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Materials compatibility concerns for hydrogen blended into natural gas (PVP2021-62045)

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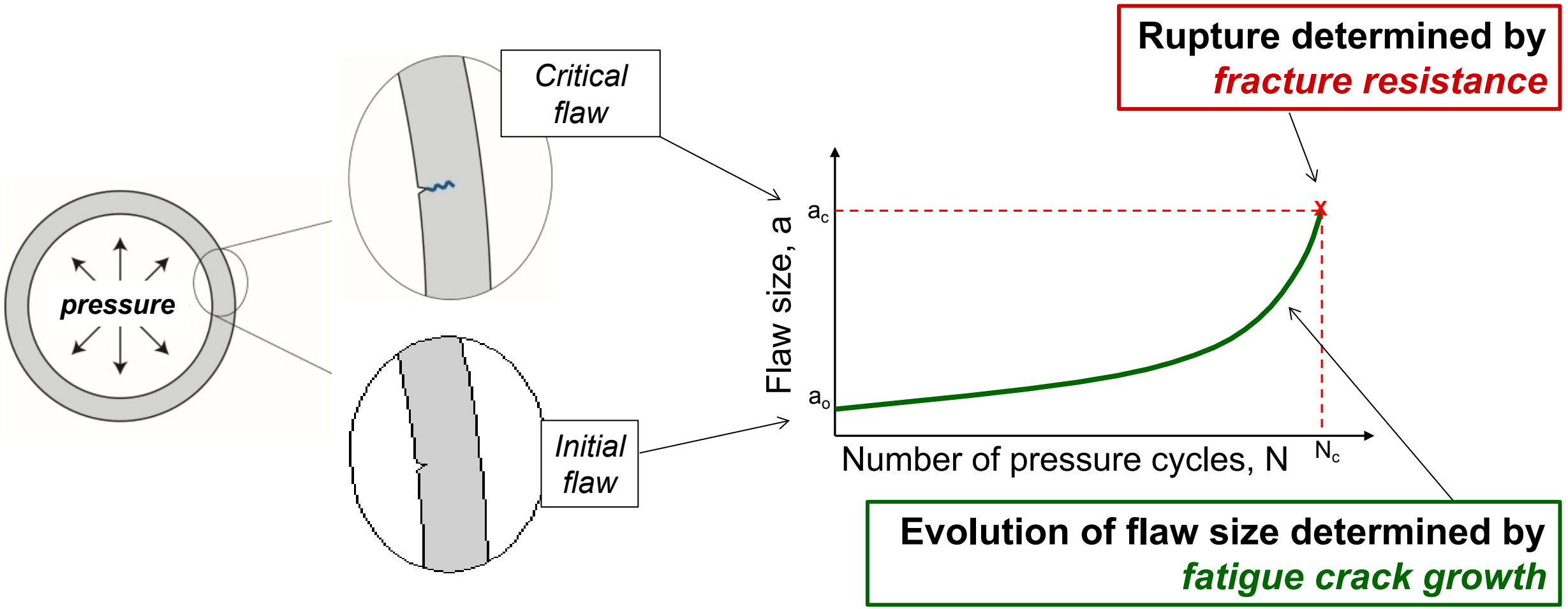
Structural integrity assessment includes fracture mechanics-based analysis

