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MATERIAL ASPECTS IN H_2 INFRASTRUCTURE

Case example with DN500 *t* = 12.7 mm natural gas pipeline conversion for hydrogen transportation

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CONTENTS

- Influencing parameters
- Crack growth rate
- Modelling approach
- Case example

Work published as part of Use of existing gas infrastructure in European hydrogen economy by Satu Lipiäinen, Kalle Lipiäinen, Antti Ahola and Esa Vakkilainen. International Journal of Hydrogen Energy (2023).

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MATERIAL PARAMETERS

TENSILE STRENGTH

H_2 environment may influence

DUCTILITY AND TOUGHNESS

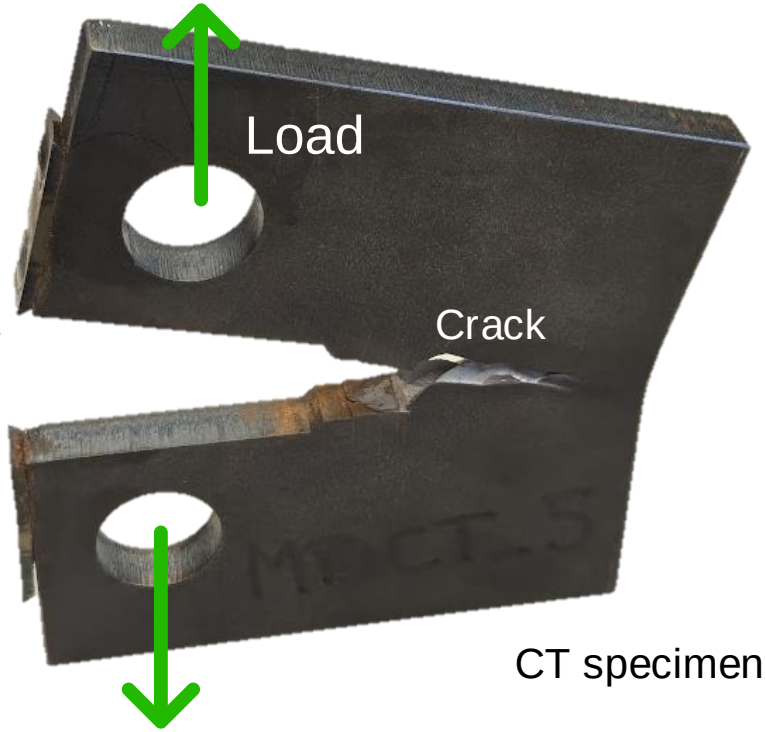
Decreases in H_2 environment – Negative effect

