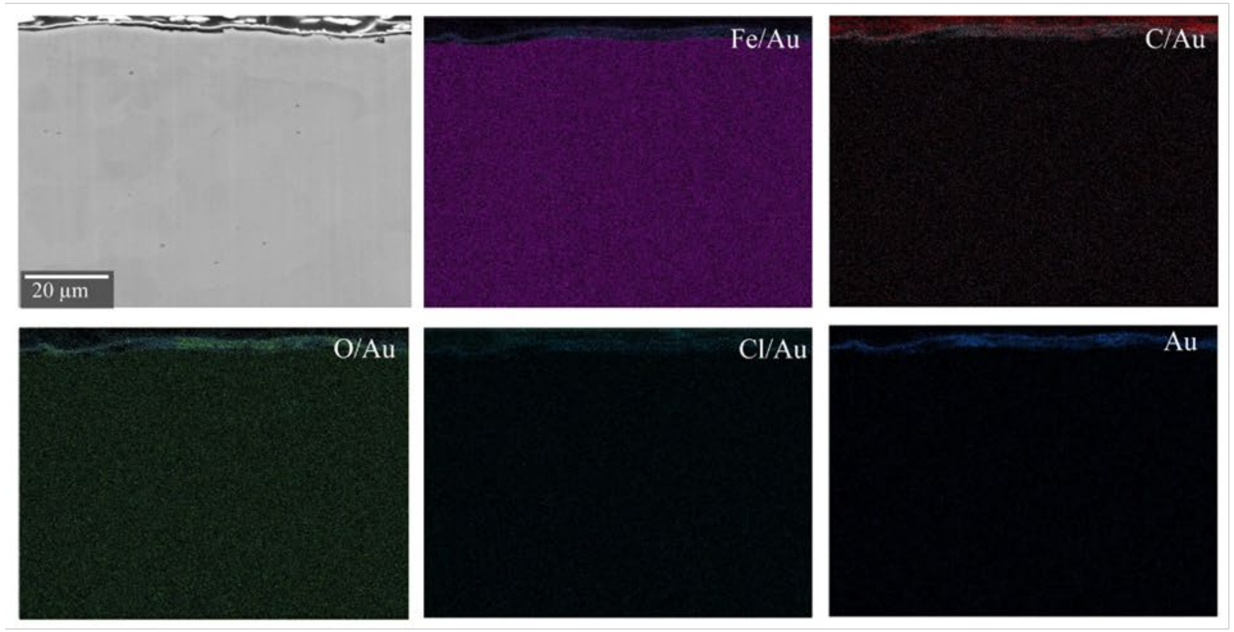


CO_2-saturated + 1.5 wt. % NaCl +1000 ppm HPAM

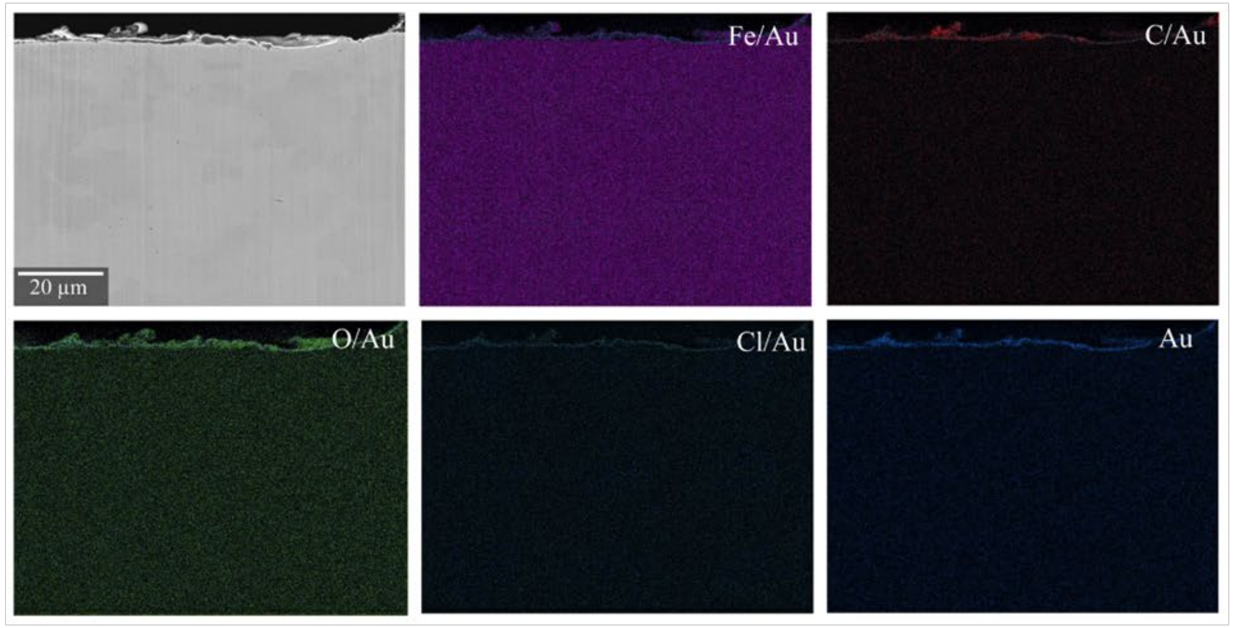
solution 120 h at 75 °C.

