
ONGOING ACTIVITIES IN GERMANY FOR THE USAGE OF THE NATURAL GAS GRID FOR HYDROGEN TRANSPORTATION: A PERSPECTIVE FROM MATERIALS SCIENCES

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Outline

- Who we are
 - The Fraunhofer-Gesellschaft at a Glance
 - Fraunhofer Institute for Mechanics of Materials IWM
- Recent projects for hydrogen pipelines at the Fraunhofer IWM
- Regulations of German gas grid for hydrogen
- Questions of research for materials qualification for a hydrogen grid

The Fraunhofer-Gesellschaft at a Glance

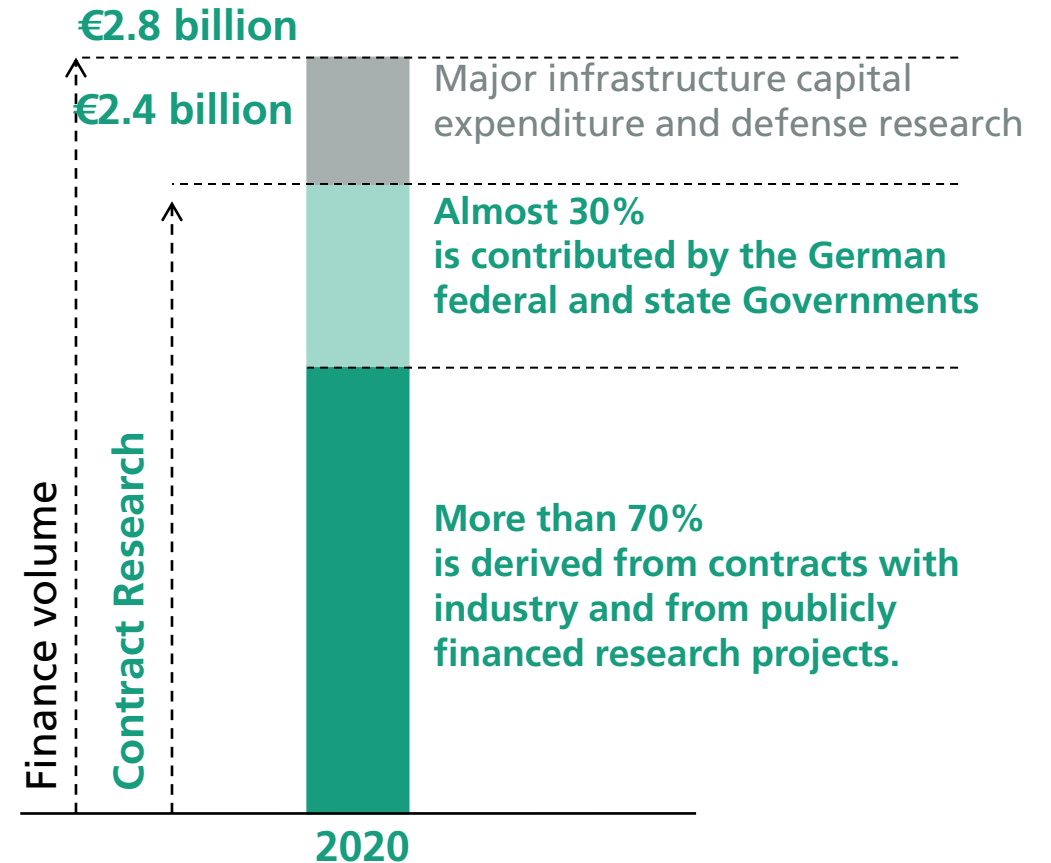
The Fraunhofer-Gesellschaft undertakes applied research which is of direct utility to private and public enterprise as well as of wide benefit to society.



