The Repurposing of Subsea Pipelines for the Use of Transporting Hydrogen

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1 INTRODUCTION

Hydrogen has been identified as an important area of development for the achievement of net zero green house gas emissions by 2050.

To reach this goal rapid development of hydrogen production, transportation and storage is required. It has been predicted that in the UK, the demand for hydrogen will reach 270 Twh, compared to the current 15 TwH. [1]

There is a requirement for the repurposing of the current gas network to transport hydrogen gas. It has been stated that up to 80% reuse if required to achieve net zero by 2050. [2] This aspect is important to minimise the waste of material, energy and time as part of a circular economy.

2 HYDROGEN EMBRITTLEMENT

When steel is in contact with hydrogen, the mechanical properties are affected. This is primarily particularly the ductility, tensile strength and fracture toughness. This is a complex phenomenon is known as hydrogen embrittlement (HE). HE is highly sensitive to grain structure, chemical composition, dislocation on density, inclusions, etc.

The effects of this have been shown to increase with the strength of the steel. As subsea pipelines are typically of higher strength (than onshore), this is a particularly important concern.

3 SUBSEA INSTALLATION

Depending on the depth of the pipeline, different methods of installation are deployed. Most commonly S-Lay (Figure 1) or J-Lay (Figure 2) are used. Both methods introduce plastic strain on the pipelines, which could affect the susceptibility to hydrogen embrittlement. This study has been designed to improve the understanding of this phenomenon.

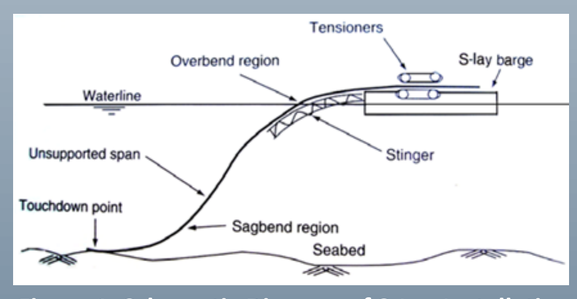


Figure 1: Schematic Diagram of S-Lay Installation

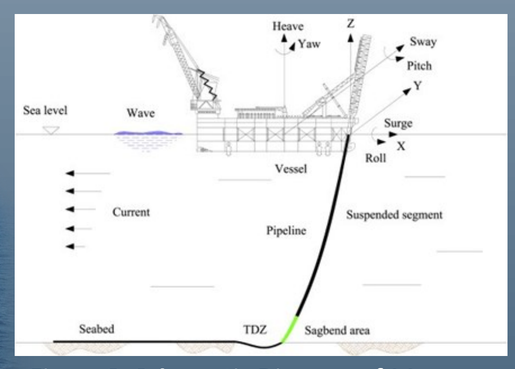


Figure 2: Schematic Diagram of J-Lay Installation

NET ZERO 2050

270 Twh

80% REUSE

[3]

4 CURRENT FINDINGS

Sections of a decommissioned API 5L X52 pipeline were used to provide a material with similar properties to that of pipes currently in service.

To imitate the strain from installation, tensile samples were pre-strained to 6% before being cathodically charged with hydrogen. This method will simulate the most aggressive hydrogen environments.

By comparing the results of uncharged, charged and pre-strained samples the level and susceptibility to hydrogen embrittlement can be seen (Figure 3 & 4). The results are inline with the literature as there is limited effect on the ultimate tensile strength, however the elastic modulus of the material has changed (From 268 and 260 MPa to 134 and 189 MPa respectively).

The pre-strained samples were shown to be highly affected by the hydrogen. The elongation (ductility) in these samples were shown to be reduced significantly compared to the baseline and charged samples.

