REPURPOSING OF EXISTING PIPELINES FOR HYDROGEN TRANSPORTATION

Ángel A. Izquierdo-Sánchez[1], Hannah Shaw[1]

[1]ROSEN, Newcastle upon Tyne, UK

ABSTRACT

Hydrogen will play an important role in the energy transition. The pipeline industry will have to manage the challenges associated with hydrogen embrittlement. To assist the transition to hydrogen ROSEN has developed an integrity-lead repurposing roadmap.

Keywords: Hydrogen repurposing, hydrogen embrittlement, repurposing roadmap.

1. INTRODUCTION

As the demand for hydrogen grows within the industry, pipeline transportation will play a pivotal role in connecting hydrogen production, storage and end use. It is technically feasible to convert existing hydrocarbon pipelines at an estimated cost of 10-35% of the construction costs [1] to build a new hydrogen pipeline. However, the introduction of hydrogen into a pipeline designed for oil or gas service presents many integrity challenges. To assess the threat level of each challenge, ROSEN has developed an integrity-led 'Pipeline Repurposing Roadmap'. This abstract summarises this approach to hydrogen repurposing.

2. BACKGROUND

In order to assess the challenges associated with repurposing natural gas pipelines to hydrogen service, it is necessary to understand the detrimental effects of hydrogen on the mechanical properties of pipeline steel. It is commonly referred to as hydrogen Embrittlement (HE). HE is the reduction of the desired mechanical properties of metals and alloys due to the presence of hydrogen. The term "embrittlement" may not necessarily lead to brittle fracture, but the degradation of mechanical properties can lead to cracking without the application of stress, delayed fracture, increased fatigue crack growth rates (FCGR) and sub-critical crack growth.

Safe and cost-effective repurposing will require a better understanding of the HE process, which for gaseous hydrogen pipelines, is thought to occur in the following steps: (1) adsorption of H_2 molecules on the inner pipe wall that is exposed to high-pressure hydrogen gas, (2) adsorbed H_2 molecules dissociate into atomic hydrogen, (3) hydrogen atoms on the surface are absorbed into the steel matrix, (4) dissolved hydrogen atoms can readily diffuse to thermodynamically favourable sites such as crack-tips, grain boundaries and dislocation cores, where (5) embrittlement occurs (mechanisms are unclear).

From the perspective of a pipeline operator, it is important to know if it is technically feasible to convert a particular pipeline to a hydrogen service. The roadmap aims to support operators in collecting the necessary engineering data, in a step-by-step and logical process, to assist in the decision-making process for (i) the suitability to safe repurposing (ii) the development of practical economic rehabilitation and mitigation measures to achieve safe conversion. This process will assist in safe utilization and maximizing throughput capacity, energy efficiency and the hydrogen chain value. ROSEN has investigated the effects of hydrogen in the pipeline integrity, as presented in previous papers [2, 3, 4, 5].

2.1 Hydrogen Repurposing Road Map

ROSEN's Pipeline Repurposing Roadmap consists of 5 stages:

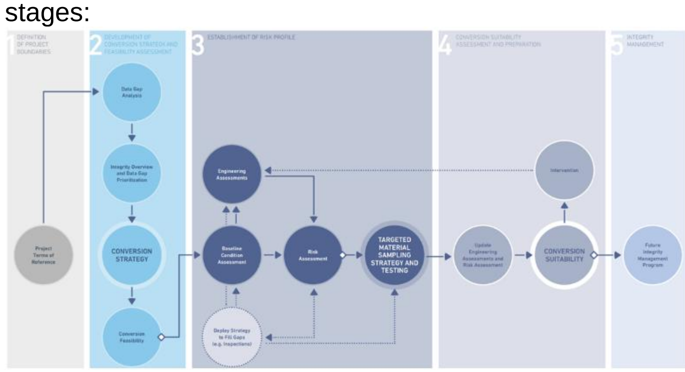

Figure 1 - Pipeline repurposing road map.