29 000 staff



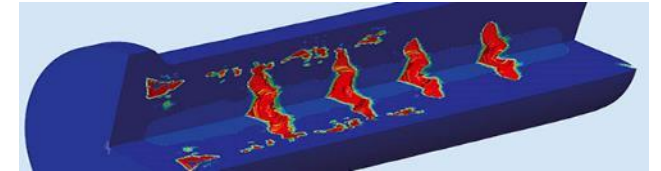
75 institutes and research units



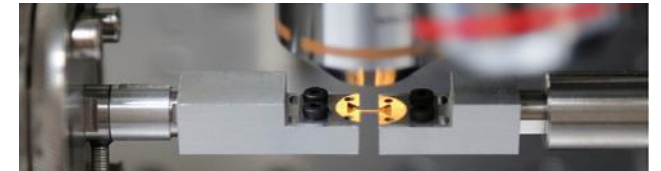
Fraunhofer Institute for Mechanics of Materials IWM

Making intelligent use of materials means:

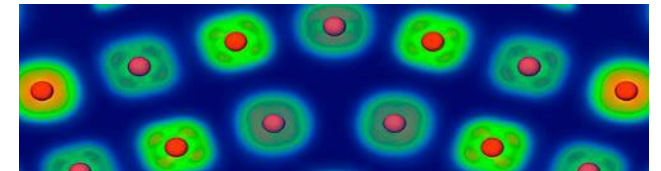
- Make the mechanisms and processes in materials and material systems manageable
→ extract more of the potential performance and efficiency from technical systems
- Measure materials down to their atomic structures and influence interactions
→ modify material properties to meet requirements
- Scrutinize material systems and manufacturing processes
→ transfer into reliable products and technologies



simulation of production processes



micromechanical material testing



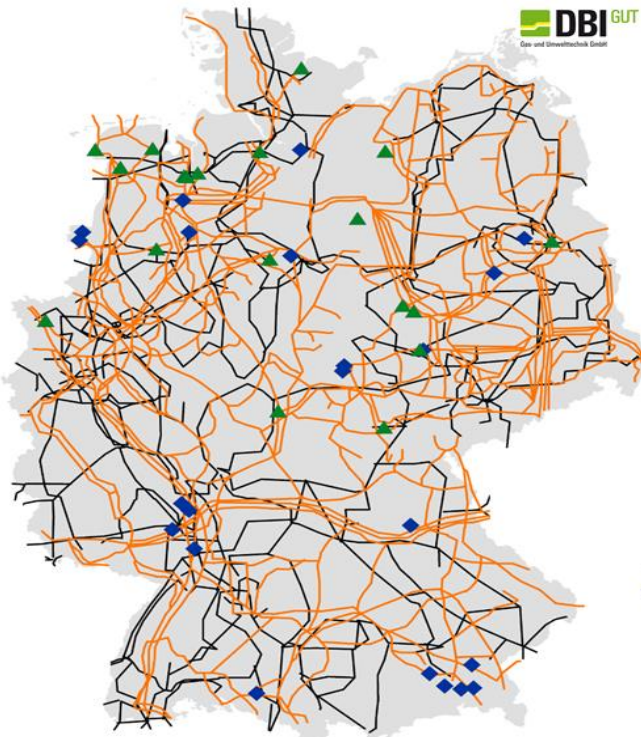
novel magnetic materials



innovative cutting processes

Recent Projects

»H2-PIMS« Using the natural gas pipelines for hydrogen and development of a pipeline integrity management system



- ▲ 29 Kavernenspeicher (12 Mrd. m³)
- ◆ 21 Porenspeicher (11 Mrd. m³)
- Erdgasleitung > 60 bar
- Stromleitung 220 kV / 380 kV

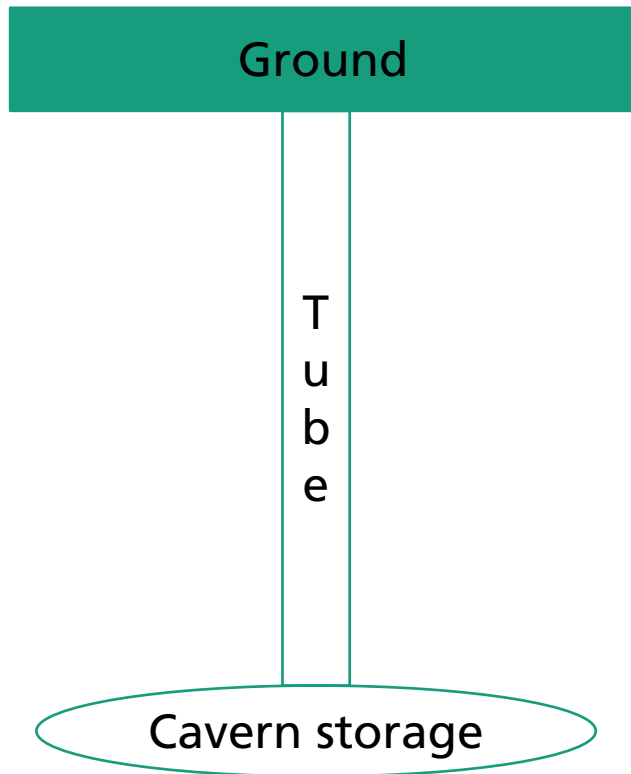
IWM Focus:

Characterization on the influence of hydrogen on the mechanical properties of materials and weldments of existing pipelines.



