IV.D.1h System Design and Media Structuring for On-Board hydrogen Storage Technologies

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Objectives

Main objectives of this project are:

- to develop system simulation models for on-board hydrogen storage systems using metal hydride and adsorbent materials and to determine system compliance with the DOE technical targets, and
- to develop storage media structures with optimized engineering properties for use in storage systems.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Storage section of the Hydrogen, Fuel cells and Infrastructure Technologies Program Multi-Year Research, Development, and Demonstration Plan (MYPP):

(A) System Weight and Volume
(B) Efficiency
(C) Charging/Discharging Rates
(D) Thermal Management

Technical Targets

This project addresses the design of on-board hydrogen storage systems for two types of storage media - adsorbent materials and metal hydrides. In particular, the system design will be optimized with emphasis on meeting following DOE 2010 targets.

Storage Parameter	Units	2010	2015
System gravimetric capacity	(kg H_2/kg system)	0.045	0.055
System volumetric capacity	(kg H_2/L system)	0.028	0.040
System fill time (for 5 kg H_2)	min	4.2	3.3
Minimum full flow rate	(g/s)/kW	0.02	0.02
Min-max delivery temperature	°C	-40/85	-40/85

Approach

As part of the Hydrogen Storage Engineering Center of Excellence team, GM has taken up the tasks of building system models for on-board hydrogen storage systems using metal hydrides and adsorbent materials, storage media structuring and enhancement studies, and building a cryoadsorption vessel for validation of cryoadsorption models.

System Modeling: In the first few months, we have concentrated our efforts on adsorbent system simulation modeling. Known adsorbent system materials are generally based on activated carbon or metal-organic frameworks materials. These systems need to be operated at close to liquid nitrogen temperatures and 20-50 bar pressures to provide adsorption capacity necessary for on-board hydrogen storage systems. Therefore, often these systems are also called cryoadsorption systems. For automotive systems, the four cryoadsorption processes occur over different time scales: refueling over a few minutes, discharge over a few hours, dormancy over a few days, and venting over a few weeks. We plan to develop a hierarchy of physics-based models for cryoadsorption hydrogen storage tank to study the relevant engineering issues in these four tank processes. While a lumped parameter model might suffice for the slow processes, we expect significant temperature gradients within the bed for the faster process of refueling, warranting a higher dimensional model. A lumped parameter model for the cryoadsorber tank and a study of the four tank processes has earlier been completed at GM [1].

Storage Media Structuring and Enhancement: To enable fast refueling, it is extremely important to employ storage media with good thermal transport properties in conjunction with an optimized heat exchanger system to remove the heat generated by the exothermic process of hydrogen uptake. For metal hydrides, another challenge is the fracture of storage media during cycling. Fracturing decreases the heat transfer and enables the increasingly smaller particles to move in the containment vessel and collect at the bottom of the tank with an adverse impact on the system performance. In addition to the potential fracturing of the hydrides, volumetric expansion during hydriding needs to be addressed. By using dimensionally stable media structure and/or a heat exchanger with a pocket design, the negative effects of volumetric expansion can be mitigated. One major objective of this project is to develop, test, and optimize metal hydride composites in the form of pellets or other similar shapes to greatly enhance thermal conductivity of the storage material, to reduce thermal contact resistance and gas flow resistance, and to improve cycling stability and durability of the metal hydride materials. Similarly for adsorbent materials, forming mechanically stable composite pellets out of a powderous material is one promising solution to overcome some of the challenges that we face for on-board hydrogen storage. Pellets or similar-shaped composites of the adsorbent material will be formed using small amounts of binders in combination with thermal enhancing materials. As with metal hydrides, the main objective is to improve thermal conductivity of the storage material, reduce gas flow resistance and to improve cycling stability and durability of adsorbent materials.

Accomplishments

System Modeling: We have selected the lumped parameter model developed earlier at GM [1] to develop system simulation models for the processes in the cryoadsorber tank.

A system simulation schematic for the discharge cycle of a cryoadsorption system is shown in Figure 1. Hydrogen is discharged from the cryoadsorber tank using pressure and temperature control. It is necessary to both raise the tank temperature and reduce pressure to desorb and use most of the hydrogen stored in the tank. Temperature of the system is increased by supplying heat through a heated sidestream of hydrogen. The flow rate and temperature of the sidestream are two control variables that need to be determined through system simulations.

Storage Media Structuring and Enhancement: We have chosen AX-21 activated carbon as the adsorbent material of choice for media structuring studies. A literature study of various binders used in forming pellets has been completed.

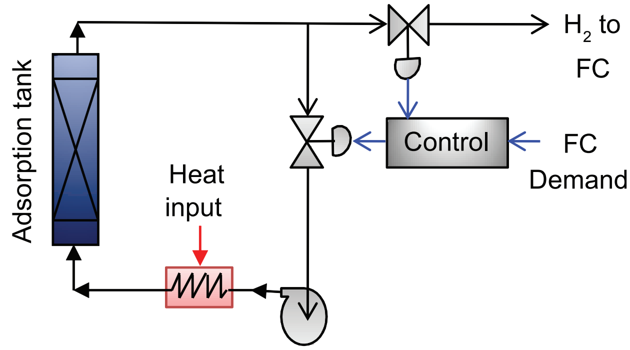

FIGURE 1. A schematic of the cryoadsorption storage system for the discharge cycle. (FC - fuel cell)

Future Directions

- Develop system simulation model for the cryoadsorbent system.
- Develop system simulation model for the metal hydride system.
- Conduct simulation studies for both the refueling and discharge cycles for both the metal hydride and adsorbent material systems.
- Test various binders for pelletizing activated carbon and metal hydride materials.
- Measure engineering properties of the pellets for various pellet sizes and optimize composition with respect to engineering properties.

References

1. Senthil Kumar V. et al: A lumped-parameter model for cryo-adsorber hydrogen storage tank, Int. J. Hydrogen Energy 2009; 34: 5466-5475.

FY 2009 Publications/Presentations

1. S. (Darsh) Kumar: Poster Presentation at the 2009 Hydrogen program Annual Merit Review Meeting, stp_12_Kumar.

2. Senthil Kumar V. et al: A lumped-parameter model for cryo-adsorber hydrogen storage tank, Int. J. Hydrogen Energy 2009; 34: 5466-5475.