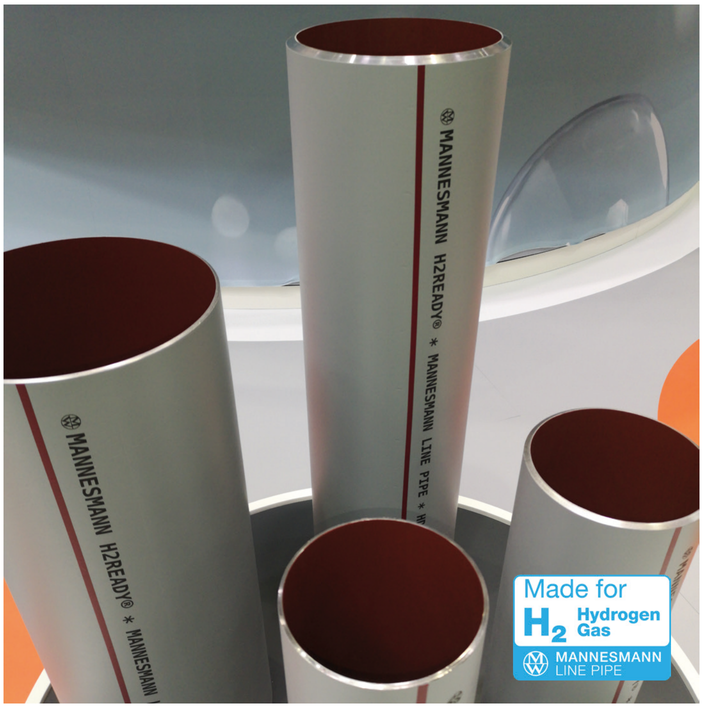
HFI-welded Steel Pipes

for the transportation and storage of hydrogen

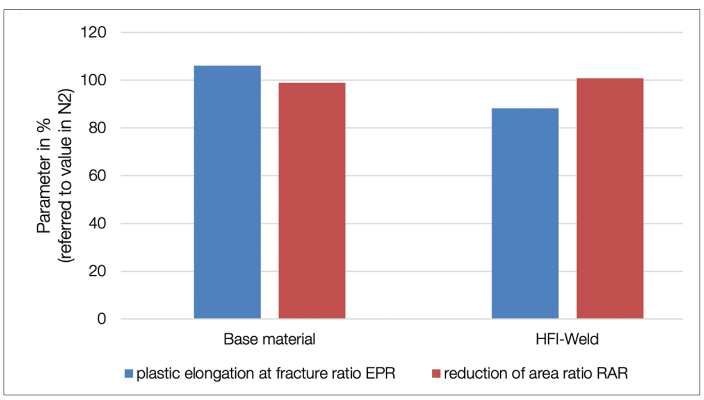
MANNESMANN
LINE PIPE
A Member of the Salzgitter Group

Product description

"Mannesmann H2ready®" steel pipes from Mannesmann Line Pipe offer maximum flexibility and safety for the transport and storage of gaseous hydrogen and of hydrogen admixed to natural gas.

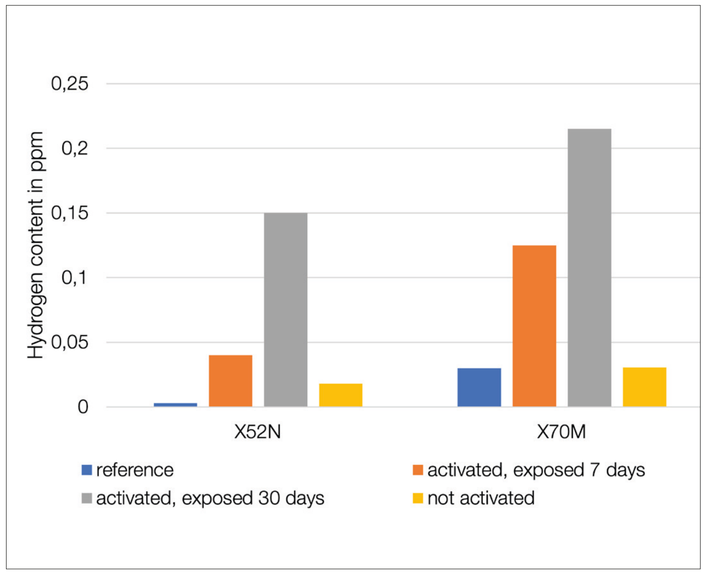


Our pipes feature an optimum service life. Previous tests and existing standards already show that the use of line pipe grades up to API 5L X52 (L360) is non-critical. Another object of examination is the usage of higher-strength materials of grade



