Crack Management in Hydrogen Pipelines

In cooperation with
Neil Gallon
Dr. Robert Andrews
Roland Palmer-Jones

presented by
Dr. Daniel Sandana
Principal Engineer
GRADUAL CREATION OF A DEDICATED HYDROGEN INFRASTRUCTURE

Connecting industrial clusters to an emerging infrastructure in 2030
Dedicated European Hydrogen Backbone can develop with a total length of approximately 11,600 km, consisting mainly of retrofitted existing natural gas pipelines.
Regional backbones are expected to form in and around first-mover hydrogen valleys.

Growing network by 2035 covers more countries and enables import
The European Hydrogen Backbone will continue to grow, covering more regions and developing new interconnections across member states.
Dedicated hydrogen storage facilities such as salt caverns, depleted fields and aquifers become increasingly important to balance fluctuations in supply and demand.

Mature infrastructure stretching towards all directions by 2040
The proposed backbone can have a total length of 39,700 km, consisting of approximately 69% retrofitted existing infrastructure and 31% of new hydrogen pipelines.
Total estimate investment is expected to be between 43 and 81 billion euros.
HYDROGEN PIPELINES?

Rest of world
Europe
US

Distance (km)

0 500 1000 1500 2000 2500 3000

337
1598
2608

ASME B31.12 / EIGA / AIGA

Low grade
Relatively small diameter
Low utilisation
PIPELINE OPERATORS ARE NOW FACING NEW CHALLENGES

Can I convert my existing natural gas pipeline?

Existing cracking threats?

Conversion

Operation

New cracking threats?

Crack management?

How do I manage the integrity of my hydrogen pipeline?
The DNA of Natural Gas Transmission Pipelines & Existing crack threats
THE AGE OF NATURAL GAS TRANSMISSION LINES IN EUROPE

- >50 yrs: 21%
- 40-50 yrs: 16%
- 30-40 yrs: 25%
- 20-30 yrs: 16%
- 10-20 yrs: 17%
- <10 yrs: 5%
STEEL GRADES IN NATURAL GAS TRANSMISSION LINES IN EUROPE

Caution! (SMYS vs AYS)
COATINGS IN NATURAL GAS TRANSMISSION LINES IN EUROPE
EU NATURAL GAS TRANSMISSION…
EXISTING CRACK THREATS?

Fatigue not an issue

NG ≠ Hydrogen
EU NATURAL GAS TRANSMISSION… EXISTING CRACK THREATS?

External SCC

H pH SCC.

NNpH SCC.

Impact of gaseous H₂?

Hydrogen-Cracking due to CP

HIC

HISC

EU NATURAL GAS TRANSMISSION… EXISTING CRACK THREATS?

External SCC

H pH SCC.

NNpH SCC.

Impact of gaseous H₂?

Hydrogen-Cracking due to CP

HIC

HISC
Hydrogen transport
...Crack Threats?
**H₂ TRANSPORT… SUSCEPTIBILITY VS MICROSTRUCTURE**

Interaction vs Steel Materials..

..Microstructure driven!... (Not just grade!)

Don’t assume lower bound Properties!

Hydrogen Interaction

Koyama et al.
**H₂ TRANSPORT… IMPACT ON MECHANICAL PROPERTIES**

<table>
<thead>
<tr>
<th>Property</th>
<th>Effect of Hydrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td>$\leftrightarrow (?)$</td>
</tr>
<tr>
<td>Ductility</td>
<td>$\downarrow$</td>
</tr>
<tr>
<td>Fracture Toughness</td>
<td>$\downarrow$</td>
</tr>
<tr>
<td>Fatigue Crack Growth Rate</td>
<td>$\uparrow$</td>
</tr>
</tbody>
</table>

**Graphs and Diagrams:**
- Diagram showing fracture toughness vs. hydrogen pressure.
- Graphs illustrating the effect of hydrogen on various properties: strength, ductility, and fatigue crack growth rate.

---

This document is the property of ROSEN Swiss AG who will safeguard its rights according to the civil and penal provisions of law. No part of this document may be reproduced or disclosed to any other party without the prior permission of ROSEN.
**H₂ TRANSPORT... NEW CRACK THREATS?**

The metrics are ranked and normalized based on their positions (percentiles) within the sample, resulting in normalized metric values between 0 and 1. The $\Phi$ value is calculated as a weighted average between normalized feature density and normalized maximum depth, subtracted from a value of 1, i.e. $\Phi = 1 - 0.5 \times (\text{feature density}_{\text{norm}} + \text{maximum depth}_{\text{norm}})$.

**ROSEN IDW global crack population in NG lines**

**Hydrogen-Environment Assisted Cracking**

**Growth solely at pre-existing cracks under static stress**

**...Threshold SIF criteria?...**
**H₂ TRANSPORT... NEW CRACK THREATS?**

The metrics are ranked and normalized based on their positions (percentiles) within the sample, resulting in normalized metric values between 0 and 1. The \( \Phi \) value is calculated as a weighted average between normalized feature density and normalized maximum depth, subtracted from a value of 1, i.e., \( \Phi = 1 - 0.5 \times (\text{feature density}_{\text{norm}} + \text{maximum depth}_{\text{norm}}) \).
H₂ TRANSPORT…
INFLUENCE ON EXISTING CRACK THREATS?

Key influence of H₂

Enhances transition from initiation to propagation

Enhances SCC GRs

...CP interaction...

Interaction of CP & H₂ Transport?

CP levels & Pp H₂

Grades

Geom. Anom. / bend. Strain / Hard spots

Gaps… Threat Quantification? Expects escalation
Impact of Hydrogen on Crack Management
**H₂ TRANSPORT... THREAT ASSESSMENT**

Understand your *materials*

“Targeted Smarter Sampling”

Testing
**H₂ TRANSPORT... THREAT ASSESSMENT**

Understand your ‘hot spots’

“Targeted Smarter Sampling”

Testing

- Hard spots
- Geometric defects
- Bending strain
Higher CGRs…
Specific testing required

Acceptability of cracks in
Low toughness material …

Acceptability of cracks
at SAW and Girth welds…

…Conversion economic alternatives?
**H₂ Transport .... Crack management**

**Conversion strategy**
- Evaluation of Pre-existing crack threats (NG ops)
- Materials Population
- Hard spots

**Baseline crack ILI**
- Targeted Material Sampling

**Expected Hydrogen Operational Framework**
- Data integration
- Testing
- Eng. Analysis

**Threat assessment**
- Critical Flaw Analysis
- Growth rates

- Fatigue
- Ext. SCC
- HISC & HIC
- HEAC (static load)

**Conversion strategy**
- X – Not suitable for conversion
- Review ops constraints
- Pipeline rehabilitation strategy

**Other key considerations:**
- High Bending strain sites
- Geometric anomalies

**Future Pipeline Integrity Management**
- Inspection & Integrity assessment
- CP
- Additional sampling & testing
- Repairs

**Type & frequency?**
**Acceptable CP criteria?**

Crack Management in Hydrogen Pipelines · ICHS 2021 · © ROSEN Group · 22-Sep-2021
Conclusions

Crack Management Complex topic
...NG vs Hydrogen...

Preexisting crack threats
Escalation...Quantification?

...New threats...
HEAC and Fatigue
...Gaps...

...Understand your materials...

...Understand your Hot spots...
Hard spots, bending strain, geometric, etc.

Targeted sampling & Testing

• Ext SCC (NNpH, HpH)
• CP-related H Cracking

• Crack threat susceptibilities
• Growth rates
THANK YOU FOR JOINING!