CT specimen
more complex
and accurate

CT for Compact Tension

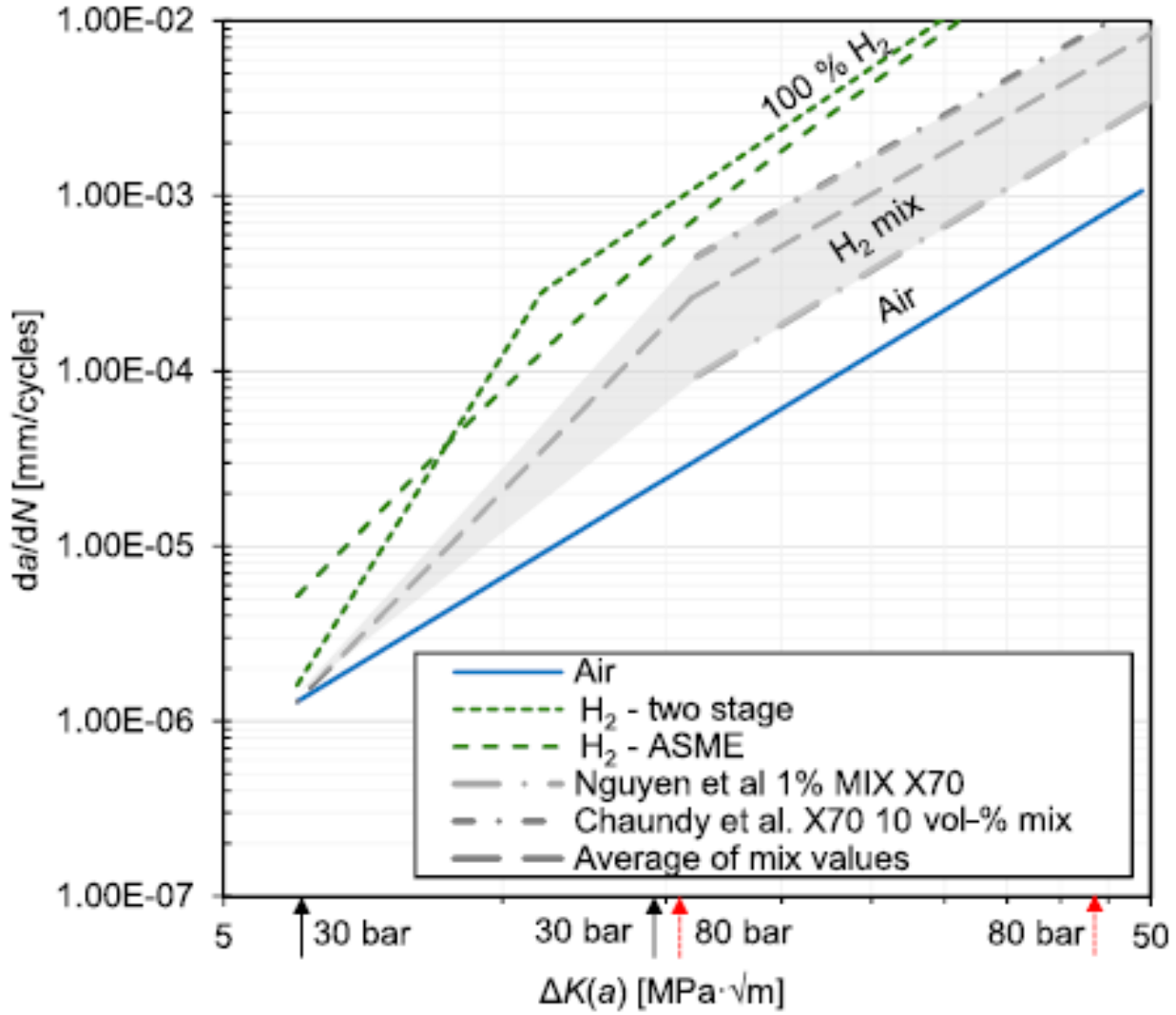
FATIGUE CRACK GROWTH RATE

Increases in H_2 environment – Negative effect



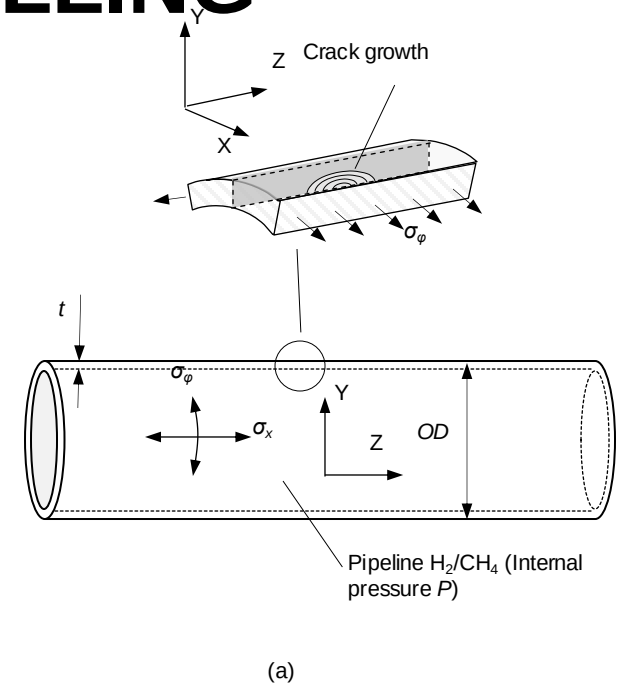
CRACK GROWTH RATE IN HYDROGEN ENVIRONMENT

- Standard (e.g. ASME) or material or pipeline specific values obtained by experimental testing
- Specimens can be extracted from pipeline
- Consideration of welding and residual stresses important
- CT-specimen with dynamic loading tested under H_2 pressure

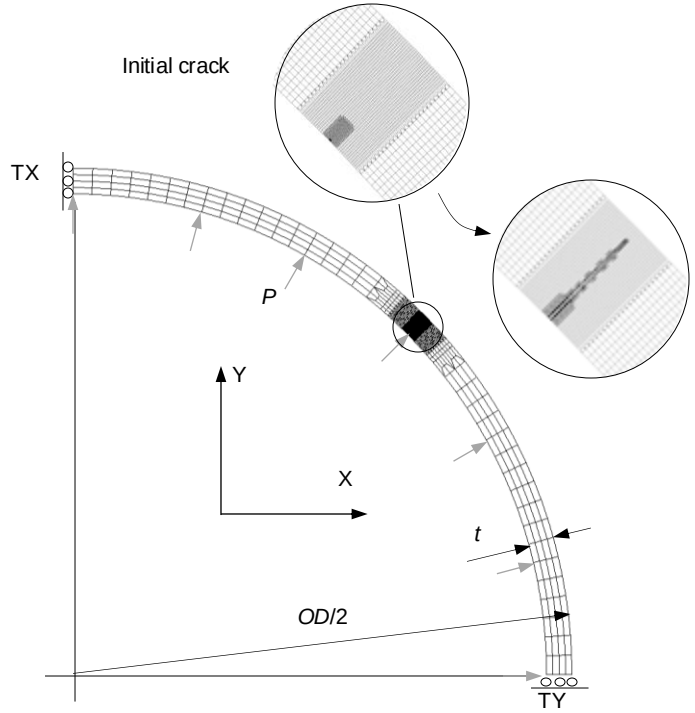


CRACK GROWTH MODELLING

- Tools and software available for crack growth modelling and stress intensity factor estimation (in respect to crack size)
- Crack and stress direction important
- Hoop stress twice larger than longitudinal stress



