VI.5 Continuous Fiber Composite Electrofusion Coupler

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Subcontractors:
- NOV Fiberglass Systems, Houston, TX
- Savannah River National Laboratory, Aiken, SC

Project Start Date: December 1, 2015
Project End Date: December 30, 2018

Overall Objectives

- Quantify
  - Various mechanical characteristics of coupler: burst strength, axial strength, leak rates, fatigue characteristics.
  - Manufacturing costs of coupler.
- Optimize
  - Mechanical design of composite coupler: maximize strength characteristics while constraining costs.
- Demonstrate
  - Coupler without mechanical components, which would require underground maintenance.
  - Manufacturability of a robust coupler that reduces cost and complexity of hydrogen pipeline installation.
  - Advanced electrofusion coupler meets mechanical requirements for pipeline designed to transport hydrogen at 100 bar (and pass test at 350 bar)

Fiscal Year (FY) 2017 Objectives

- Demonstrate a functioning coupler that passes required burst, leak, and fatigue tests consistently through testing.
- Optimize the electrofusion process to melt-bond components sufficiently but without overheating given variation in both coupler's componentry and fusion equipment.
- Analyze the coupler's fatigue life and failure modes by finite element modeling of the multi-material coupler.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Delivery section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

(D) High As-Installed Cost of Pipelines

Contribution to Achievement of DOE Hydrogen Delivery Milestones

This project will contribute to achievement of the following DOE milestones from the Hydrogen Delivery section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

- Milestone 1.5: Coordinating with the H_2 Production and Storage sub-programs, identify optimized delivery pathways that meet a H_2 delivery and dispensing cost of <$2/gge for use in consumer vehicles. (4Q, 2020)
- Milestone 6.3: By 2020, reduce the cost of hydrogen delivery from the point of production to the point of use in consumer vehicles to <$2/gge of hydrogen for the gaseous delivery pathway (4Q, 2020)

FY 2017 Accomplishments

- Identified near-final design configuration. Testing to date has met requirements set forth for hydrogen pipelines:
  - Passed multiple burst tests at 350 bar with water.
  - Passed leak rate tests by an order of magnitude greater than that required (5×10^{-4} cm^3 He/s required).
  - Passed tensile load requirements of 10,000 lb tension.

- Selected and implemented a singular electrofusion machine and process allowing consistent fusion parameters to be used.
- Shown through finite element analysis that the coupler should survive fatigue loading required of 28,500 cycles at R = 0.5, at 350 bar maximum pressure.

INTRODUCTION

Traditional pipe couplers considered for a nonmetallic buried hydrogen pipeline employ elastomeric sealing components, such as O-rings. The American Society of Mechanical Engineers code committee responsible for hydrogen piping and pipelines has expressed concerns that such underground maintenance would be problematic and unsatisfactory.

The proposed coupler design under this project will eliminate need for such elastomeric seals. This coupler seals adjacent nonmetallic composite pipes by the electrofusion of two adjacent cylindrical plastic surfaces (applying heat via electrical current). State of the art electrofusion couplers are rated at too low of a pressure for the hydrogen pipeline proposed. Therefore, a new design is required.

APPROACH

This research draws from existing electrofusion pipe coupling technology, but extends to be suitable for use on a variety of materials available for composite pipelines. Automated Dynamics' technology is well-suited to couple thermoplastic bonded pipes (where each of the pipe's radial adjacent layers are bonded to each other) by our fiber placement technology that bonds continuous media (fiber reinforced composite, plastic coated wire) on the fly without need for post-curing. The coupler designed in this program shall be available for such pipes and for non-bonded pipes. Existing electrofusion couplers do not allow continuous fiber composite reinforcement necessary to achieve high pressures sought by the DOE. Our coupler will employ this continuous fiber thermoplastic composite as a structural layer for high pressures and high induced axial loads.

RESULTS

The project has been focused on achieving the following results:

- Passed tensile test requirements, failing pipe before failing coupler on average at 11,000 lb.
- Passed burst test requirements, failing pipe before failing coupler on average at 5,400 psig.
- Passed leak-rate test requirements, achieving 10×10^{-5} cm^3 He/s leak rate.
- Demonstrated through analysis that coupler will pass fatigue requirements (28,500 cycles at minimum/maximum stress, R = 0.5). Actual tests slated for later this year.

Further progress of the past fiscal year includes finalizing the design of most of the components and the associated manufacturing and machining processes to produce the custom components. While the first year was spent optimizing some manufacturing processes such as wire placement and fiber placement of the custom electrofusion coupler, this past fiscal year has focused on refining design and geometric tolerances and refining the electrofusion and assembly process, both of which are nearly final.

CONCLUSIONS AND UPCOMING ACTIVITIES

We expect to pass the last of the three milestones in 2017 (fatigue testing) to proceed into the last year of this active project. Then a final design will be chosen and fatigue testing will be performed to yield statistically significant results. Additionally, the manufacturing and quality plans will become more detailed, which will aid in the evolving commercialization plan.

Further funding in 2017 and 2018 will be spent on final fatigue testing and design of procedures for in-field assembly, such as machining the pipe-ends in preparation for fusion.

Lastly, commercialization preparation remains a challenge and focus for this hydrogen line infrastructure. With less than 2,000 miles of currently installed hydrogen pipeline in the United States, the existing market for this infrastructure pales compared to natural gas pipeline infrastructure which is three orders of magnitudes greater.