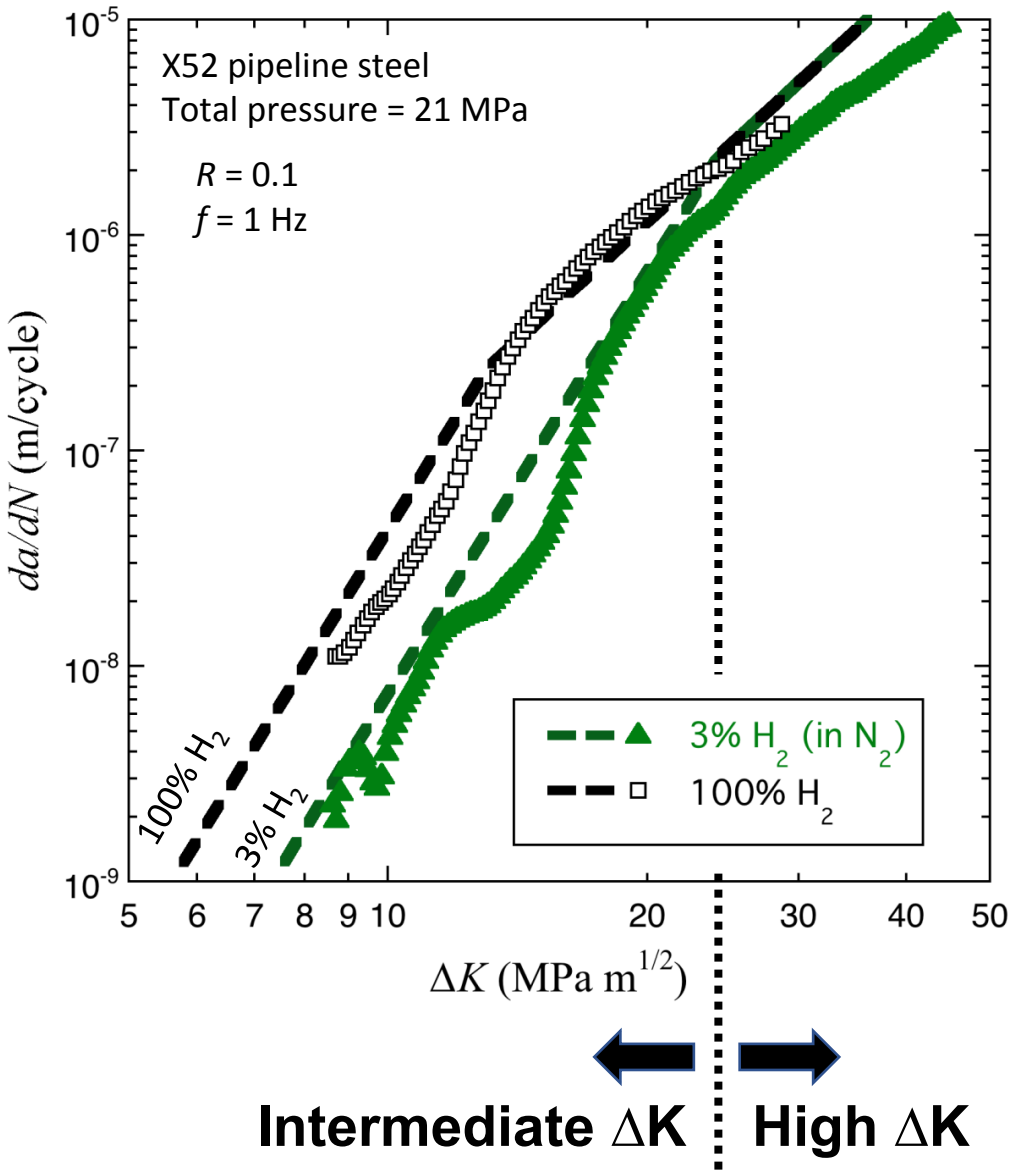


ASME B31.12 describes rules for hydrogen pipelines with reference to ASME BPVC Section VIII, Division 3, Article KD-10

Summary: materials perspective

Gaseous hydrogen strongly affects fatigue and fracture properties of steels, even at low pressure

- Fatigue crack growth
  - Large ΔK: FCG in H_2 is not dependent on pressure and is >10x faster than in air
  - Intermediate ΔK: FCG in H_2 scales with square root of the thermodynamic pressure (i.e., fugacity)
  - Small ΔK: FCG can be quite low and similar to air
- Fracture resistance
  - Significant reductions even for low pressure, but K_{JIH} >100 MPa $m^{1/2}$ in 21 MPa hydrogen