Recent Projects

»H2-UGS« Enabling salt caverns as hydrogen storage facilities



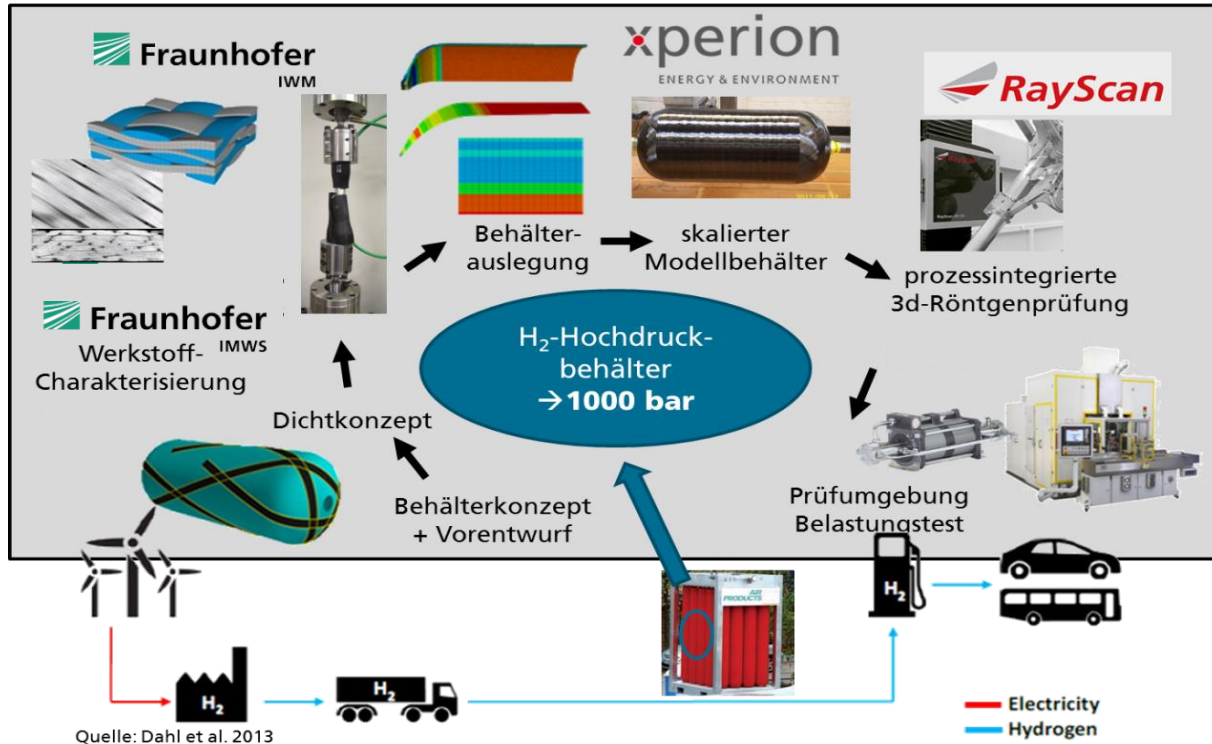
IWM Focus:

Influence of internal (due to welding) and external hydrogen and loading conditions on strength properties of welded X50 /X50 tubes



Recent Projects

»H2-HD« High pressure tank systems for hydrogen storage



IWM Focus:

Experimental characterization and modelling of the long term behavior of carbon fiber composites in contact with hydrogen and at very low temperature



GEFÖRDERT VOM



Regulations of German gas grid for hydrogen

The DVGW (Deutscher Verein Gas und Wasser)

