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HYDROGEN EMBRITTLEMENT SUSCEPTIBILITY OF L485MB PIPELINE STEEL AND WELD THROUGH TENSILE TESTING WITH DIFFERENT STRESS TRIAXIALITIES

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Abstract
With the ambition to reuse existing pipelines for hydrogen transport and/or storage, the industry is looking for ways to timely and reliably evaluate pipeline steels and welds for their hydrogen embrittlement sensitivity. A L485MB steel and weld are screened in this work, based on ex-situ tensile testing of hydrogen-charged specimens. Additionally, the effect of notches to generate stress triaxiality in tensile specimens is investigated. The paper reveals differences in the hydrogen embrittlement sensitivity of different materials, at different stress triaxiality levels.

1. Introduction
Retrofitting existing natural gas pipelines will be essential for the hydrogen transport and storage in light of the global energy transition. However, pipeline steels are prone to hydrogen embrittlement, i.e., hydrogen reduces their ductility and fracture toughness. The authors are developing a screening methodology supported by tensile testing of hydrogen-pre-charged and uncharged specimens in air.

Published studies have adopted tensile tests of different stress triaxiality levels to screen the hydrogen embrittlement [1]. Three different specimen geometries are investigated on two pipeline steels and a girth weld. At this point, the study is confined to weld metal. Heat affected zones are known to be potentially prone to hydrogen embrittlement as well [2]. However, testing these zones with the techniques adopted in this paper is impractical.

2. Materials & methods
Two L485MB ISO 3183 pipeline steels from different batches, further called base metal 1 and 2 (BM1 and BM2) and a girth weld (GW), produced with GMAW according to EN ISO 4063, were investigated in this work. The base metals had a ferrite-pearlite microstructure. BM2 has additional pronounced segregation bands with martensite and bainite structures at mid-thickness. The GW is a multi-pass weld with a ferrite and acicular ferrite microstructure.

On these materials, tensile tests were performed with three different geometries: conventional smooth round bars (SRB) and notched round bars with a radius of 6 and 2 mm (NRB_R6 and NRB_R2). All geometries had the same nominal minimum section diameter of 6 mm. The specimens were taken in the longitudinal direction of the pipe, except for the smooth round bars of the girth weld material (all-weld metal samples, taken in the welding direction). The specimens were electrochemically pre-charged for 18 hours in 0.5M H_2SO_4 containing 1 g/l thiourea at 0.8 mA/cm². After charging, the specimens were stored in liquid nitrogen. The total time in air before the start of the tensile test was limited to 7 minutes. The tensile tests were performed ex-situ with a strain rate based on the recommendations in ISO 6892-1:2016.

Using image analysis of camera recordings, the area reduction was measured. In order to compare specimens across materials and geometries, a so-called hydrogen embrittlement index is calculated based on the area reduction for each type of mechanical property examined in this study.

3. Results and discussion

The mean value and standard deviation of the hydrogen embrittlement indices are illustrated in Figure 1.

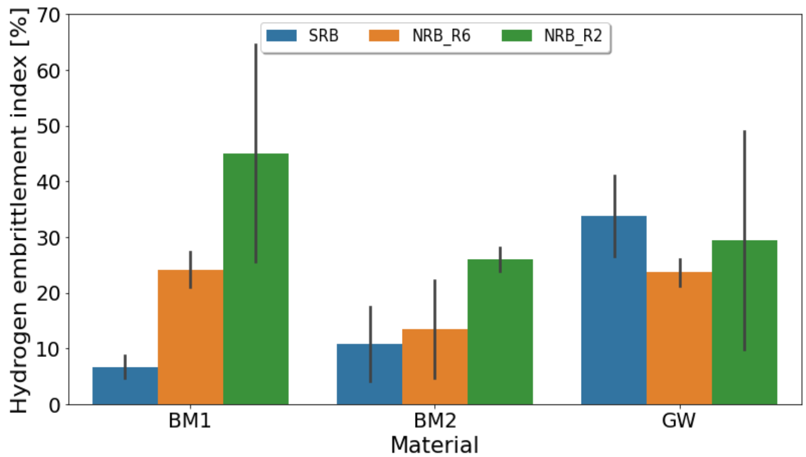

Figure 1: Hydrogen embrittlement based on area reduction

Firstly, although both base materials are equally classified as L485MB, their hydrogen embrittlement susceptibility differs, due to differences in their microstructural characteristics.

Secondly, in contrast to the base materials where the higher stress states resulted in higher embrittlement indices, the SRB extracted from the GW embrittled more than the NRB's. This difference is attributed the different orientation of welded NRB and SRB specimens.

A remarkable aspect is the scattering in the NRB_R2 for BM1. Possible explanation for this can be that the deformation in these specimens is less and therefore, smaller variation can lead to larger effect on the embrittlement index.

4. Conclusions

In this study, pipeline steels of the same grade but with different microstructures embrittled differently under the same test conditions. With exception of the girth weld, an increased stress state resulted in a higher hydrogen embrittlement index. The deviating observation for the girth weld may be attributed to differences in specimen orientation. For the materials studied in this paper, the levels of embrittlement of the girth weld metal did not significantly differ from those of the base metals.

The full paper will elaborate on the abovementioned observations and provide supporting microstructural information.

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