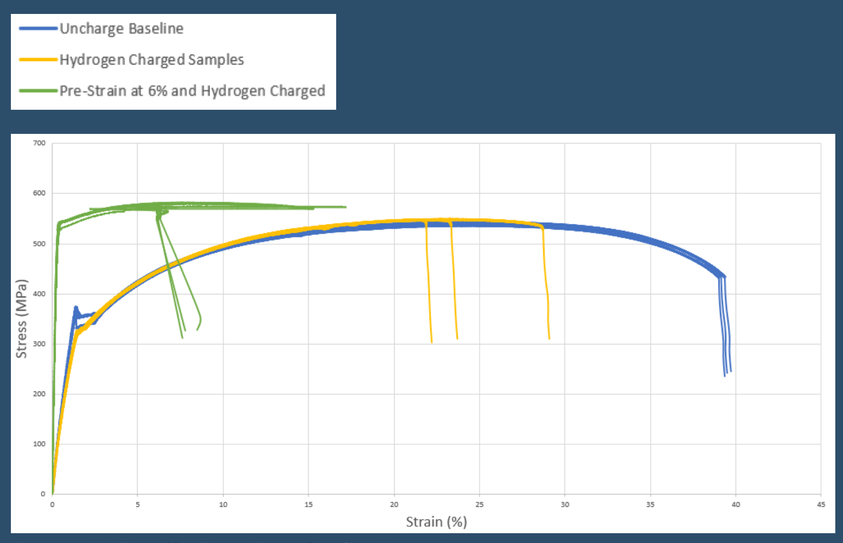


Figure 3: Tensile Test Results for Pipe 1

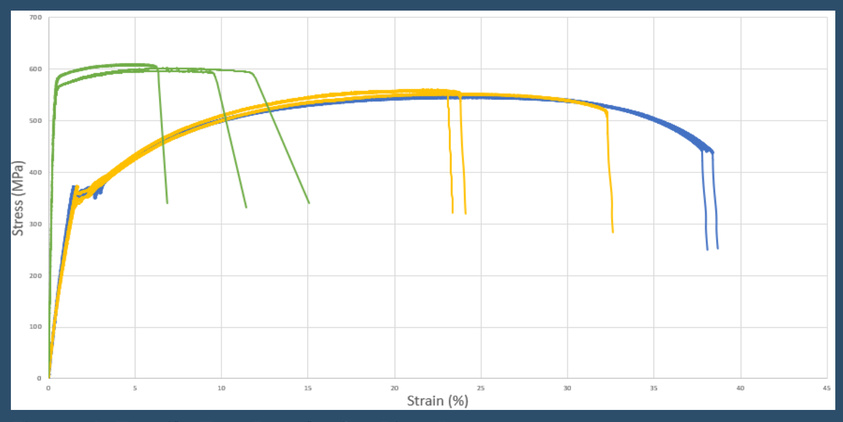


Figure 4: Tensile Test Results for Pipe 2

5 CONCLUSIONS

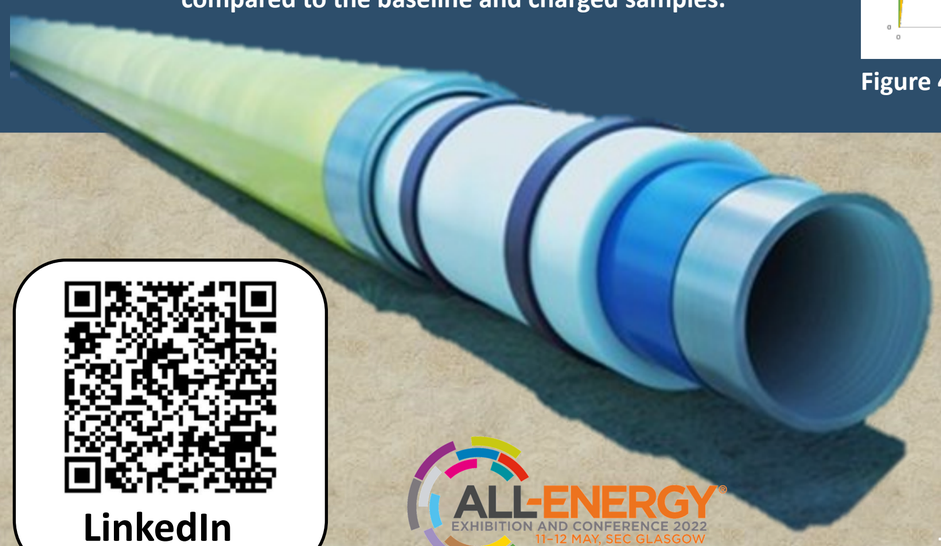
Subsea pipelines require repurposing for the transportation and storage of hydrogen gas. Their high strength and deformation induced due to installation methods increase the susceptibility to hydrogen embrittlement.

The deformation that occurs during installation of subsea pipelines causes an increased susceptibly to hydrogen embrittlement, most notably with the reduction in ductility.

6 FUTURE WORK

To further this research the following will be conducted:

- 3% pre-strain to analyse the relationship between strain and susceptibility to hydrogen embrittlement.
- The residual stress in the inner and outer pipeline samples will be measured and correlated to the induced strain and resultant hydrogen embrittlement.
- Investigate the effect of strain introduced through dents and damage.



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References

[1] S. French, “The role of zero and low carbon hydrogen in enabling the energy transition and the path to net zero greenhouse gas emissions with global policies and demonstration projects hydrogen can play a role in a net zero future,” Johnson Matthey Technology Review, vol. 64, no. 3, pp. 357–370, Jul. 2020, doi: 10.1595/205651320x15910225395383.

[2] DNV, “HYDROGEN FORECAST TO 2050,” Høvik, Norway, Jun. 2022.

[3] C. Stokel-Walker, “Here’s how the Nord Stream gas pipelines could be fixed _ MIT Technology Review,” MIT Technology Review, Oct. 03, 2022.

Acknowledgments

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