DOE Hydrogen Program

Materials Joining Technology for Hydrogen Delivery Infrastructure

Understanding the Effects of Welding on Material Property Degradation

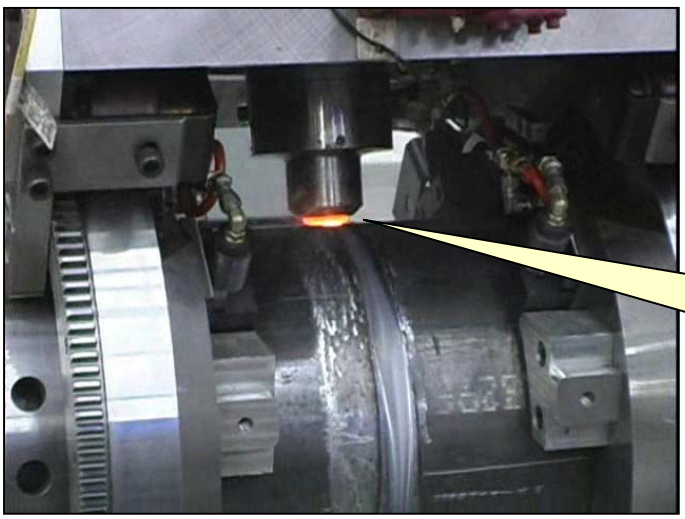
Background

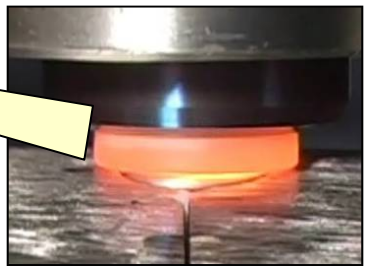
Pipeline systems are likely to prove the most effective mechanism of transporting large quantities of hydrogen from production site to the point of use. To be cost effective, hydrogen pipelines must be constructed of economically viable materials such as steel. Economic hydrogen delivery by pipeline would require the gaseous hydrogen (H_2) be transmitted at very high pressures (e.g., 1500 psi). Steel pipelines, however are subject to hydrogen embrittlement which reduces the structural integrity of the pipeline.

Welding is the most economical way to construct pipelines. However, the welding process introduces unfavorable microstructures and high residual stresses that increase the susceptibility of welds to hydrogen embrittlement. Welds have been demonstrated to exhibit delayed cracking when exposed to high pressure hydrogen, and have lower resistance to crack initiation and higher crack growth rates. The problem of hydrogen embrittlement of welds is not limited to pipelines, but is also applicable to a variety of metallic parts in hydrogen storage and delivery systems (e.g. compressors and vessels).

Technology

The goal of this R&D effort is (1) to gain the basic understanding of the welding effects on the material property degradation of metallic materials, particularly high-strength pipeline steels exposed to high-pressure gaseous hydrogen, (2) to develop the technical basis and guidelines for management of stress and microstructure in the weld region for structural integrity and safety of hydrogen pipelines, and (3) to develop welding/joining technology that can be used to safely and economically construct new pipelines and/or retrofit existing pipelines for hydrogen delivery.

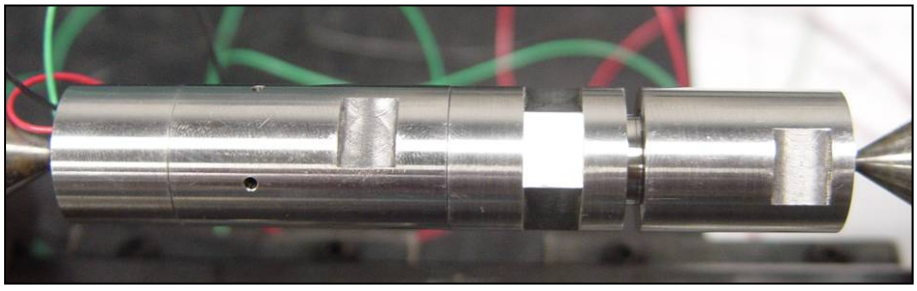




Friction Stir Welding of Metal Pipe

An internally heated pressure vessel (rated at 120,000 psi) is used to study the hydrogen transport in metals. This system has been upgraded to improve temperature control at the ambient temperature range (0-100°C) and to improve the accuracy at low pressures for detection of initial hydrogen breakthrough during hydrogen diffusion experiments. Benchmarking measurements on Pd (for which diffusion behavior has been extensively studied) confirmed the performance of the experiment system. Measurements on pipeline steels have been initiated.

To adequately address the effects of microstructure and property inhomogeneity in welds, a special miniature, self-loading testing apparatus was designed and fabricated for in-situ measurement of the mechanical property degradation of weld metal under high-pressure gaseous hydrogen environment. This testing device can be used to study the effects of hydrogen pressure and steel grade on potential hydrogen embrittlement in pipeline steels and weld metals.



Miniature testing assembly for in-situ testing of weld property changes

Benefits

- A systematic approach to managing weld property degradation under high-pressure hydrogen gas is critical to ensure the safe, cost-effective operation and long-term reliability of the hydrogen delivery infrastructure.
- The results of this project will help reduce the high capital cost of pipelines and reduce problems with hydrogen embrittlement of pipelines.

Points of Contact

Z. Feng, 865-576-3797, fengz@ornl.gov
T. Armstrong, 865-574-7996, armstrongt@ornl.gov