Results

- Surface analysis and corrosion products



CO_2-saturated + 1.5 wt. % NaCl +1000 ppm HPAM + 100 ppm inhibitor, solution 120 h at 25 °C.



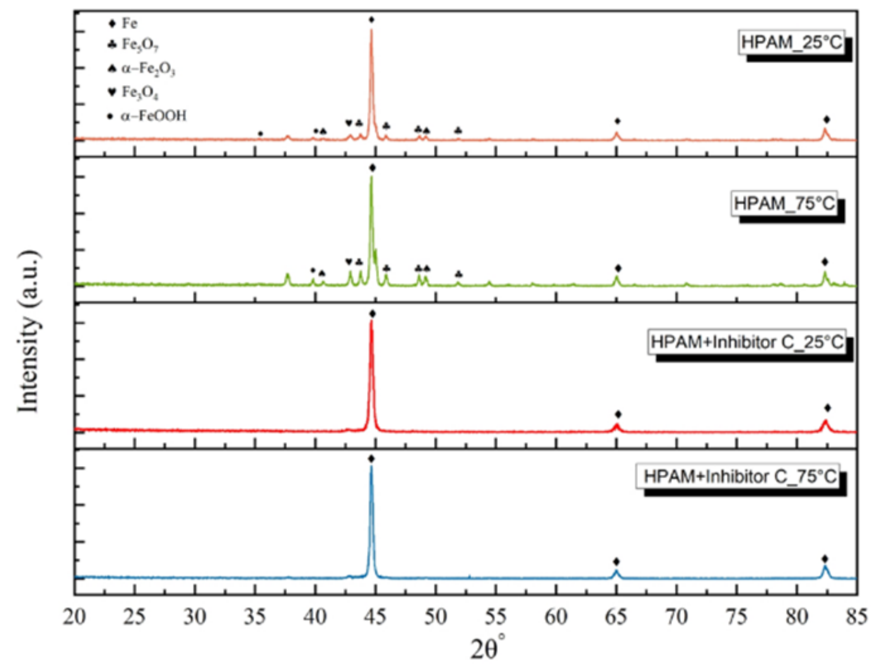
CO_2-saturated + 1.5 wt. % NaCl +1000 ppm HPAM + 100 ppm inhibitor, solution 120 h at 75 °C.

Results

- Iron oxide formation in the presence of HPAM and inhibitor C instead of iron carbonate.
- XPS results show HPAM is bound to the surface of carbon steel.

$$Fe^{2+} + 2OH^{-} \rightarrow Fe(OH)_2$$
$$4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3$$
$$4Fe(OH)_3 \rightarrow FeO(OH) \rightarrow Fe_5O_7 \cdot 4H_2O$$
$$4Fe(OH)_3 \rightarrow Fe_3O_4$$
$$Fe_5O_7 \cdot 4H_2O \rightleftharpoons Fe_5O_{7.5} + 4.5H_2O$$