- A simplified view
- The regulations of the DVGW (German Society for Gas and Water Grid) determine the operation of the German gas grid, including for example
 - Allowable gases in the grid
 - Methods for life time assessment
 - Maintenance requirements and monitoring
- Existing regulation: G409 - Regulation of conversion of pipelines for natural gas for the transportation of hydrogen:
 - The regulation allows hydrogen pipelines when there is a proof of integrity and operation specifically for this pipeline
 - Not functional for whole grid

Regulations of German gas grid for hydrogen

Ongoing work

- Ongoing project: DVGW-Working Group G-PK-1-1-12
 - Regulation for life time assessment and maintenance of straight pipelines for hydrogen transportation
 - Basis will be fracture mechanic methods, e.g. US standard for pipelines ASTM B31.12
- Open questions and possibilities for combined research:
 - Ongoing discussion about the consideration of residual stresses in the welds specifically for hydrogen pipelines
 - Ongoing discussion about methods of potential crack evaluation in future.
 - Details of lifetime assessment methods

Regulations of German gas grid for hydrogen

Ongoing work

- Open questions which are mostly in the early stages:
 - Integrity assessment of compressors, bends and tees
 - How to locate leakage?
 - Methods for inspection, e.g. pigging
 - How does hydrogen affects the gaskets and the lubricants of valves

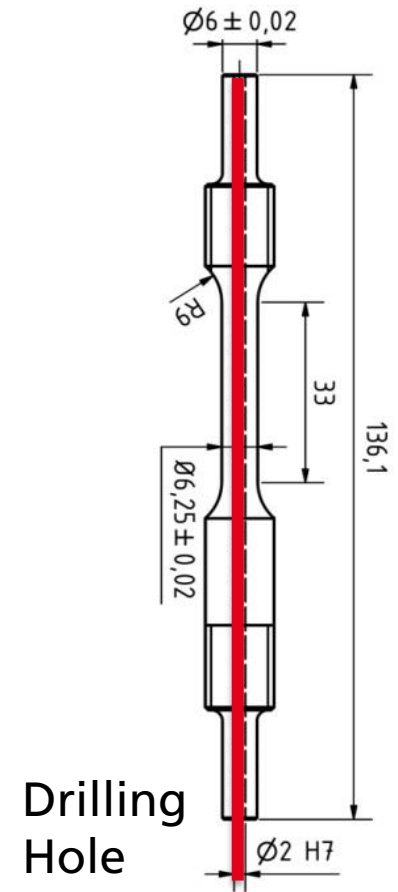
Questions of research for materials qualification for a hydrogen grid

Tensile tests on hollow specimen

Hollow specimen technique

- Tensile test specimen with axial drilling hole
- Hole can be filled with pressurized hydrogen
- New working group for standardization is initiated: ISO TC164 SC1 WG9