(a)



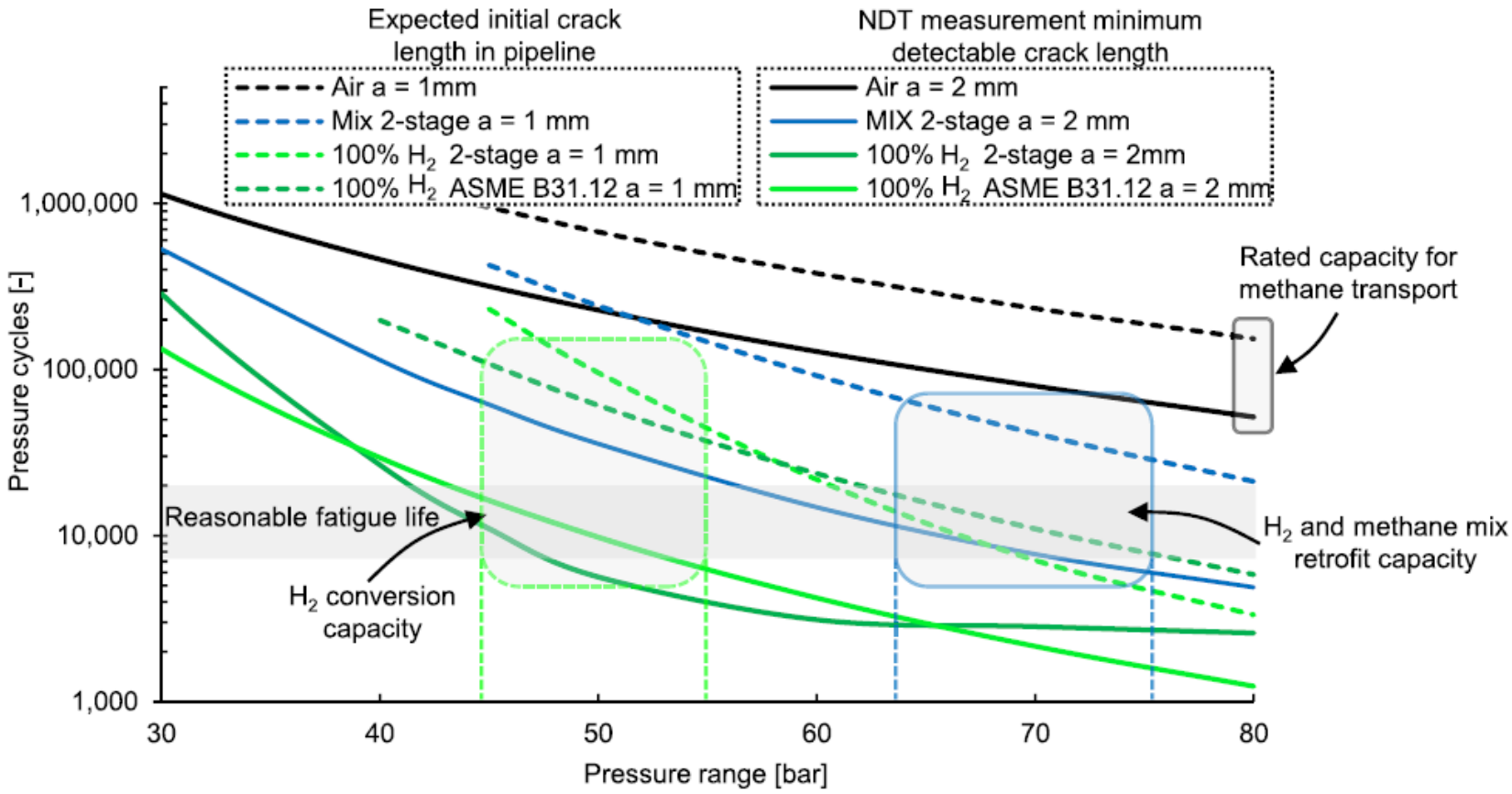
(b)

