Materialprüfungsanstalt Universität Stuttgart

OGE

Deutscher Verein des Gas- und Wasserfaches e.V.

DVGW

www.h2-dvgw.de

Key messages of DVGW research project

H_2 suitability of steels (SyWest H2)

Project

Project duration September 2020 – January 2023

Project name Sample testing of steel materials for gas pipelines and systems in order to evaluate their hydrogen suitability – Systematic materials appraisal of steel (SyWeSt H2)

Funding number G 202006

Objectives

- Fracture mechanics tests on a representative cross-section of typical pipeline steels
- Comparison with American standard ASME B31.12
- Evaluation of H_2 suitability of the steel grades tested

DVGW Innovation Programme Hydrogen

Read the study

Background to the research

Hydrogen, an energy carrier, is crucial for achieving national and European climate goals and decarbonizing broad sections of today's CO_2-emitters. Because generation and consumption are usually geographically separate, hydrogen has to be transported around Germany to the relevant consumers, but also across borders into Germany, as is the case today with natural gas. For the purposes of assessing the safety and suitability of switching from natural gas to hydrogen, it is therefore critically important that the suitability of the steel components installed in the German (and European) gas network is proven for use with hydrogen in real operating conditions – as typical in the gas industry. This is required because when high stress intensities occur – caused by high or frequently fluctuating pressures – hydrogen atoms, due to their small size, diffuse into defects in the material surface and lead to the accelerated formation of cracks. To ensure safe operation, technical rules are available in DVGW Codes of Practice G 409 and G 463 when converting pipelines for hydrogen and for new construction, which, along with the required scaling, provide for a fracture-mechanical examination of the pipelines and pipeline components where necessary.

Methodology

Selection of materials

Representative selection of all steel grades typically installed in Germany (and Europe) on different areas of pipe (base metal, weld metal, heat-affected zone

> 200 tests

Testing system

Servohydraulic testing system with integrated H_2 autoclaves at the MPA in Stuttgart

Standard H_2 setting of 100 bar with a stress ratio R of 0.5. Impact of these parameters through variation on selected components (0/0.2/1/2/5/10/20/100 bar or R = 0.1/0.5/0.7)

Test parameters

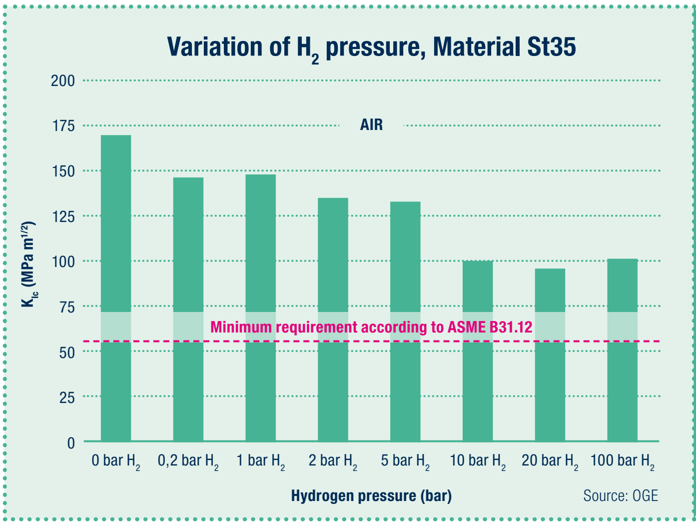
Minimum fracture toughness K_{Ic}
= resistance of a material against uncontrolled crack growth

Crack growth da/dN
= incremental increase in crack length per load cycle depending on cyclical stress intensity factor Δk

Comparison with results of fracture mechanics tests on American steel grades, on which ASMEB31.12 is based. Evaluation of the hydrogen suitability based on a representative selection of steel components.

Selected results and summary

Influence of H_2 partial pressure

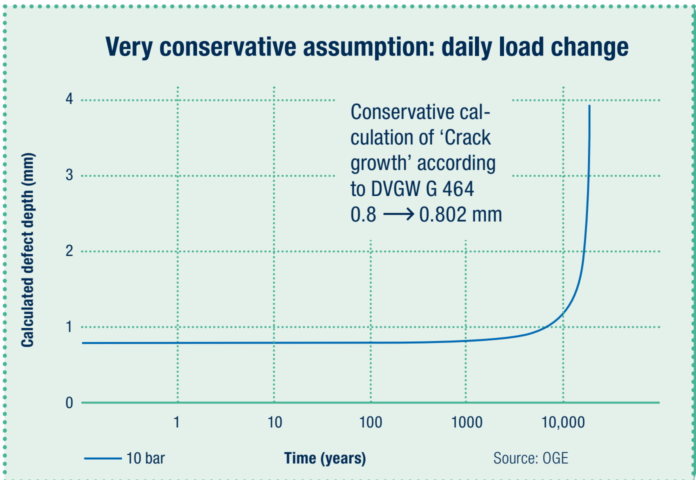


Increasing H_2 partial pressure leads to slightly decreased fracture toughness K_{Ic}. Subsequently saturation.

All results are considerably higher than the required limit of 55 MPa $m^{1/2}$ (ASME B31.12)

Calculation example

Conservative assumptions with a steel pipe (DN 600, DP 67.5, L 415, wall thickness 8mm) and def. defect (50mm long & 0.8mm deep)



At a daily load change of 10 bar (very conservative assumption), the crack radically increases after more than 10,000 years and fails.

Alternative interpretation:
After 100 years, the crack increases by 0.002 mm.

- **100% suitability proven for all steel materials typically used in Germany (and Europe).**
- **100% suitability of gas pipelines proven that are made of steel for normal operation, according to the fracture mechanics calculations in line with DVGW G 464**
- **No relevant variance of test results for all tested pipeline materials, types and test locations.**
- **Confirmation of the results from ASME B31.12 and addition of a bilinear and conservative model**
- **Adaptation of the DVGW standards for high-pressure pipelines under hydrogen**
- **Results are transferable to distribution networks and admixtures**