Stress-strain behavior in Slow-Strain-Rate Tensile Tests of X70 in 100 % hydrogen (H_2) compared to an inert nitrogen atmosphere (N_2) on specimens from the base material and HFI-weld

X70 (L485) used for "Mannesmann H2ready®" steel pipes to transport pure compressed hydrogen as well as hydrogen-/natural gas mixtures. As a result, neither base material nor HFI- or girth weld showed i.a. in Slow-Strain-Rate Tensile Tests at 80 bar any increased sensitivity towards hydrogen as far as the structurally relevant part of the curve is concerned. Moreover, there is no significant absorption of hydrogen to be found in the material, blocked by the natural oxide layer on the pipe surface.



Influence of the surface condition on the absorbed hydrogen content in the steel: hydrogen absorption into the steel can only be detected for the specimen with an activated surface; the amount is in the expected low range

Hydrogen has only about one third of the calorific value of natural gas. This means that to transport roughly the same quantity of energy as natural gas, the pressure in the pipeline would have to be increased accordingly. However, this is not possible for safety reasons. Alternatively, it is possible to operate the hydrogen pipeline at a higher flow rate. To facilitate this, a coating can be applied to the inside of the pipe to reduce the friction between the pipe wall and the medium. Mannesmann Line Pipe's Flow Coat is the ideal solution for this.

We have involved Salzgitter Mannesmann Forschung, the research institute of the Salzgitter group, in the testing and realization of the highest quality standards. Together we continuously work on broadening our knowledge base. This way, we were able to prove evidence that the minimum for the stress intensity K_{IH} required in ASME B31.12-2019 is met and even excelled for our "Mannesmann H2ready®" materials, tested so far. Further details are illustrated on page 3.

Application

Apart from the increasing energy demand worldwide, it is particularly political efforts to reduce greenhouse gas emissions that are causing a growing demand for alternative energy sources. This is accompanied by a decline in base-load generation capacity, which is being accelerated in Germany by the forced phase-out of nuclear power.

Given an energy mix with a strong regenerative focus, the technical compensation of fluctuating electricity production and demand-based long-distance conveyance to the centers of consumption will be of critical importance. Thus, innovations in energy storage and transportation are decisive for a successful energy turn-around.

In the power-to-gas sector, hydrogen in particular is proving to be a useful storage and transport medium. New fields of application can be found, for example, in the conversion of electricity, the heat market, automotive industry (fuel cell technology), steel industry, glass industry, chemical industry and food industry.
Especially in Germany, increasing the use of hydrogen makes good sense for several reasons.

- The country has over 100 years of experience with the commercial handling of hydrogen
- It ranks among the group of global leaders in the development of H_2 and fuel cell technologies
- Its chemical industry is searching for hydrogen from increasingly carbon-extensive sources
- There are salt caverns for large-volume H_2 storage in northern Germany (unlike in California or Japan)
- Energy-intensive premium steel production and further processing

However, the increased use of hydrogen calls for corresponding infrastructure in order to transport and store the medium. This creates an enormous demand for new gas pipelines, suitable for hydrogen conveyance. In the simulation of a hydrogen network infrastructure with mass-storage facilities, the following possible future scenario has been determined: For the complete

conversion of mobility to hydrogen as an energy source by the year 2052 with 33.9 million fuel-cell vehicles, 9,450 H_2 filling stations would be required nationwide. Since hydrogen technology is also being seriously promoted in countries with extremely high traffic density, such as the USA, Japan, China and India, there is no question that new pipelines are needed.

High-frequency induction-welded “Mannesmann H2ready®” pipes from Mannesmann Line Pipe with chemical, mechanical and geometric properties specially adapted to the transport of hydrogen is ideally suited to the imminent expansion of pipeline capacity. Proven welding technology and the use of modern steel grades resistant to the corrosive effect of hydrogen make our line pipe a cost-effective and environment-friendly solution.

Product properties

Steel as a material is noted for its extremely high toughness, durability and high resistance to external influences. Our supply range with a broad spectrum of steel pipe dimensions from DN 100 to DN 600 is fully amenable to a wide range of applications and special uses. Thanks to an optimized combination of materials and grades, our "Mannesmann H2ready®" pipes are not only clean and safe but also economical.