XRD results

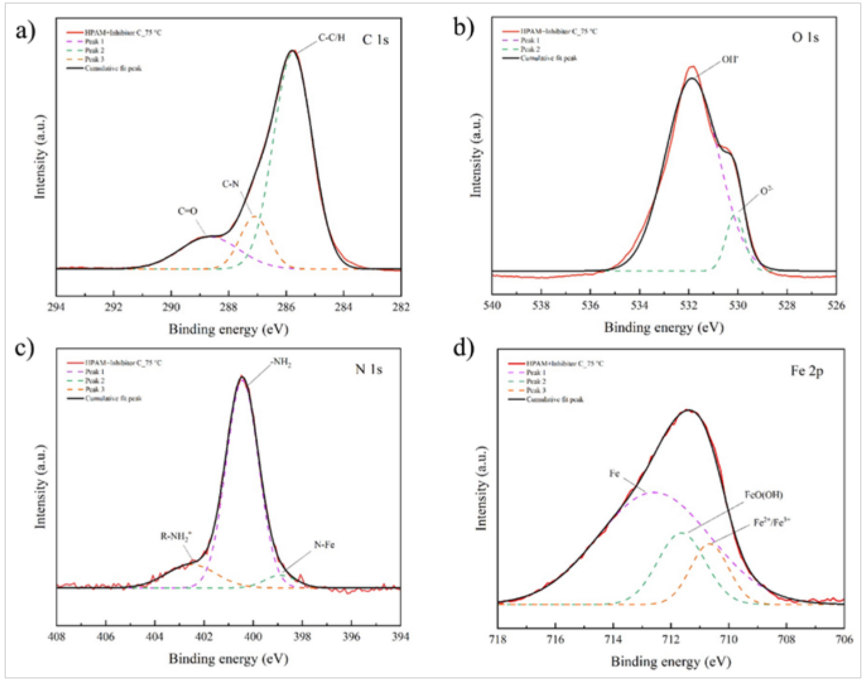


XPS of

1.5 wt.% NaCl

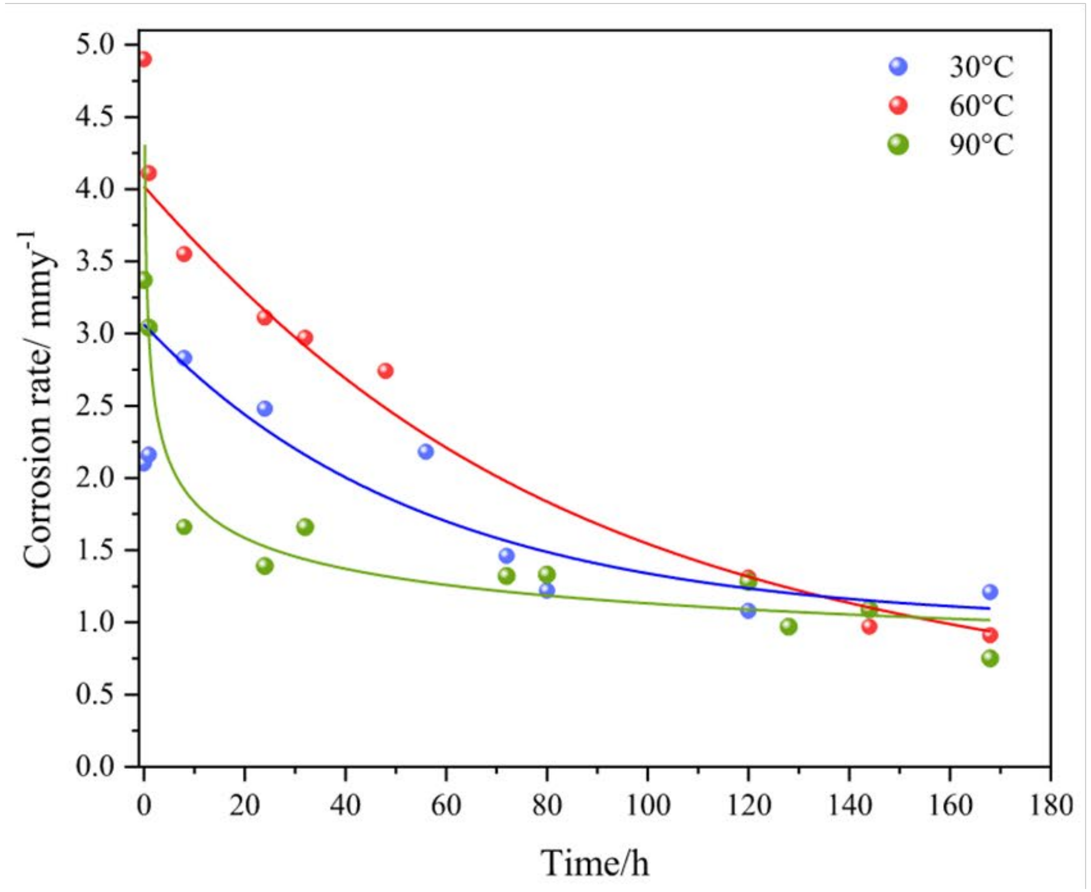
+ HPAM + Inhibitor C

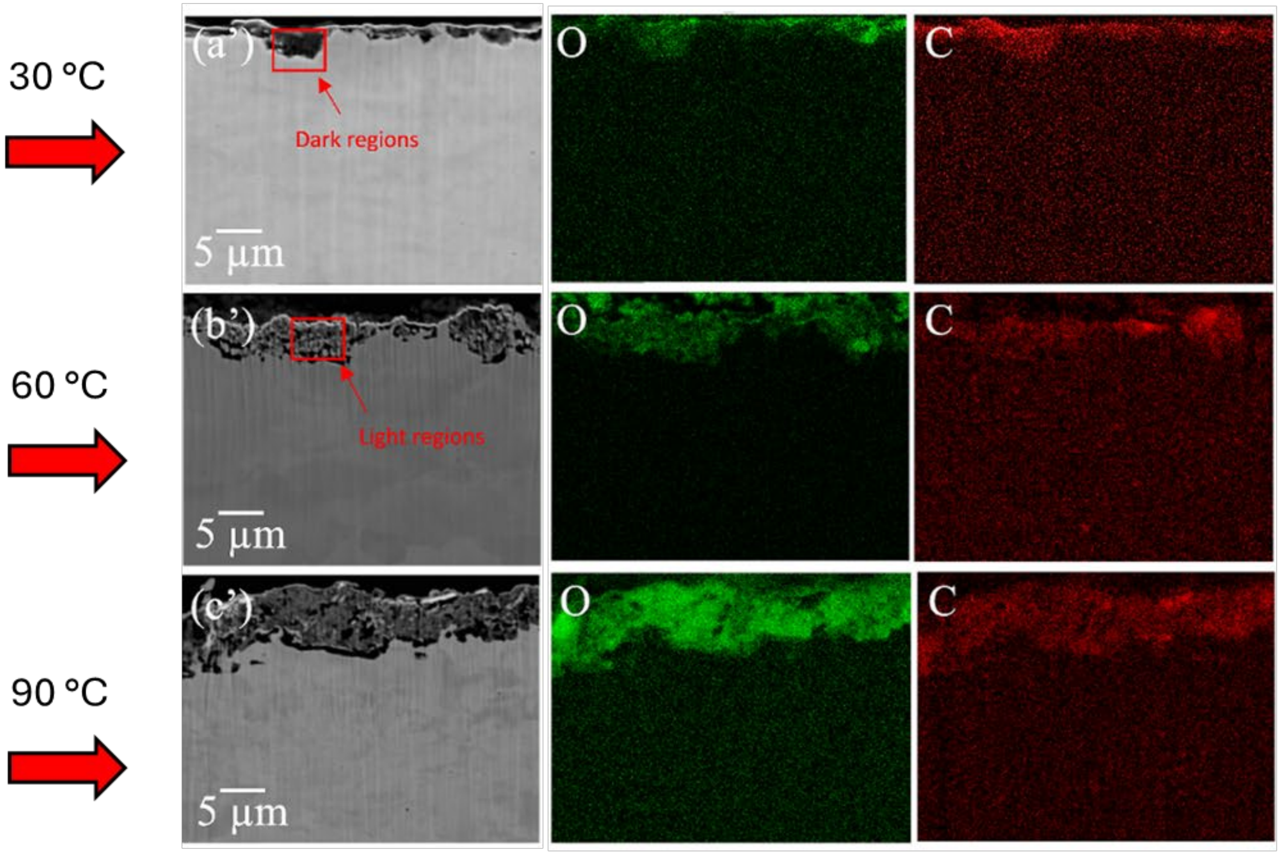
at 75 °C



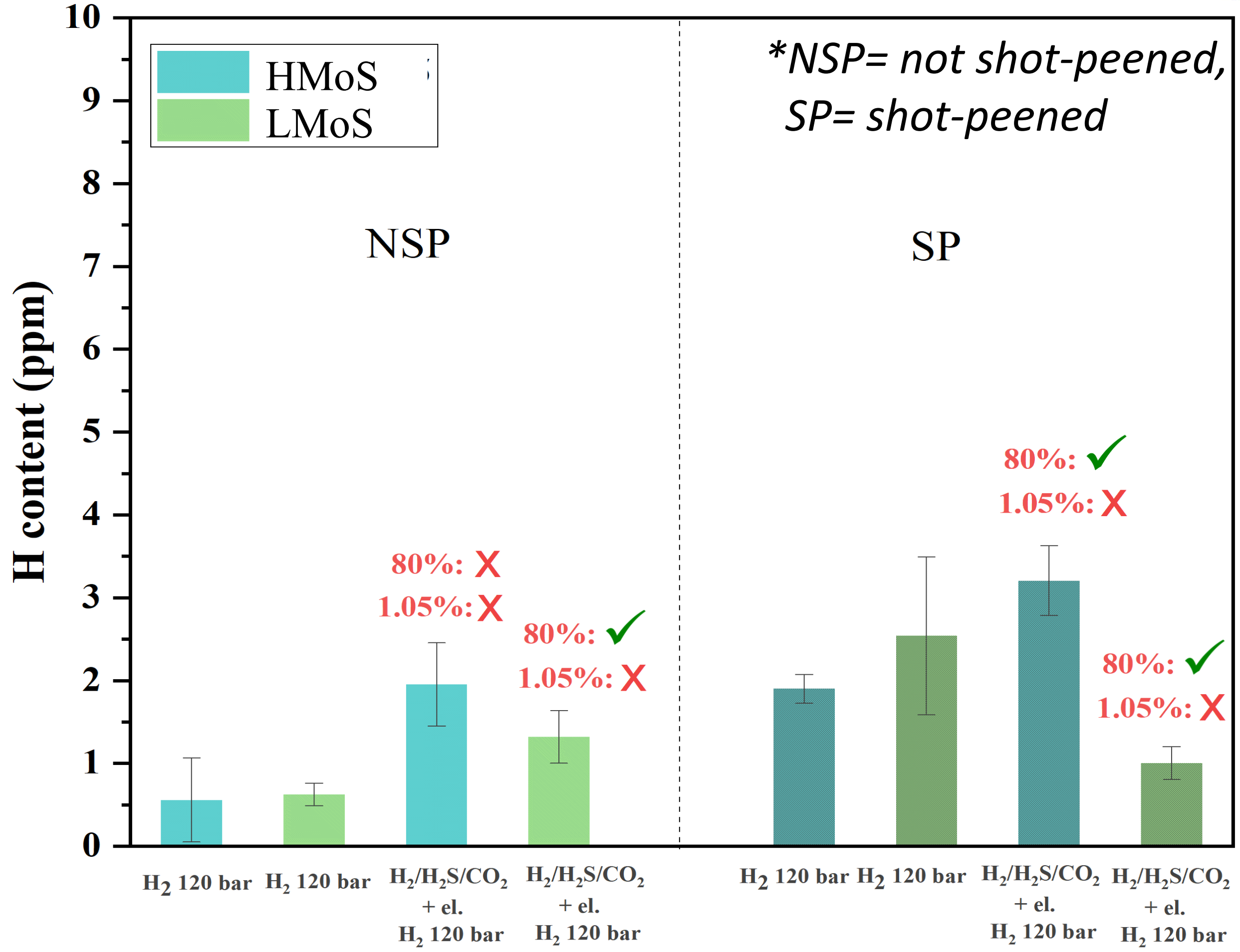
Results

➢ The effect of temperature on corrosion rate and product in 1.5 wt.% NaCl and CO_2-rich environment.





Mixture of Gaseous hydrogen & CO2



- Shot-peened specimens exhibited higher H uptake under both conditions

Recently published works:

- Moshtaghi, M., Eškinja, M., Mori, G., Griesser, T., Safyari, M., Cole, I., 2023. The effect of HPAM polymer for enhanced oil recovery on corrosion behaviour of a carbon steel and interaction with the inhibitor under simulated brine conditions. Corrosion Science. https://doi.org/10.1016/J.CORSCI.2023.111118
