HyBlend:
Hydrogen blending into natural gas pipelines

Quantify value proposition of blending hydrogen into natural gas infrastructure

Planned work (anticipated start date July 2021)

- **Structural integrity of existing piping and pipeline infrastructure with hydrogen**
  - ***Transmission pipelines and associated equipment*** **- establish baseline performance of materials as function of system variables (such as pressure) and develop probabilistic tool to assess performance**
  - ***Distribution piping and soft materials*** **- assess hydrogen-induced degradation of polymer piping materials and provide guidance on soft materials (such as, seals)**
- **Life cycle analysis**
  - **Analyze the life cycle emissions of hydrogen and natural gas blends as well as alternative pathways (e.g., synthetic natural gas)**
- **Technoeconomic analysis**
  - **Quantify the costs and opportunities for hydrogen blending in the natural gas network based on pipeline components and design. Benchmark against alternative pathways (e.g., synthetic natural gas)**

Why hydrogen in pipelines?

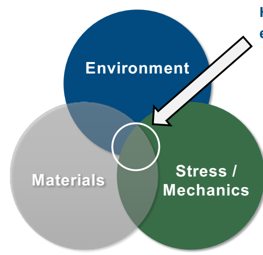
Hydrogen is a carbon-free energy carrier and key enabler of large-scale storage of renewable energy

Hydrogen has potential to enable decarbonization across a diverse range of sectors and technologies; however, hydrogen must be delivered to end-use locations, ideally with existing infrastructure, such as pipelines

- Blending hydrogen is a necessary step to establish hydrogen demand markets to enable transition to decarbonized gas networks
- High concentrations of hydrogen in natural gas are needed for significant reduction of carbon emissions
- Hydrogen pipelines could be an economic way to leverage existing infrastructure and decarbonize multiple sectors across the U.S

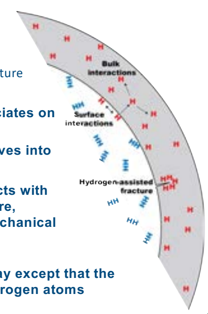
What is hydrogen embrittlement and when is it important?

Hydrogen degrades mechanical properties of most materials



Hydrogen embrittlement
also called hydrogen-assisted fatigue and fracture

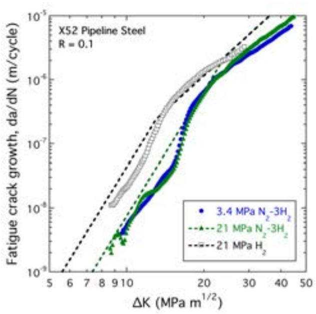
- Hydrogen dissociates on metal surfaces
- Hydrogen dissolves into the metal lattice
- Hydrogen interacts with the microstructure, changing the mechanical response



Hydrogen interacts with polymers in a similar way except that the hydrogen molecule does not dissociate into hydrogen atoms

Is there a threshold below which hydrogen effects on materials properties can be ignored?

Even small amounts of hydrogen have large effects on materials properties, whereas effects on structures depend on the operating conditions



Low partial pressure of hydrogen can have as significant an effect as high pressure hydrogen

- Fatigue crack growth data (left) is used in design assessment
- Fatigue response is sensitive to hydrogen partial pressure
- However, for high 'stress' (large ΔK) fatigue effects are significant and nominally independent of pressure

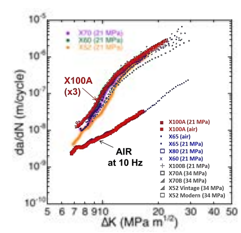
Plot shows fatigue crack growth for:
- 100% H_2 at pressure of 21 MPa
- 3% H_2 at total pressure of 21 MPa
- 3% H_2 at total pressure of 3.4 MPa

How does gaseous H_2 affect fatigue & fracture of materials?

Fatigue is accelerated by up to 10x, fracture resistance is reduced by >50%

Extensive hydrogen-assisted fatigue and fracture of pipeline steels show similar behavior to other construction steels used for hydrogen service

- Hydrogen-assisted fatigue crack growth is similar for typical API grades of transmission pipeline steel (right)
- In contrast, hydrogen-assisted fracture is sensitive to the strength of steel
- Long-term effects on polymer pipe have not been studied, but initial evaluation suggest there are no concerns for distribution piping



These effects are managed in existing H_2 pipelines for safe, reliable operation

HyBlend will develop industry-focused tools to assess the role of hydrogen on structural integrity, emissions and economies at scale

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