2008 DOE Hydrogen Program

Rapid Manufacturing of Carbon Composite High Pressure Storage Cylinders

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Project ID # MF4

This presentation does not contain any proprietary, confidential , or otherwise restricted information

Project Lead and IP

OEM and Technology Evaluation

Automated Manufacturing Systems

Fiber Preform and Design

Bayer MaterialScience, LLC

Resin and processing

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Rapid Manufacturing of Carbon Composite High Pressure Storage Cylinders

Overview

Timeline

- Start – December 2006
- Finish – June 2008
- 75 % complete

Budget

- Total Project Funding
  - DOE - $685K
  - Industry - $430K
- Funding Received in FY07
  - $250K
- Funding for FY08
  - $435K
- Funding increment underway for approach involving tooling and process improvement for manufacturability

Barriers

- A – Rate of manufacturing cylinders
- B – Cost of finished cylinders
- C – Performance of cylinders
- Targets – storage systems overall

	2007	2010	2015
Storage System Cost ($/kWh net)	6	4	2

Partners

- NCMS – Project Management
- Profile Composites – Project Lead
- Collaborators, cost sharing partners
  - Toyota, A&P, Bayer, MAG-Cincinnati

Objectives

Primary Objective is to demonstrate high-rate manufacturing of 35MPa carbon composite hydrogen storage cylinders

- No process stage to be greater than 20 minutes
- All individual steps to be “production capable”
- All materials to be available in quantity and with potential for automotive volume production
- Major process risk areas to be demonstrated physically
- Cylinders to be validated by test program
- Show complete engineering analysis and process model to achieve under 10 minute production cycle time per cylinder, for 70 MPa cylinders

Relevance

- Allow for production capacity off a single tooling line to approach that of specialty vehicle manufacturing
- Over 20,000 tanks/line/year based on 3 shift operation

Milestones

Month/Year	Milestone
May 2007	First subscale demonstration article to indicate process feasibility, show major challenges with processes and integration, and provide clear guidelines for focusing efforts
November 2007	First complete article to provide degree of confidence in technology and test system performance
June 2008	Manufacturing and assembly process rate demonstration, demonstration of full process systems and tooling line approach, demonstration of each process stage in under 20 minutes, production of tank in under 20 minutes

Approach

Task	Major technical focus
Design	• Fiber system design for processability • Fiber system design for optimized stress • Liner design for manufacturability
Materials Development	• Fiber/resin performance under accelerated cure • Resin system designs
Manufacturing Processes	• Novel manufacturing approach - experimental development • Development of fiber placement systems • Design and development of automated materials handling system • Development of tooling approach to optimize cure
Testing	• Subscale cylinder burst pressure tests • Subscale cylinder laminate tests • Full-scale cylinder pressure and cycle tests
Commercialization	• Demonstrate each process step in under 20 minutes • Physically show automation and handling system components • Analyze each process stage and integration into production to predict path to 10 minute cycle time • Fabricate full-scale cylinders for vehicle testing

Results

Developed design of Type 3 tank with separation of fiber placement and resin processing

- Subscale tank processed in closed mold
- Process control from internal and external sources
- Resin system accelerated for under 30 minute cure currently

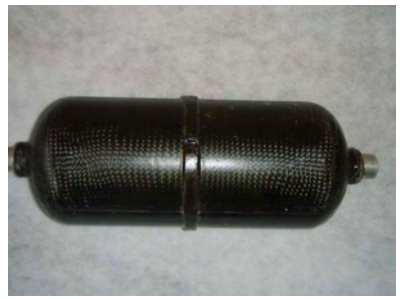
Achieved 30 minute process cycle

- Reached 30 minute process stage capability in FY 2008 with no automation
- Used prototype tooling with mixed results, moved into hard tooling development
- Designed automation systems to overcome major materials handling issues and implemented development of systems

Results (2)

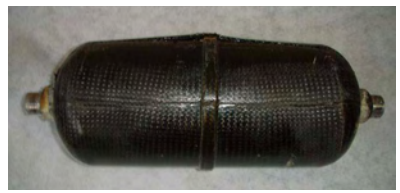
Developed novel methodology to control fiber wrap

- Allowed acceleration of fiber placement
- Improved processability of materials



Demonstrated process for achieving 20 minutes, currently implementing more robust and repeatable systems

- Tooling up for full-scale cylinder, re-designed tooling approach as required for control of overall process
- Developed and designed and currently implementing 3rd-generation materials handling system



Results (3)

Approach to achieve 10 minute overall cylinder production cycle time

Process Stage	Current Time (min)	Feasible Time (min)	Production Potential
Cylinder wrapping (independent)	15	10	2
Tool load and cure cycle	20.25	12.25	15
Cool-down	5.0	2.0	2
De-mold part/clean mold	5.0	4.0	2
TOTAL	**30.25**	**18.25***	**19**

* Sub-scale cylinder times

Future Work

FY08

- Complete new tooling approach for full-scale cylinder
- Demonstrations of automation and handling systems
- Process demonstration for complete manufacturing cycle
- Refine cost model and include automation factors
- Complete test cycle for cylinders and provide cylinders for partners

FY09

- Initiate systems for health monitoring of cylinders
- Begin development for 70MPa cylinders
- Initiate production for 35MPa cylinders

Summary

Project has developed a novel approach to manufacturing hydrogen storage cylinders

- **Achieved 30 minute cycle times with no automation**
- **On target to achieve 20 minute cycle times**
- **Capable to be lights-out manufacturing technology**
- **Process is robust and repeatable**
- **This is first process that may achieve production rates compatible with vehicle production without major parallel production line requirements**
- **Also possible to implement for low-pressure cases for other storage systems**