Phase 1 – Definition of Project Boundaries

The intent of Phase 1 is to identify the boundaries of the project, specifically the asset, context and objectives. Within this phase, operational framework boundaries, including the predicted future operating regime (hydrogen blend percentage, predicted operating pressure, temperature and cyclic loading) are defined. Applicable codes and regulations are specified, as well as ensuring any legal jurisdiction requirements are addressed in this phase.

Phase 2 – Development of Conversion Strategy and Feasibility Assessment

Phase 2 is a desktop-based study providing an early screening of gaps and any major barriers (Data, Integrity, Regulation compliance, Economic) potentially compromising repurposing. This is done using available data or by making reasonable assumptions. This phase determines what the operator needs to know in terms of material properties in hydrogen and what is needed to know in terms of the threats (e.g. crack-like defects, corrosion, dents) present. Calculations are then performed to assess the risk each defect poses. From here, the critical gaps, and which of them are likely to lead to significant issues, are determined. The level of inspection and testing required to acquire the real, pipeline-specific data, is determined within this phase.

Phase 3 – Establishment of Risk Profile

The goal of Phase 3 is to address the critical gaps and assumptions identified in Phase 2, to create an accurate representation of the pipeline risk profile in hydrogen and to assess the feasibility of repurposing against operational expectations. Here, the real data, specific to the asset being converted to hydrogen service, is acquired by carrying out inspections, targeted sampling and testing within hydrogen. This data is then put through various engineering assessments, whilst taking into account the potential effects of hydrogen on the asset and determining if any of the features that are present are going to be hazardous once converted to hydrogen service. Corrective actions are identified to mitigate any major uncertainties/barriers to conversion.

Phase 4 – Conversion Suitability Assessment & Preparation

Upon completion of Phase 3, the material test data is used to determine if any intervention (e.g., repairs, replacements, updating of engineering/risk assessments) is required. At this stage, it is possible that this intervention may result in going back to the start of the roadmap process.

All necessary documentation and inputs are then filed and integrated to formalise conversion suitability. When all stakeholders are confident that the pipeline is suitable for repurposing, the process of planning and operation of the repurposed pipeline can commence.

Phase 5 – Hydrogen Pipeline Integrity Management

In the final phase of the repurposing roadmap, an Integrity Management Program shall be developed to maintain safe operations under hydrogen service and ensure that the risks remain ALARP. This includes the definition and implementation of management controls, operational integrity windows (e.g. MAOP, pressure cycles, composition specification, etc.), as well as risk-based planning, inspection, monitoring and maintenance.

3. CONCLUSION

Hydrogen has already been positioned as a key element of the energy transition. A great part of the future hydrogen infrastructure will consist of repurposed assets. While safe repurposing is possible, it is a challenging task due to the effects of hydrogen on pipeline materials.

ROSEN has developed an integrity-led 'Pipeline repurposing roadmap' for hydrogen service to address the gaps and challenges faced currently by the industry. This process aims to support operators in collecting all required engineering data, logically, to ensure an asset remains fit for service.

REFERENCES

[1] DNV, "Repurposing onshore pipelines is essential to scaling hydrogen. How can it be done in practice?," [Online]. Available: https://www.dnv.com/focus-areas/hydrogen/repurposing-pipelines-for-hydrogen-guiding-operators-through-the-re-evaluation-process.html.

[2] D. Sandana, N. Gallon, R. Andrews and R. and Palmer-Jones, "Crack Management of Hydrogen Pipelines," in *International Conference on Hydrogen Safety*, Edinburgh, 2021.

[3] D. Sandana, N. Gallon, O. Burkinshaw and A. Bhatia, "Safe Repurposing of Vintage Pipelines for Hydrogen in North America," in *International Pipeline Conference*, Alberta, 2022.

[4] O. Burkinshaw, D. Sandana, N. Gallon and A. Bhatia, "Susceptibility of a Virtual Pipeline Network to Fatigue and Cracking Threats in Hydrogen Service.," in *International Pipeline Conference*, Alberta, 2022.

[5] R. Andrews, N. Gallon and O. Huising, "Assessing Damaged Pipelines Transporting Hydrogen," in *Technology for Future and Ageing Pipelines*, Gent, 2021.