Two stage LEFM calculation for fatigue life

$$N = \int_{a_{i,1}}^{a_{f,1}} \frac{da}{C_1 \Delta K(a)^{m_1}} + \int_{a_{f,1}}^{a_{f,2}} \frac{da}{C_2 \Delta K(a)^{m_2}}$$

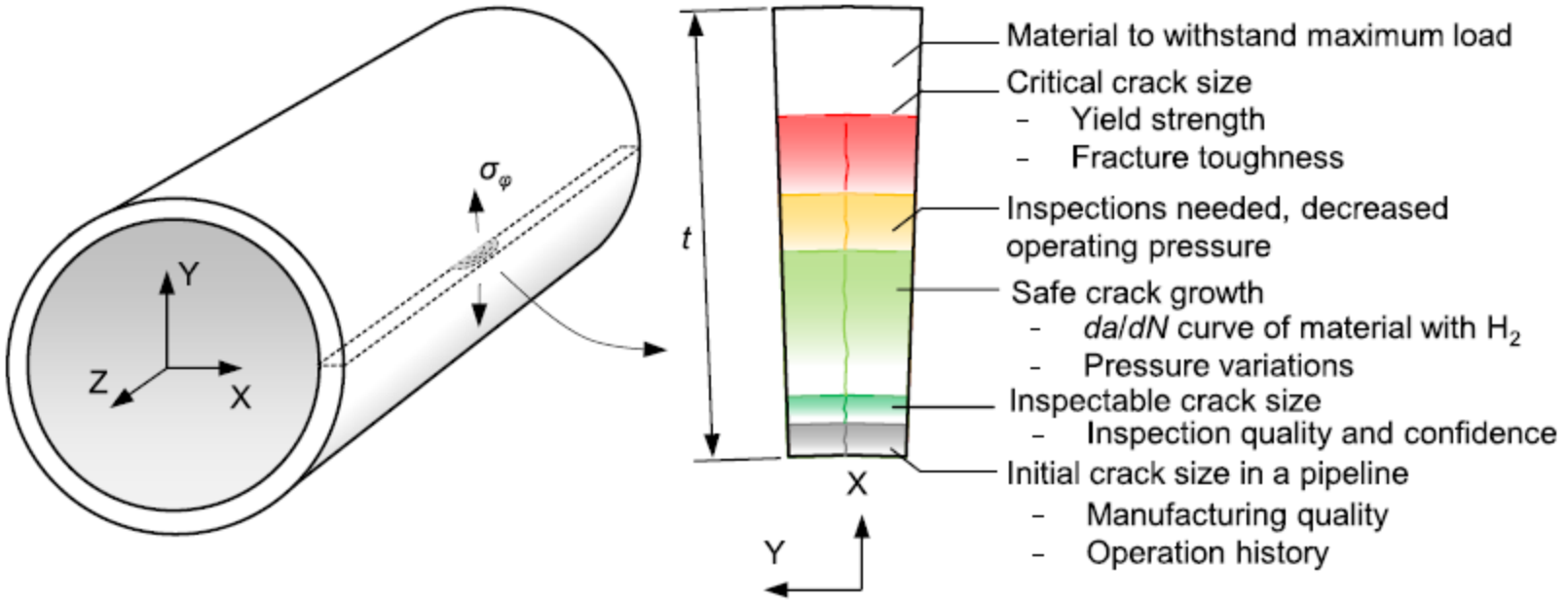
CALCULATION RESULTS FOR AN EXAMPLE PIPE

- Maximum operating pressure
  - 80 bar for NG
  - 50 bar for H_2
- Fatigue not critical with NG
- Fatigue one of the main aspects for H_2 converted pipeline



STAGES OF PIPELINE CRACK GROWTH

- Performance of pipeline defined by material characteristics, manufacturing quality and operation
- Three stages
  - Crack growth under NDT detectable length
    - Manufacturing quality
  - Crack growth
    - Influence of hydrogen
  - Final fracture
    - influenced by ductility and strength



ONLINE FATIGUE MONITORING

- Commercial business – Example reframo
- They apply for e.g. maritime and railway sectors
- Theoretical background should be valid. For hydrogen pipeline LEFM instead of typical stress-based analysis. Monitoring could be applied by pressure or strain gauges glued on pipeline
- Somehow more complex to apply for hydrogen pipeline than e.g. bridge structures
- Maintenance important part of gas transmission
  - Fatigue monitoring one tool together with inspection

Could be applied to pipelines and storages

CONCLUSIONS

- Possibility of converting natural gas pipeline for hydrogen transport was studied using literature review and numerical analysis
- Numerical analysis showed that example DN500 t = 12.7 mm (80 bar NG operation pressure) could be utilized as 50 bar hydrogen pipeline
- Concept for fatigue life monitoring was discussed and the approach should be implemented in more detailed way for real life applications

Spiral welded district heating pipeline

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THANK YOU

Questions and comment welcome

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