Next-Generation Materials Characterization: Developing a New Paradigm for Nondestructive Testing

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OPS ACCOMPLISHMENTS

Pipeline Safety Research and Development for Assessment of Hydrogen and Microstructure in Welds, Pipeline Steels, and Other Advanced Materials

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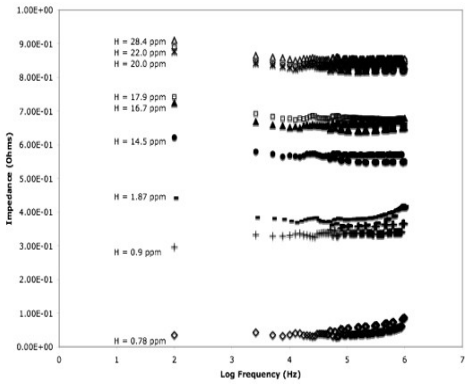
Challenge

Hydrogen is notorious for its dynamic, hard-to-detect, and corrosive nature in materials. A new paradigm in materials characterization is being developed in which hydrogen, microstructure, and other crucial material properties are monitored to allow accurate mitigation of problems well before cracking or other damage can occur. In many cases, hydrogen damage is responsible for failures in which hydrogen was never attributed as the cause, including many cases commonly ascribed to stress corrosion cracking and a variety of other failure mechanisms. Nondestructive sensors have been developed for rapid determination of hydrogen and hydride content in steels, stainless steels, titanium, and other advanced materials. These nondestructive sensors operate at the electronic level making them more sensitive even than existing destructive analytical techniques, especially at very low hydrogen concentrations. The sensors assess the electronic structure of the material and any perturbations in the electronic structure. After proper calibration and standardization, electronic and electromagnetic techniques can be utilized for real-time, nondestructive materials characterization measurements.

Technology

A new series of portable nondestructive materials characterization systems are being developed for the assessment of hydrogen, microstructure, and other crucial materials properties. Based on the success of field testing in a variety of applications, the commercialization of sensors for the energy, welding, nuclear, and chemical markets is in process. Hydrogen content sensors show improved accuracy when compared with current destructive techniques. Assess the microstructure and metal aging due to hydrogen in tubing, piping, and pressure vessels that throughout the materials lifetime, including fabrication, joining, and in-service.

Low Frequency Impedance Measurements



Low frequency impedance measurements of hydrogen charged X65 steels at various levels exhibit a sensitivity that exceeds the sensitivity of current destructive techniques.

Accomplishments

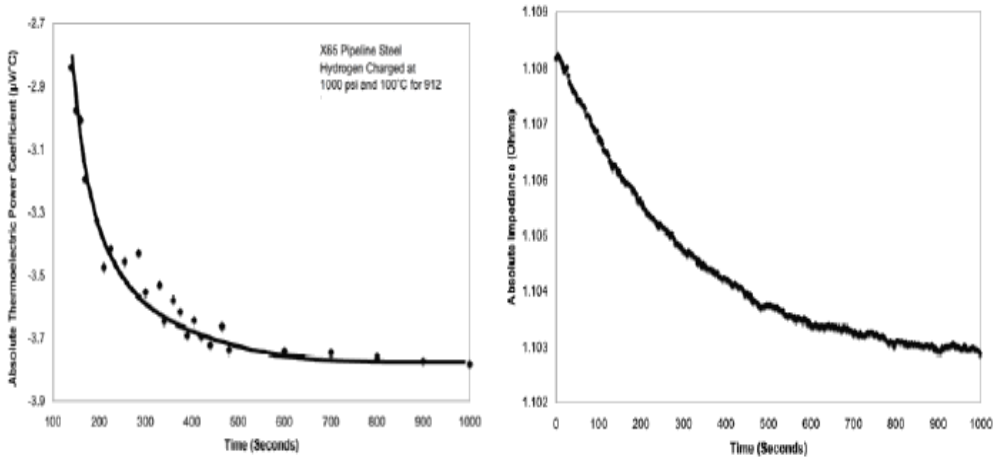
The researchers from the previous CSM-NIST "In-Situ Hydrogen Analysis in Weldment'" sponsored by DOT started Generation 2 Materials Technology (G2MT) to further the development and commercialization of hydrogen and other nondestructive testing tools and G2MT Services to perform in-field services.

The continuing collaboration between CSM, G2MT, and NIST-Boulder is investigating the effect of mechanical properties testing in a gaseous hydrogen environment, including nondestructive hydrogen measurements that correlate with the DOT testing.

♦ Groundbreaking insights have been made into the influence of oxides and coatings on corrosion and hydrogen. These will change the way corrosion testing is performed and how previous research and results should be analyzed.

Office of Pipeline Safety

Research & Special Programs Administration



Thermoelectric power (left) and impedance (right) as a function of time as hydrogen diffuses out of X65 pipeline steel. These results are from 3 to 1ppm and below which is beginning to exceed the accuracy of common techniques.

Benefits

The technologies developed through this research are part of a paradigm shift in the assessment of materials that will substantially improve safety and integrity and reduce costs associated with corrosion. Improvement of the safety of pipelines and other crucial components of the nation's infrastructure is being achieved through Specific Benefits include:
1.) The ability to accurately assess microstructure of materials as they are produced, fabricated, and while in service, 2.) No need to remove coatings to make measurements, 3.) Manpower to perform inspections drastically reduced, 4.) Improved data quality and value.,5.) Determines areas where corrosion are most prone to happen, well before damage occurs, 6.) Interstitial hydrogen and hydride contents can be separately determined.

Future Activities

G2MT is actively expanding the range and capabilities of the tools as well as developing portable and wireless versions that can be applied in a variety of markets. The development of codes and standards for steel and titanium, with a focus on piping, tubing, and pressure vessels, is being pursued in collaboration with ASME Standards and Technology. Further improvements of the sensing capabilities and of calibrations for a variety of materials are being performed. Sensors for the assessment of titanium tubing should enable a substantial improvement of operating integrity, downtime losses, and extend the materials safe operating lifetime.

Partners in Success

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- US Department of Transportation
- National Institute of Standards and Technology www.boulder.nist.gov
- XCEL Energy www.xcelenergy.com
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