- Eškinja, M., Moshtaghi, M., Hönig, S., Zehethofer, G., Mori, G., 2022. Investigation of the effects of temperature and exposure time on the corrosion behavior of a ferritic steel in CO2 environment using the optimized linear polarization resistance method. Results in materials. https://doi.org/10.1016/J.RINMA.2022.100282

Corrosion Science 217 (2023) 111118

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ELSEVIER

The effect of HPAM polymer for enhanced oil recovery on corrosion behaviour of a carbon steel and interaction with the inhibitor under simulated brine conditions

Masoud Moshtaghi [a,*], Magdalena Eškinja [a], Gregor Mori [a], Thomas Griesser [b], Mahdieh Safyari [a,c], Ivan Cole [d]

Results in Materials 14 (2022) 100282

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ELSEVIER

Investigation of the effects of temperature and exposure time on the corrosion behavior of a ferritic steel in CO_2 environment using the optimized linear polarization resistance method

Magdalena Eškinja [a], Masoud Moshtaghi [a,*], Stefan Hönig [b], Gerald Zehethofer [b], Gregor Mori [a]

LUT University

Conclusions:

- **Dual Functionality of HPAM Enhances ROI**: HPAM not only improves oil recovery but also exhibits corrosion inhibition capabilities, offering cost savings by reducing the need for additional corrosion inhibitors in CO_2-exposed environments.

