Going far beyond

Marion Erdelen-Peppler, ROSEN Group, Germany, considers the issues surrounding the use of hydrogen in exisiting pipelines, and explains why ROSEN has decided to build a hydrogen test laboratory.

There are currently more than 4500 km of pipelines transporting hydrogen, and almost 1600 km of these are located in Europe. Most of these pipelines are dedicated hydrogen product lines that were designed and built to bring process gas hydrogen from gas producers to industrial users, such as chemical plants and refineries.

The plans for the European Hydrogen Backbone have a different focus; they are established around the vision of hydrogen as a source of energy. In this scenario, the quantities of hydrogen that are needed will be significantly larger than they are today; the network will eventually be able to deliver the gas across the continent. This can be achieved by making use of the existing natural gas grid, adding dedicated new lines only where needed. However, because of the differences between hydrogen and natural gas, these plans for the future pose significantly different challenges to the system, mainly related to volume, pressure and, with this, maintaining pipeline integrity and safety.

For both new and repurposed pipelines, it is necessary to assess the relevant threats and define a strategy for integrity management. This understanding and assessment

encompasses a robust knowledge of material properties to form the basis of a 'Fitness for Hydrogen' assessment. Currently, the main standard that is used is ASME B31.12[1], which provides a strategy for both new pipelines and the repurposing of existing lines to transport hydrogen.

Difficult hydrogen issues associated with steel pipelines

While hydrogen, being a gas, has many similarities with natural gas when it comes to transportation via pipelines, there is one notable effect that differentiates it from other gases. This fundamental feature, which drives much of the integrity concerns and challenges associated with gaseous hydrogen pipelines, is the absorption of atomic hydrogen within the steel microstructure. Under certain conditions, it can diffuse into the steel and interact with the microstructure, leading to a change of the properties that are determined in air. There is a consensus that such interactions lead to a major degradation of ductility and fracture toughness, and an acceleration of fatigue crack growth. However, the material strength remains largely unaffected in the presence of hydrogen. These effects are

Figure 1. The ROSEN Group has recently invested in building a dedicated hydrogen testing lab in Lingen, Germany.

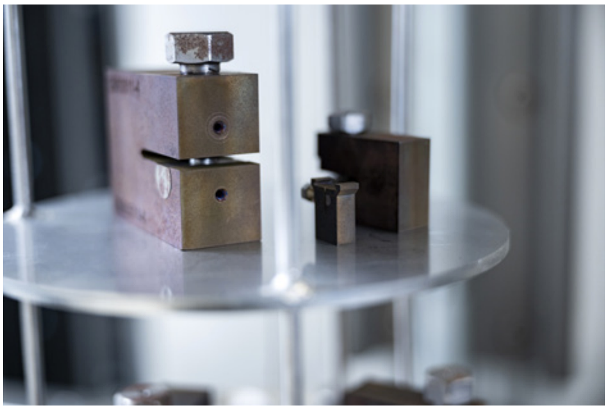

Figure 2. Various material specimens can be tested at ROSEN's hydrogen lab.

commonly referred to as hydrogen embrittlement. While the existing codes relate these effects to the steel grade, there are indications suggesting that the effects are in fact dominated by the steel microstructure and chemistry.[2,3]

If this is the case, it could be the source of an increased degree of scatter in the existing data when assessed only against the steel grade. In addition, the factor that describes the relationship between properties in air and in hydrogen could be different for vintage and modern material, as they tend to exhibit a different microstructure. These correlations need to be understood in order to deliver both practical and safe requirements to the industry.

As the need to fully understand steel performance in hydrogen grows, and the design requirements extend, it will become increasingly important to understand the influence of hydrogen on the integrity of new and existing pipelines in the context of mechanical properties as well as chemical composition and microstructure.

Hydrogen test laboratory

Consequently, ROSEN decided to build a hydrogen test lab to support the industry in its efforts to foster the energy transition. The lab is capable of delivering the full suite of fracture mechanics tests in a high-pressure hydrogen atmosphere. Standard fracture mechanic testing, such as J-R curves and fatigue crack growth rate (FCGR) testing in air and under hydrogen gas load, can be performed to enable a comparison of the well-known effects and results in air with the ones from hydrogen testing.

Autoclaves are designed to perform standard K_{IH} and exposure testing in a temperature range of between -20 and +200°C – a range which covers the main operational envelope for pipelines. The autoclaves are equipped with an automated gas mixing unit for the gases hydrogen (H_2), methane (CH_4), carbon dioxide (CO_2), carbon monoxide (CO) and oxygen (O_2) to enable flexible test gas mixture. There are plans to equip the tensile testing machine with a comparable device in the near future.

Additionally, standard mechanical testing in air (such as tensile, crack tip opening displacement [CTOD] and hardness), as well as metallographic examination, can be performed to complement fracture mechanical testing in hydrogen. This service portfolio not only enables ROSEN to deliver the results that are required by the dedicated standards to the customer, but also reaches beyond to generate more knowledge and understanding of the effects associated with hydrogen.

The competencies that ROSEN seeks to build include those related to the effect of the testing variables such as gas composition, hold times, test frequency and specimen geometry. Currently, there is a general understanding in the industry that, on the one hand, there is a lack of guidance in the testing standards – specifically in those details that are unique to the hydrogen test, e.g., load rate and frequency. On the other hand, some existing requirements are unrealistic to achieve in the usual test set-up, such as criteria on plastic deformation.

Collaboration within the industry is vital to develop the standards further, making results even more reliable while maintaining the practicality of the execution. Working beyond these necessary limits and promoting the understanding of the material performance and how it is linked to parameters such as age and microstructure will benefit the wider industry.

International collaborations and close exchange with the standardisation committees will help to ensure that any progress achieved is made available to all stakeholders in the industry.

With this new service, ROSEN will progress beyond today's requirements, and will help to ensure a safe and reliable energy supply in the future.

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