FRACTOGRAPHIC STUDY FOR SCREENING THE HYDROGEN COMPATIBILITY OF X70 PIPELINE STEELS AND WELDS

Lisa Claeys, Ghent University, Department of Materials, Textiles and Chemical Engineering, Research Group Sustainable Materials Science, Technologiepark 46, 9052 Zwijnaarde, Belgium
Lisa.Claeys@UGent.be
Jubica, Ghent University, Department of Materials, Textiles and Chemical Engineering, Research Group Sustainable Materials Science, Technologiepark 46, 9052 Zwijnaarde, Belgium
Laura De Pue, Ghent University, Department of ElectroMechanical, Systems and Metal Engineering, Soete Laboratory, Technologiepark 46, 9052 Zwijnaarde, Belgium
Stijn Hertelé, Ghent University, Department of ElectroMechanical, Systems and Metal Engineering, Soete Laboratory, Technologiepark 46, 9052 Zwijnaarde, Belgium
Wim De Waele, Ghent University, Department of ElectroMechanical, Systems and Metal Engineering, Soete Laboratory, Technologiepark 46, 9052 Zwijnaarde, Belgium
Tom Depover, Ghent University, Department of Materials, Textiles and Chemical Engineering, Research Group Sustainable Materials Science, Technologiepark 46, 9052 Zwijnaarde, Belgium
Kim Verbeken, Ghent University, Department of Materials, Textiles and Chemical Engineering, Research Group Sustainable Materials Science, Technologiepark 46, 9052 Zwijnaarde, Belgium

The natural gas pipeline grid that is currently in use will be partly repurposed for transport of gaseous hydrogen to decarbonize the energy landscape. Very conservative guidelines exist for the operating conditions at which hydrogen will be transported in these pipelines. However, despite its necessity, evaluating the fracture toughness and fatigue properties of pipeline steels in gaseous hydrogen at high pressures to reconsider these guidelines is very time consuming, needs to follow strict safety regulations and is thus expensive. We, therefore, developed a screening methodology to evaluate the hydrogen embrittlement sensitivity of different pipelines steels and their welds in a relatively fast and less expensive way. For the development of this screening methodology, four X70 pipeline steels were extracted from the Belgian natural gas grid and were subjected to quasi-static tensile tests (both uncharged and ex-situ charged) on three different specimen geometries, i.e. smooth round bars, notched round bars with radius 6 mm as well as with radius 2 mm, thus including different stress triaxialities. Additionally, two welds were investigated: a longitudinal pipe weld and a girth weld. Both the weld metal and the heat-affected zone were targeted. Three different hydrogen conditions were tested: hydrogen uncharged and electrochemically hydrogen charged with two different hydrogen contents. The obtained results were linked to quantitative measures of the microstructure as well as to the hydrogen properties (solubility and diffusivity) that were determined for the eight different material conditions. Moreover, all fracture surfaces were analyzed and different features were linked to the microstructure underneath as well as to the embrittlement sensitivity. In depth cross-sectional analysis was performed on selected specimens to find the microstructural origin of these specific features observed on the fracture surface. The mechanical results showed a higher embrittlement sensitivity with increasing level of stress triaxiality. Moreover, central segregation bands had a profound influence on the occurrence of delaminations with and without the presence of hydrogen, which largely impacted the mechanical behavior. Inclusions (e.g. oxides, sulphides), hard microstructural bands and small weld imperfections were found to initiate quasi-cleavage fracture in the two hydrogen charged conditions, leading to fisheyes distributed over the fracture surface in different shapes and sizes. The results of the heat-affected zone specimens showed a lot of spread which was explained by the challenges in consistently positioning the notches within the narrow region of strongly variable microstructures. A brittle transgranular facetted fracture was observed when the coarse grained heat-affected zone was targeted, indicating the importance of including weld microstructures in screening methods.