- **Extended Asset Lifespan**: The use of HPAM and its synergistic combination with QAC-based inhibitors significantly reduces corrosion in carbon steel, potentially extending the operational life of pipelines and downhole equipment.

- **Cost-Effective Corrosion Mitigation**: Integrating HPAM in EOR operations can decrease the frequency and cost of maintenance interventions associated with CO_2-induced corrosion in carbon steel infrastructure.

- **Optimized Inhibitor Use Reduces Chemical Costs**: The study shows that a lower concentration of QAC inhibitor (100 ppm) is effective when combined with HPAM, leading to lower chemical usage and associated operational costs.

- **High-Temperature Stability**: The HPAM + inhibitor system performs well at 75 °C, suggesting it is suitable for high-temperature reservoirs, expanding its applicability across a broader range of oilfield conditions.

- **Lower Environmental Impact**: Reducing corrosion through polymer-inhibitor synergy lessens the environmental risk of leakage and spills, supporting ESG and sustainability targets.

Conclusions:

- **Improved Operational Predictability**: The stability and consistency of corrosion mitigation over 120 hours (long-duration exposure) enhances operational reliability and reduces unplanned downtimes.

- **Decreased Risk in CO_2 Pipelines**: For companies involved in CO_2 transport and storage (CCS), applying HPAM or HPAM-inhibitor systems can help reduce internal corrosion risks, enhancing pipeline safety.

- **Compatibility with Existing Infrastructure**: HPAM and QAC-based inhibitors do not require material upgrades or changes in standard steel compositions, allowing easy integration into existing systems.

- **Reduced Risk of Scale and Biofouling**: The study suggests no major microbial corrosion or scaling issues associated with HPAM at tested concentrations, supporting cleaner operations.

- **Enables Leaner Corrosion Monitoring Programs**: Improved corrosion control with HPAM reduces variability, potentially allowing operators to streamline monitoring protocols and reduce inspection frequency.

- **Supports Polymeric EOR Adoption**: Demonstrating corrosion protection removes a key barrier to broader adoption of HPAM-based polymer flooding, unlocking higher EOR yields.

Conclusions:

- **Scalability for Large Field Operations**: The effectiveness of HPAM at standard operational concentrations (500–1000 ppm) makes it scalable and economical for large-field deployment.

- **Improved Risk Management in CO_2-EOR Projects**: The findings enhance confidence in managing corrosion risks in CO_2-EOR applications, where corrosion has historically been a critical challenge.

- **Alignment with Regulatory Compliance**: The formation of stable, protective iron oxide layers (Fe_5O_7, Fe_2O_3, Fe_3O_4) indicates passive protection mechanisms that align with long-term integrity standards for CO_2 storage sites.

- **There is a high dependence of the CO2 damage to the specific condition and application of the CO2: CO2 storage, CO2 transporting pipeline, CO2 underground storage, etc.**

Open questions:

- How is the interaction of the metallic infrastructure with mixed CO_2 with other energy carriers such as H_2, methane, and NaCl, water and others? The complexity of the real environment requires specific test in simulated conditions in laboratory.

- How can we predict the life-time of the infrastructure to avoid leakage, collapses, etc?

- Corrosion fatigue prediction methods require to be developed?

- What is the role of welded zones with high residual stress? How can we control the material degradation?

LUT Mechanics of Materials Goal: New Standards Required for qualification of materials in CO2 and gasmixtures

LUT University

- Prof. Masoud Moshtaghi is a member of the **Standard Committee** at NACE, API and IIW C-XI for hydrogen transport and storage testing procedures.

NACE INTERNATIONAL

SC 26 - Carbon Capture, Alternative Fuels, and Energy Storage

Discussions 42 | Libraries 7 | Members 290

SC 26 - Carbon Capture, Alternative Fuels, and Energy Storage

member last person joined yesterday

IIW

Pressure Vessels, Boilers and Pipelines

https://scholar.google.com/citations?user=UgjW2j8AAAAJ&hl=en
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LUT Mechanics of Materials