Specimen Geometry

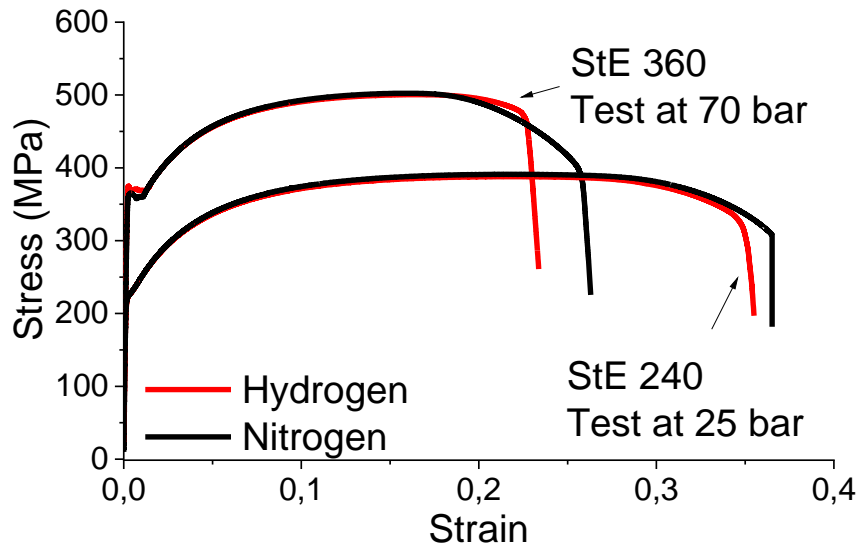


Questions of research for materials qualification for a hydrogen grid

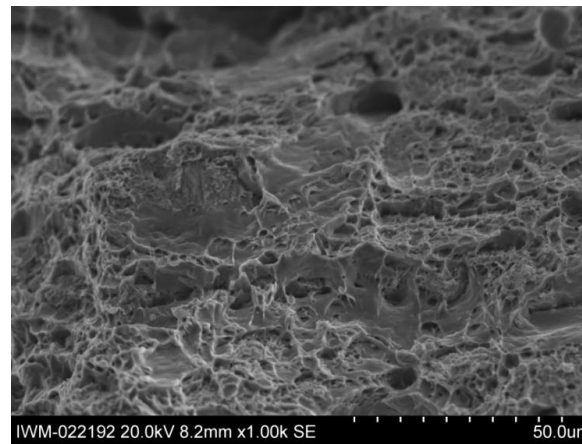
Tensile tests on hollow specimen

Specimen Geometry

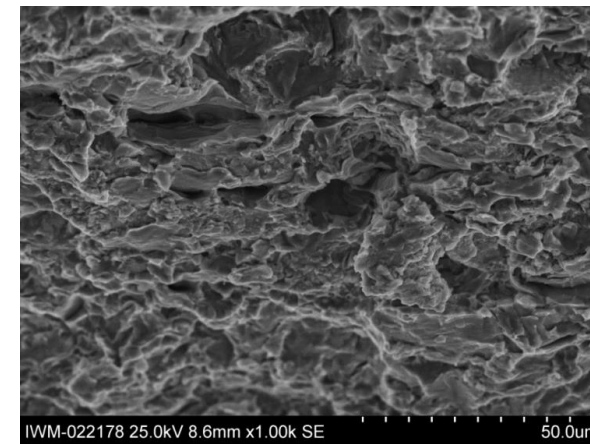
Stress-Strain-Curve



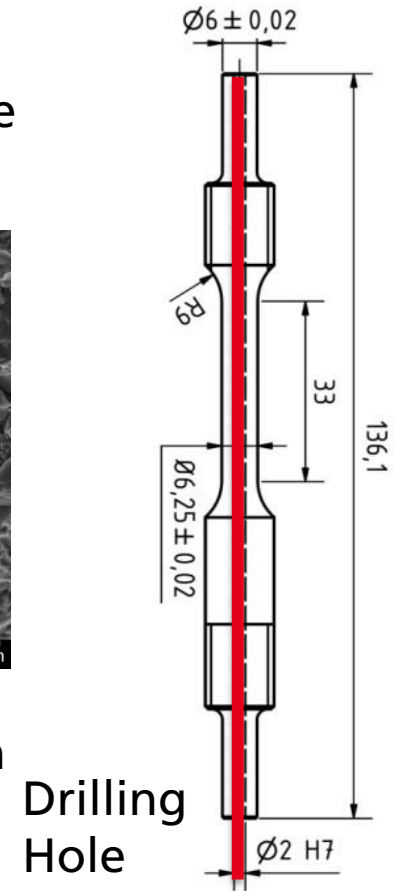
Fracture morphology in scanning electron microscope



Ductile fracture morphology for test with nitrogen



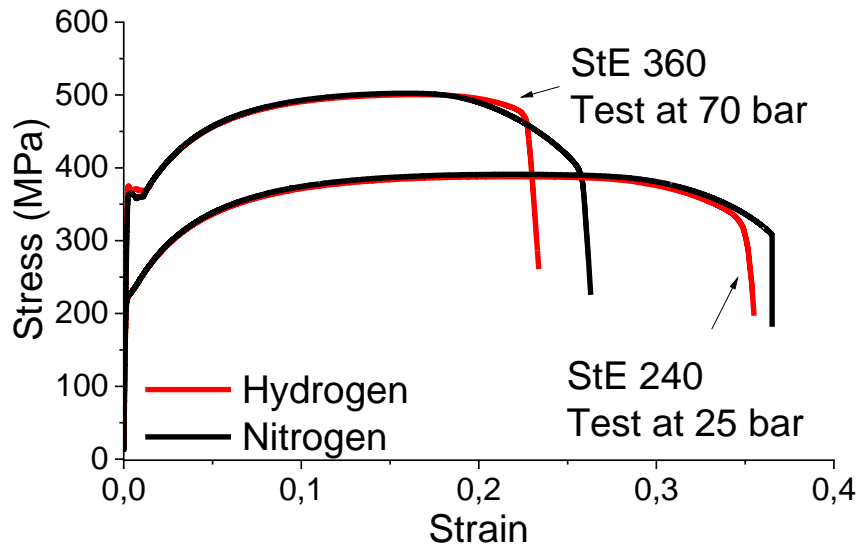
Brittle fracture morphology for test with hydrogen on StE480



