MANNESMANN
STAINLESS TUBES
A Member of the Salzgitter Group

Mannesmann Tubes for Hydrogen Applications

In the drive towards full decarbonization by 2050, together with the associated focus on CO2 reductions, the use of hydrogen is one of the important strategies. The development of the Hydrogen economy with the use of hydrogen in the fields of industry such as transport, electric and thermal energy is expected in the coming decades. The use of Hydrogen is focused on sectors where the opportunities for the use of decarbonizing technologies do not exist or are prohibitively expensive.

In general, the technological solutions for the production and use of Hydrogen are long established however, in the context of the extensive hydrogen economy development changes are required. Starting with the production of ‘green’ hydrogen instead of ‘grey’ hydrogen together with the development of the infrastructure and capacity for transport and storage of hydrogen to the level of readiness required to support the level of application in, for example, vehicles: car, ship, truck or train.

The increase and development of renewable energy technologies for the production of ‘green’ hydrogen is a key factor in the economy growth. The consequent upscaling of both renewable energy and hydrogen production is labelled as turquoise, blue and green. While green hydrogen is created based on renewable energy only, the processing of methane to hydrogen and solid carbon is called turquoise. The traditional hydrogen produced from natural gas is called blue hydrogen – the remaining carbon (dioxide) is mostly released to the atmosphere. In the south of Europe, the focus will naturally be on solar energy whereas in the north wind energy is more relevant. The production of hydrogen can be performed either using transmitted electricity or to produce hydrogen local to the energy production sites and transport the resultant ‘green’ hydrogen. Transportation via gas pipelines is a very efficient process, with distribution to the utilization sites by pipelines or by transport with trailers via road or rail with gas storage tanks being moved and repurposed e.g. in filling stations. For passenger cars, the use of electric battery vehicles is topical discussion whereas fuel cells and hydrogen-generated power may be more of interest for heavy goods vehicles like trucks, ships and trains. To achieve the required level of industrialization of these processes significant development and high investments are likely to be required. For Salzgitter group the carbon steel production strategy needs to be modified from conventional blast furnace route to reduction of iron ore by hydrogen with subsequent production by electric arc furnace.

For further information see https://salcos.salzgitter-ag.com/

In all of these fields of the hydrogen economy- hydrogen production, transport, infrastructure, the usage of steel components is an important consideration. The existing level of technical readiness for these applications is governed by standards and specifications being characterized by high safety factors associated with the interaction of hydrogen with steel and associated the risk of hydrogen embrittlement. Understanding the underlying mechanisms and the resultant changes of properties are decisive factors for the specific design of components and systems.
In the interaction of hydrogen with steels a physical reaction at the surface may lead to a very low absorption of hydrogen atoms within the material. This amount is sufficiently low, that there is in general a limited risk of material failure for a standard usage at constant conditions. It is reported that gas cylinders filled with hydrogen hold filling pressure for decades without any damage to the cylinders or valves. From this example, one might expect that the loss of hydrogen, as well as the risk of material degradation, seems to be very low even in carbon steels. Nevertheless, if contamination with abrasive particles, such as glass fragments, had been present in this cylinder and could potentially damage the oxide film due to movement the result could potentially be catastrophic. This being possible due to the creation of “fresh surfaces” allowing hydrogen to diffuse into the material structure.

This example shows two points: 1. it is of high importance to have a very good knowledge of the interaction between hydrogen and steel components and its relevant properties in defined applications. 2. At the current starting point of a Hydrogen Economy with increasing quantities of Hydrogen in production, transport and usage, there is an uncertainty in the technical aspects of upscaling and the decisive key factors resulting in high safety regulations. To react on both points the Mannesmann group of the Salzgitter AG is concentrating its activities on these key relevant points. Within the Group tubes and pipes of all different dimensions and materials are developed and provided for hydrogen applications.

Hence, in cooperation with its highly specialized German raw material suppliers, the Mannesmann Line Pipe GmbH early started to develop material concepts, exclusively adapted to hydrogen gas and process them into line pipes (DN 100 to DN 600). The suitability has been and is being proven in various, already completed and still ongoing funding projects as well as in our own tests, so that a "Mannesmann H2ready" pipe, manufactured using the high-frequency induction welding process (HFI), is now available. Investigations to assess the usability of spiral welded steel pipe for use in hydrogen transport with respect to their resistance to hydrogen assisted cracking have been performed successfully on different steel grades by Mannesmann Grossrohr GmbH. On their basis, technical recommendations have been derived and internal additional binding requirements for delivery conditions have been agreed regarding chemical composition, toughness and strength properties of the base material. Both companies delivered in 2020 the first H2ready pipes for projects to German customers.

Actual research: Not every stainless steel is Mannesmann H2 ready.
In the development of our understanding of the critical product performance attributes in hydrogen environments the low hydrogen absorption within steels in combination with mechanical deformation and failure modes is a key point of focus.

For the stainless steels of Mannesmann Stainless Tubes we have investigated the hydrogen absorption of austenitic steels with different compositions. It is known that the resulting amount of hydrogen in the material of an austenitic steel is higher than that of a ferritic one. Nevertheless, the austenitic steels are not expected to be susceptible to hydrogen embrittlement. Thus, these steels are used in applications in case of uncertainties of the usability of carbon steels.

It is of high importance to balance optimal composition with the required mechanical properties for the application. There is the risk of ferrite/martensite formation in metastable austenites resulting from (local) mechanical loads and deformations. Together with small discontinuities the hydrogen atoms (higher number compared to ferritic steels) might diffuse towards these positions and result in undesired failures of the component. Thus, the stability of the austenitic phase throughout the application with its temperature region and mechanical load is to be ensured.

It is foreseen to further perform investigations of different austenitic steel grades and compositions concerning the phase stability under mechanical loads and the influence on hydrogen embrittlement. Mechanical tests with low deformation rates to ensure enough time for hydrogen diffusion to the relevant failure region will be evaluated. As for carbon steels the use of fracture mechanical testing and crack propagation tests is of interest.
As a part of its customer commitment and focus, Mannesmann, together with its expert partners at the Salzgitter Mannesmann Forschung GmbH, is supporting the research and development associated with these new applications. A full range of material corrosion and abrasion, as well as mechanical tests focused primarily on our range of carbon, alloyed, stainless and Nickel alloys is performed under highly qualified technical supervision for both internal and Client based research & development .

The results of these investigations will influence the next generation of our Hydrogen related stainless steel tubes and their adaptation to Customer specific applications. With the hydrogen economy set to be such a major factor in the development of our industrial and transport landscape in the future you be reassured to have Mannesmann as your partner.

Read more at …
https://www.mannesmann-innovations.com/en/innovations/mannesmann-h2ready/#c1781