III.9 Polymer and Composite Material Performance in Hydrogen

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Project Start Date: October 1, 2013
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Identify knowledge gaps and data needs for using polymers and composite material systems in hydrogen service, particularly at high pressures (up to 100 MPa), demanding duty cycles, and long service life.
- Characterize failure mechanisms and discover mechanical behavior of polymer materials in high-pressure hydrogen gas at extreme temperature conditions.
- Place technical information in the hands of designers to positively impact performance, reliability, and safety.
- Participate in standards activities that concern the use of polymer materials and/or qualification of polymer materials.

Fiscal Year (FY) 2013 Objectives

Identify knowledge gaps and data needs for using polymers and composite material systems in hydrogen service, particularly at high pressures (up to 100 MPa), demanding duty cycles, and long service life.

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:

(B) Reliability and Costs of Gaseous Hydrogen Compression

(E) Gaseous Hydrogen Storage and Tube Trailer Delivery Costs

(J) Hydrogen Leakage and Sensors

(K) Safety, Codes and Standards, Permitting

Technical Targets

This project is focused on improving the technical basis for selecting polymer materials for use in high-pressure hydrogen gas at extreme temperature conditions. Insights gained from these studies will be applied toward improving the performance, reliability, and safety of components that use polymer materials in compression, storage, dispensing, and vehicle fuel system applications, meeting the DOE 2015 hydrogen delivery targets:

- Aggregate fueling station cost: $1.60 gasoline gallon equivalent (centralized)
- Small compressor reliability: improved
- Small compressor maintenance: 2.5% of installed capital cost
- Uninstalled cost/dispenser: $40,000 at the design pressure specified, two hoses per dispenser (860 bar)

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APPROACH

While polymers and composites are currently used in fuel cell vehicle systems and fuel delivery and dispensing systems, designers and manufacturers continually look for ways to reduce costs through implementing new materials while improving safety, performance, and reliability. Designers and manufacturers typically seek chemical and mechanical characterization data for a material either to support direct implementation or to develop a more general performance-based standard that can then be used to qualify a class of materials.

This project supports the collection and generation of performance data for critical materials in hydrogen service and strives to fill knowledge gaps that would be most impactful. The learning that has been gained from similar DOE-sponsored research efforts is published in documents such as the Technical Reference on Hydrogen Compatibility of Materials, product standards, and peer-reviewed journal articles.

The first year of the project focused on knowledge gaps and data needs for understanding polymer behavior. Data needs were identified and validated through a series of information exchanges with industry stakeholders and literature survey.

ACCOMPLISHMENTS

The work product consists of a series of stakeholder meetings, literature reviews, and summary reports.

- Co-facilitated a panel session on *Assessing knowledge gaps for hydrogen vehicle and infrastructure codes and standards* at the August 2012 Composites Conference
- Facilitated an information-sharing meeting on the use of polymer and composite materials in hydrogen applications, October 17–18, 2012 [1]:
  - Identified knowledge gaps and data needs for using polymers and composite material systems in hydrogen service, particularly at high pressures (up to 100 MPa), demanding duty cycles, and long service life.
  - Provided important input to enable lower-cost, higher-performance systems through improved knowledge and revised codes and standards.
  - Informed testing needs to better enable near-term applications of polymers and composite systems in hydrogen service, including components at high pressure and extreme temperatures.
- Meeting participants identified material knowledge gaps in six different topical areas, motivated by safety, performance, and reliability concerns. The topical areas were:
  - Thermal performance of polymers at service conditions and impact of thermal excursions.
  - Evaluation and minimization of gas permeation and absorption into polymers.
  - Polymer performance characterization tests considering significant material variability.
  - Characterization and performance of seals and o-rings.
  - Liner buckling in pressure systems.
  - Low-cost composite material systems.
- Performed a literature review focused on the mechanical behavior (e.g. stress-strain, strength, ductility, fatigue resistance, failure) of polymer materials in hydrogen gas at extreme pressures and temperatures [2].
- Documented use-cases, available data, and data gaps for various polymer materials (to be completed by October 2013).

FUTURE DIRECTIONS

- Develop the capability to characterize mechanics and failure for polymers exposed to extreme conditions.
  - 100 MPa hydrogen exposure
  - -70°C to 120°C
- Execute characterization experiments for commonly used polymer materials that have insufficient performance data identified from FY 2013 and develop mathematical models of mechanical behavior.
- Disseminate research findings through publications and standards engagement.

FY 2013 PUBLICATIONS/PRESENTATIONS

1. “Polymer and composite materials used in hydrogen service”, Polymer and Composite Materials Information Exchange Meeting Proceedings, SAND2012-10860P, Sandia National Laboratories, 2012.

2. Hecht, “Review on the effects of hydrogen pressure at extreme temperatures on polymer mechanics”, SAND2013-2512, Sandia National Laboratories, 2013.