Questions of research for materials qualification for a hydrogen grid

Tensile tests on hollow specimen

Stress-Strain-Curve

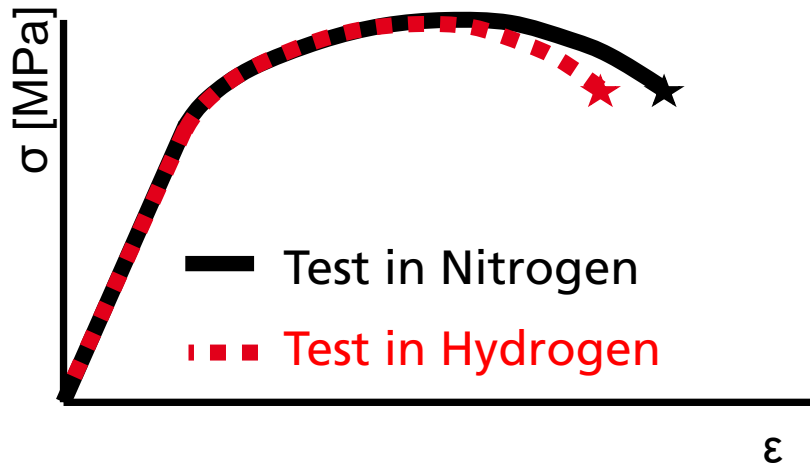


- Hollow specimen technique basically allows to test for hydrogen embrittlement for ferritic steels.
- Pipelines material are susceptible to hydrogen embrittlement
- Amount of susceptibility deepens on tensile strength
- Low strength materials show less effect of hydrogen embrittlement
- Open question: Are low strength steels safely usable for hydrogen pipelines as they do not show hydrogen embrittlement in tensile test under relevant operations conditions?

Questions of research for materials qualification for a hydrogen grid

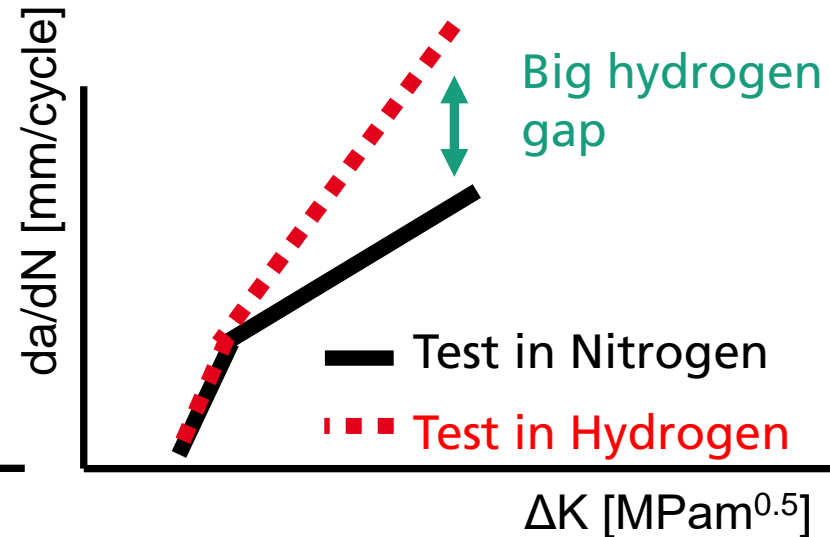
Dependence of hydrogen embrittlement on test method

