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: April 30, 2019

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 O-ring sealing 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) 2018 Objectives

- Demonstrate a functioning coupler that passes the required fatigue test consistently (burst and leak tests already passed). Fatigue test goal is minimum 10,000 cycles, R=0.5, 1,500 psi.
- Optimize the electrofusion process cycle performed with non-standard electrofusion equipment.
- Analyze failure modes upon leaking for insight into potential improvements in 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[1]:

D. High As-Installed Cost of Pipelines.

Contribution to Achievement of DOE Technology Acceleration 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 Hydrogen Production and Storage subprograms, identify optimized delivery pathways that meet a hydrogen 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 2018 Accomplishments

- Implemented the improved design, reducing the number of components and corresponding number of bond zones and leak paths by a factor of 2. The prior design required two

[1] https://www.energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22

separate bonding layers, each of which was a hydrogen leak path in the coupler.

- Implemented a custom electrofusion process to achieve sufficient power to melt and fuse the coupler's components. Prior equipment did not output enough voltage for the modified design; it was short by more than 50% voltage capacity. The modified design required increased resistance, and therefore voltage, because of decreased wire size. Wire size decreased by over 50% effective area, significantly increasing the surface area available for bonding. This was needed due to prior fatigue test failures at the bond zone. An off-the-shelf electrofusion system with higher voltage would be used in practice.

INTRODUCTION

Traditional pipe couplers considered for a non-metallic 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 the need for such elastomeric seals. This coupler seals adjacent non-metallic 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 it to be suitable for use on a variety of materials available for composite pipelines. Automated Dynamics' (now part of Trelleborg Group) 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, as well as thermoset pipes, which require a different coupler design employing metal mechanical wedge grips and coupling threads. The coupler designed in this project shall be available for such pipes and for non-bonded pipes. Existing electrofusion couplers do not allow for the continuous fiber composite reinforcement necessary to achieve the high pressures sought by DOE. Our coupler will employ this continuous fiber thermoplastic or thermoset 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 He/s leak rate.
- **Still working toward passing fatigue test at minimum 10,000 cycles, R=0.5, 1,500 psi.**

These results are the key milestones toward commercial viability. Passing the fatigue test remains the singular most difficult hurdle. Currently, parts are in-test at Savannah River National Laboratory.

CONCLUSIONS AND UPCOMING ACTIVITIES

We expect to pass the last of the three milestones (fatigue testing) in 2018 to nearly finalize the scope of work of the active project. Minimal repeat testing will be available for statistically significant results. This is due to the greater complexity of fatigue requirements than initially considered in 2015. Additionally, the manufacturing and quality plans will become more detailed, which will aid in the evolving commercialization plan.

SPECIAL RECOGNITIONS AND AWARDS/PATENTS ISSUED

1. "Continuous fiber reinforced composite and metal electrofusion coupler," Patent application #16/175,018 (filed October 30, 2018).

FY 2018 PUBLICATIONS/PRESENTATIONS

1. David Hauber and Brett Kimball, "Continuous Fiber Composite Electrofusion Coupler," Presentation at the DOE Annual Merit Review and Peer Evaluation Meeting, Washington, D.C., June 2018.