Fracture resistance (K_{IH}) of H2Ready® pipes in pure hydrogen gas

Introduction

High-frequency induction (HFI-)welded "Mannesmann H2ready®" steel pipes from Mannesmann Line Pipe GmbH offer maximum flexibility and safety for the transport and storage of gaseous hydrogen and of hydrogen admixed to natural gas. The purpose of this series of tests is to evaluate the effect of hydrogen on the fracture resistance of a large number of Mannesmann H2ready® grades. The tests were conducted at Salzgitter Mannesmann Forschung GmbH to show the material's ability to satisfy the specifications given in ASME B31.12.

Tests

The test described here is used to determine the fracture resistance in high-pressure hydrogen gas as defined in chapter PL-3.7.1 Steel Piping Systems Design Requirements, Option B (performance-based design method) of ASME B31.12-2019. The threshold stress intensity factor K_{IH} is determined using the constant displacement method as described in ASME BPVC Section VIII Division 3-2013, article KD-10 and ASTM E1681-2013. To this end, the samples are pre-loaded to a certain constant deformation by means of a screw. The tests are performed for 1000 hours in high-pressure (100 bar) hydrogen mainly on base metal (BM). A set of three specimens for each material grade is used. One set is extracted from the HFI-weld (WM).

Results

The K_{IH} value calculated from the test results is in all cases significantly higher than the minimum specified stress intensity factor of 55 MPa√m, thus fulfilling the qualification requirements of ASME B31.12. A test on X60M with an elevated applied stress shows that the material exceeds the requirements of the standard by more than 30 MPa√m. In conclusion, the tests confirm the tested materials' superior resistance to hydrogen embrittlement under the selected conditions. In order to prove the suitability of all Mannesmann H2ready® steels for the design of hydrogen pipelines using ASME B31.12, further tests on different steel grades are ongoing or can in future be adapted to the various needs of the applications in question.

Material grade	Specimen position	$K_{IH, applied}$ in MPa√m	$K_{IH, reached}$ in MPa√m
X42N	base material	125–131	62–65
X52N	base material	116–127	58–64
X60M	base material	124–126	62–63
X60M	base material	170–172	85–86
X65M	base material	125–129	63–65
X70M	base material	125–129	62–64
X60M	weld material	127–145	63–72

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Flow Coat

Introduction

For the transport of non-corrosive gases in pipelines, epoxy Flow Coat is applied as a so-called thin-film epoxy. The purpose of the inner coating is to create a smooth pipe surface that presents as little friction as possible to the medium being transported. Improved flow is combined with lower energy requirements.

The epoxy lining also facilitates visual inspection and pipeline pigging. When the pipes are stored, Flow Coat serves as corrosion protection as well.

Flow Coat is applied in a film thickness of approx. 60 µm in accordance with API RP 5L2/ISO 15741.

Flow Coat on the pipe interior

Flow Coat application

Resistance of the coating to gas pressure changes

Hydrogen can easily diffuse into coatings. To rule out the risk of this causing blistering in the event of a sudden drop in pressure, the following tests were conducted:

Test 1

Testing of the resistance of the coating in a gaseous hydrogen environment to DIN EN 10301 Annex C

The purpose of the test is to visually inspect and determine the adhesion of the applied coating after it has been exposed to 10-fold pressure changes in a gaseous hydrogen environment. Throughout the test, the sample is stored in a hydrogen gas atmosphere. In loading cycles 1 to 4 and 6 to 9, the hydrogen pressure is increased to 100 bar for 20 hours. After each cycle, there is rapid depressurisation to atmospheric pressure, which is maintained for 3 hours. In cycles 5 and 10, however, the hydrogen pressure of 100 bar remains constant for 68 hours.

Autoclave for the Flow Coat tests

Test 2

Testing the resistance of the coating with the use of liquid media to DIN EN 10301 Annex D

The purpose of the test is to evaluate the behaviour of the coating after exposure to pressurised hydrogen in a liquid environment (water/calcium carbonate ($CaCO_3$)). For this purpose, the sample coated with Flow Coat is exposed to hydrogen gas at 100 bar in a saturated $CaCO_3$ solution for 24 hours. At the end of the test, the pressure is quickly released. This is followed by a visual inspection of the coating and an evaluation of its adhesive strength.

Results

Neither test showed any blistering on the specimens used.

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Here you can find more information.

Datasheet Mannesmann H2ready® EN 02/2023