Tensile Test



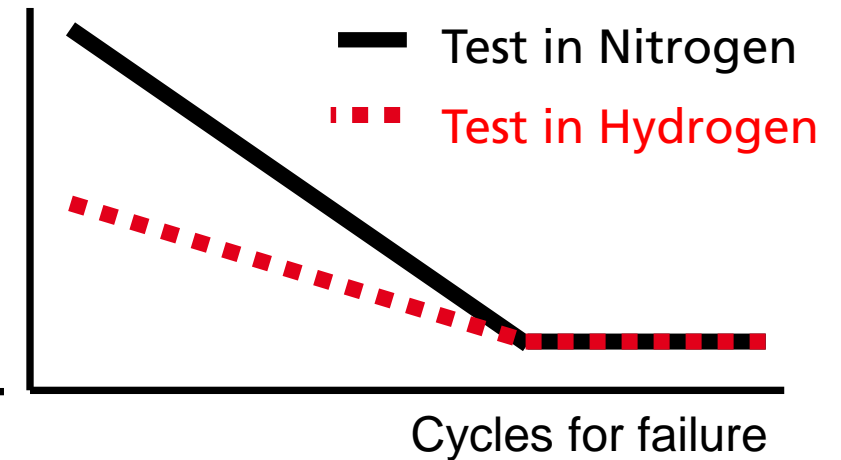
- Small change in materials properties in tensile test

Crack Propagation



- Same material can strongly be affected by hydrogen in a crack propagation test
- Missing material data for many construction materials

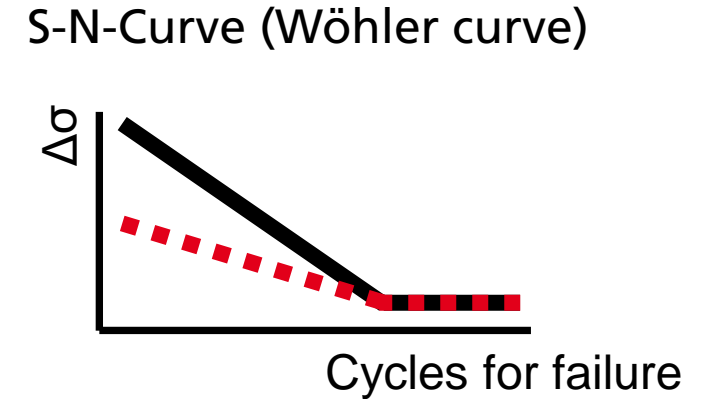
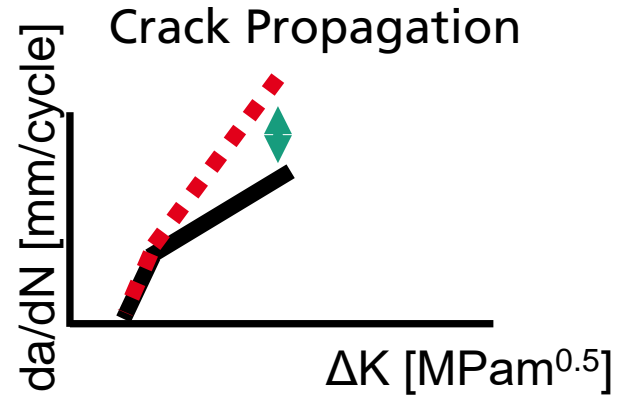
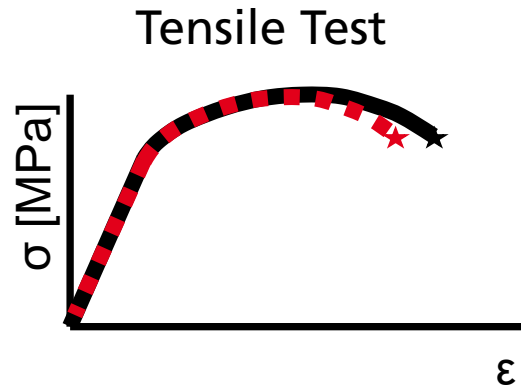
S-N-Curve (Wöhler curve)



- Material data is available only for very limited number of materials

Questions of research for materials qualification for a hydrogen grid

Dependence of hydrogen embrittlement on test method



Considerations for joint research based on understanding for the hydrogen embrittlement

Scientific topics

- Understanding the active damage mechanism for pipeline steels
- Finding a material treatment to reduce or eliminate the hydrogen embrittlement for steels

Engineering topics

- Development of a standard for life time assessment for steels in contact with hydrogen gas
- Qualification of more materials

Thanks for your attention!

