Theme: Research and development | **Authors:** Dr. Holger Brauer, Marco Henel, Albert Großmann

IN WITH THE NEW, REPURPOSING THE USED

H2-PIMS or how to safely transport hydrogen blends

Renewably sourced hydrogen is an essential energy carrier for achieving COP21 climate targets. The gas can store and deliver energy anywhere, anytime, meeting demand regardless of generation facilities and end users. However, a reliable and safe infrastructure, including pipelines and control systems, is needed to ensure that a storage medium such as hydrogen can really play to its strengths and guarantee supply. This spawned the idea of using the national pipeline system, as well as its underground storage facilities, to transport, distribute and store hydrogen blends and use, or, more specifically, convert sections of the network to deliver pure hydrogen. The challenging part is how to safely handle a gas that has very special physical properties. H2-PIMS, a project supported by the HYPOS initiative, is currently tackling this issue. It has created a rating system, PIMS, for pipelines transporting hydrogen blends. PIMS stands for Pipeline Integrity Management System, and is used to investigate, on behalf of the pipeline operator, whether the current gas infrastructure meets the safety and material standards required to deliver blends. The PIMS safety and suitability assessment will form the basis for suggestions on how to run an economically and technically viable system, what needs refurbishing and where to build new pipelines.

PIMS is based on pipeline specifications, some of which fluctuate while the network is in operation. The reasons for this are manifold, ranging from erosion and insulation issues to outside intervention, previously unknown material defects (e.g., in the weld seam) and transient process parameters.

THE BASICS Current discussions center around how to use network specifications, process parameters and pipe measurements (e.g., diameter and wall thickness, material and grade, surface quality, test results, and time in operation) to reveal the layout needed to convert pipelines. There are strong arguments for taking a staunchly conservative approach to first assessments of network stability to reduce stresses on pipe walls and provide a rough estimate of hydrogen-induced damage under steady-state operating conditions. To this end, one could use the tensile strengths mentioned in EIGA's IGC DOC 121/14 guidelines. Other quality and design issues for constructing or converting pipelines that deliver hydrogen can be found in ASME standard B31.12-2019.

Pipeline operators could also lower pipe pressure until the required threshold values are met. If that does not help either, they can turn to PIMS, supported by the German education and science ministry. This will expand the list of methods at their disposal by including tools designed for analyzing hydrogen blends. PIMS offers suitable, descriptive models and verified analytical and predictive algorithms that provide operators with highly granular analyses of network conditions and illustrate quality changes over time.

Findings can later be used to determine what pipeline sections to refurbish and which strategies to follow, for example, when expanding the network.

CHARACTERIZING MATERIALS Initially, project members focused on characterizing pipeline materials to identify both their suitability for delivering hydrogen [1] and what type of damage the gas can cause to networks. In addition to analyzing material behavior, they determined fracture toughness, i.e., fracture growth, in the presence of pressurized hydrogen, since delivering hydrogen through the pipeline system creates highly fluctuating internal pressures. A variety of studies have shown that even a small increase in pressure, combined with low-level hydrogen blends, can accelerate fracture growth by about a factor of 10 [2,3].

This means that those designing pipelines for hydrogen delivery must take material toughness into account, as well as possible discontinuities or fractures in existing pipes. The required layout is defined in British standard BS 7910 and American standard ASME B31.12-2019. Both include models of incipient and growing pipe or weld seam fractures. These can be used to calculate fracture growth at each pressure change and the related strain when pressure on a line starts to increase.

The above-described material factors, e.g., incipient fractures and fracture growth, as well as fracture toughness, may be key to determining grid resilience but are often not available for analysis. For this reason, H2-PIMS conducted a ground-breaking investigation into existing pipe materials, the results of which are expected at the end of this year. The findings will make it possible to perform a preliminary characterization of materials and decide how broad and thorough subsequent investigations into the impact of hydrogen on material properties must be.

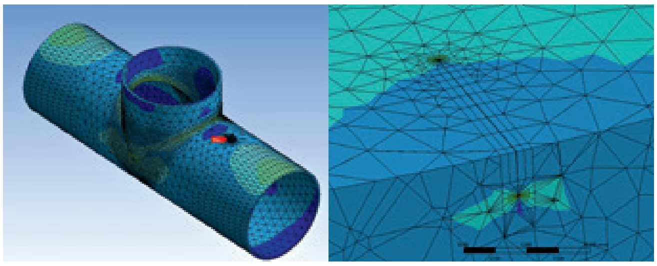

Fig. 1: Finite element model of a tee piece with a surface fracture

CREATING A MODEL H2-PIMS currently addresses creating computer models that illustrate the impact hydrogen has on the integrity and safety of pipeline components. Static and cycle tests of material properties and process parameters assess the network's condition once subjected to hydrogen-induced damage. These models also consider component-specific attributes.

More specifically, the PIMS rating system includes individual assessments for straight pipes, tees (see fig. 1), pipes with stubs, elbows and reducers. It uses not only conventional deterministic but also statistical models to render statements on network quality, allowing both a quantitative risk assessment (QRA) and a structural reliability analysis (SRA).

The advantage of statistical methods is that they consider very unlikely events, such as imprecise measurements of fracture depths or fluctuations in energy amounts absorbed by the fractures. These insights can be combined and findings included in H2-PIMS to ultimately calculate the likelihood of seeing fractures turn up in certain pipeline sections.

The likelihood of failure changes at the border of each section. Sections can be very short (e.g., covering only corroding areas that may have formed fractures or areas around the weld seams) or span great distances as long as the average pipe diameter remains the same and there are no documented issues for that section. As the basic modelling data has a profound impact on analytical results, pipeline operators need to consistently monitor network quality and track changes.

SRA results are useful whenever planning and approval procedures require thorough safety assessments (for example, when creating QRAs). When planning, surveying, constructing or operating gas pipelines that deliver hydrogen blends, the results offer proof that the network continues to meet high regulatory standards.

DEVELOPING A ROAD MAP TO CERTIFY AND REPURPOSE PIPELINES Efforts to certify or repurpose natural gas pipelines concentrate on how to blend hydrogen with natural gas within the confines of DVGW regulations and how to convert some pipelines to deliver hydrogen only. The road map for this project concentrates on making required adjustments a reality. Adjustments are grouped into the following categories: operational strategies and capacity planning, measurement techniques, client networks' hydrogen tolerances, safety concepts, maintenance schedules, marketing, legal matters and pipeline materials.

The road map targets pipeline operators and, in the course of time, distributors. It can guide them toward implementing the necessary changes. The main incentive for operators is their growing determination to provide customers with a greener gas supply, which means they have a sincere interest in making the existing infrastructure fit for the future. The road map can be a starting point for specifying, from a technical and a regulatory perspective, the measures needed to repurpose pipelines. It does not offer cost estimation models, as these depend on a wide variety of factors. Additionally, pipeline sections may differ markedly from each other, making it impossible to provide even a rough estimate. ||

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