CHARACTERIZATION of Mechanical Properties, Fatigue-Crack Propagation, and Residual Stresses in a Microalloyed Pipeline-Steel Friction-Stir Weld

Dr. Jeffrey Sowards, Metallurgist  
NIST Materials Measurement Laboratory  
Applied Chemicals and Materials Division

Abstract
Friction-stir welding (FSW) is a process where materials are joined in the solid-state using a rotating tool that frictionally heats and stirs material together. The lack of melting and solidification inherent to fusion welding processes can promote favorable weld properties in friction-stir welds. A great deal of past research has led to routine implementation of FSW for joining lower melting-point materials such as the aluminum alloys, yet the joining of higher melting-point materials has been hindered due to wear of the welding tools. Recent developments of wear-resistant tool materials has enabled FSW of alloys with higher melting-point including many of the ferrous alloys.

Implementation of the FSW technique to join high-strength steel pipelines could enable significant gains in field welding productivity since thin and medium wall pipes can be joined with a single welding pass and without the restrictions of low-hydrogen welding practices. Welding procedures for joining API 5L X80 pipeline steel have been developed by collaborators at the Brazilian Nanotechnology National Laboratory. The welding procedures, which take advantage of a polycrystalline cubic boron nitride welding tool, have been optimized to promote weld fracture toughness. However, further optimization of the welding procedure and the structural integrity of the pipelines requires more detailed mechanical property studies. This presentation will discuss recent results of an ongoing characterization study that is evaluating FSW properties with mechanical and fatigue crack growth testing, and other measurement techniques including mini Charpy impact testing, and neutron diffraction. So far, the FSW process has produced microstructures that vary significantly from those observed in the base metal, namely by the redistribution and resizing of MA constituent in the heat-affected zone and stir zone regions of the welds. Mechanical properties of the welds and base metal revealed overmatching welds and a hard zone within the weld stir zone. Mini Charpy testing revealed that the highest Charpy transition temperature occurred locally in the weld hard zone, indicating this region may control overall weld toughness.

Residual stresses were determined in several weld orientations with neutron diffraction revealing that stress in the longitudinal direction is highest, yet well below material yield strength. Fatigue crack propagation behavior was characterized in the different weld regions and base metal showing that welds have impeded fatigue crack growth compared to base metal due to welding-induced residual stress fields interacting with the crack.

Biography
Jeffrey Sowards is a Metallurgist in the Applied Chemicals and Materials Division at the National Institute of Standards and Technology (NIST) in Boulder, CO. His experience at NIST began with an appointment as an NRC postdoctoral research associate in 2009 in the former Materials Reliability Division. Since then, his research has focused on developing structure-property relationships of engineering materials with emphasis on examining the effects of welding, and service-related environmental damage. This work has supported NIST pipeline and infrastructure safety research efforts, and several major metallurgical failure investigations for other government agencies. Prior to joining NIST, he was a graduate student and postdoctoral fellow at The Ohio State University and a guest researcher at the Brazilian Synchrotron Light National Laboratory. He received a B.S.W.E., M.S., and Ph.D. from The Ohio State University where he studied welding metallurgy and corrosion.

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