THE HYDROGEN EFFECTS ON MATERIALS PROGRAM AT NIST-BOULDER

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The effect of hydrogen on structural materials has impacts in a wide range of fields including materials design, codes and standards development, engineering, and fundamental science. As such, the Hydrogen Effects on Materials Program at NIST-Boulder utilizes three interrelated approaches: materials testing, science, and advanced modeling. NIST's *materials testing* capabilities include ASTM E8 tensile testing, ASTM E646 fatigue crack growth rate testing, ASTM E1820 fracture toughness testing, and ASTM E616 strain-life testing, all in gaseous hydrogen with pressures up to 138 MPa (20,000 psi), as well as ASTM E23 Charpy impact testing on pre-charged specimens. These testing capabilities have been used to collect a large dataset necessary to update ASME B31.12 hydrogen pipeline code. NIST furthers *scientific* understanding of the effects of hydrogen on materials through advanced characterization techniques including Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Scanning Kelvin Probe Force Microscopy (SKPFM), x-ray computed tomography, and even in-situ mechanical testing on x-ray and neutron beamlines using NIST's unique experimental equipment. NIST's *modeling* efforts, in conjunction with mechanical testing, are currently aimed at addressing issues in hydrogen pressure vessel codes and standards.

NIST's Hydrogen Effects on Materials project has recently kicked-off a DOT/PHMSA sponsored project "Determining Steel Weld Qualification and Performance for Hydrogen Pipelines" (https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=976). This project was derived from the 2021 PHMSA R&D Forum and seeks to address stakeholders' concerns, including from industry and manufacturers, on the transportation of hydrogen by pipelines. Specifically, this project intends to study how welds and heat-affected zones (HAZs) may behave differently in a hydrogen or blended hydrogen/natural gas environment compared to base metals and develop an understanding of welding procedures that result in microstructures with low hydrogen susceptibility. This work is intended to contribute to possible modifications of industry codes and standards and will include a comparison of existing codes and standards with regulations for pipelines carrying natural gas under 49 CFR Part 192.

Here we will present NIST's capabilities in mechanical testing, science, and modeling, as well as some recent developments and success stories.