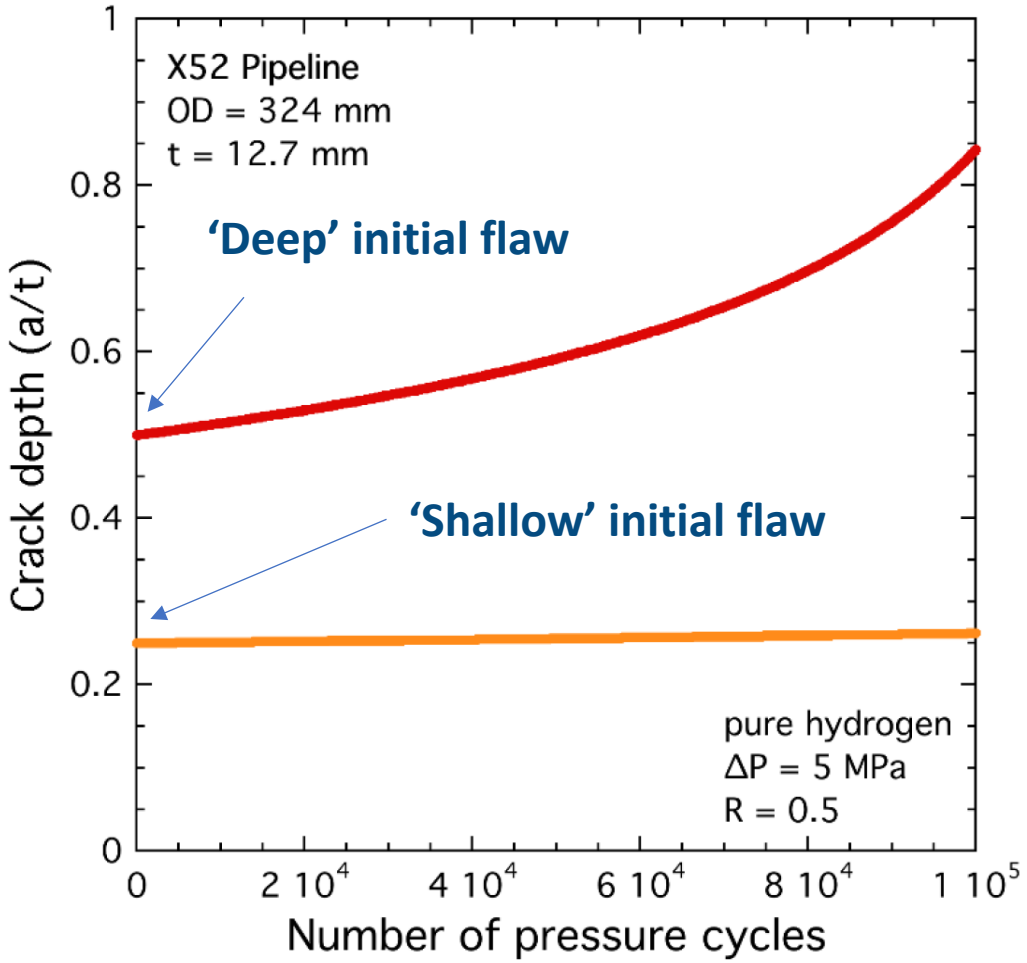


Summary: structural integrity perspective

Effects of pure gaseous hydrogen are generally manageable if the stresses (driving forces) are sufficiently low

- *Transmission pipeline*
  - Very large flaws are needed for significant crack extension in fatigue and cracks are stable as they approach through wall
    - $K_{JIC} > 4x\ K_{applied}^{\dagger}$
- *Distribution piping*
  - Hydrogen is unlikely to be an issue for ductile steels
    - for P < 1 MPa, $K_{applied}^{\dagger} < 5$ MPa $m^{1/2}$
    - $K_{JIC} \sim 100$ MPa $m^{1/2}$

†crack depth: a/t = 0.8



Actual results will depend on stresses and defect population

Thank You!

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