2008 DOE Hydrogen Program H_2 Tank Manufacturing Optimization

Quantum Fuel Systems Technologies Worldwide Inc.

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Carter Liu, PhD

Project ID # STP 30

Overview

Timeline

- Project start date TBD by DOE
- Project Duration: 18-24 months from start date

Barriers

- Materials development
- Manufacturability

Budget

- Total project funding under negotiation with the DOE

Partners

- None currently

Objectives

Improve the cost and weight efficiency of H_2 storage vessels to approach the 2010 DOE targets by reducing raw material costs through material development, design and manufacturing parameter modifications.

The following tasks will be undertaken:

- Liner material development
- Metal fitting material development
- Optimization of carbon fiber composite usage

Performance Measure	2008 (baseline)	2010 target	
Carbon Fiber Composite Usage	100%	75%	
Liner Material Cost	100%	20%	80% raw material cost reduction
Metal Fitting Cost	100%	20%	80% raw material cost reduction

Milestones

Month	Milestone
Month 0	Program Kick-off: Liner material development literature review Metal fitting literature review
Month 2	GO-NOGO: Result form the literature review Liner material property characterization/evaluation Investigate injection/blow molding processes Metal fitting to liner interface design & FEA
Month 6	Initiate carbon fiber optimization DOE
Month 7	Revised liner process development
Month 10	Liner characterization/testing GO-NOGO: Cost/weight reduction % from target for activities prior to boss-liner interface design Boss-liner interface design
Month 14	Carbon Fiber Design of Experiment report GO-NOGO: Decision pending test results to proceed with assembly/fabrication of optimized tank
Month 15	Fabricate tanks→ EIHP Testing
Month 18	Merit Review

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Approach Outline

- **Liner Development**
  - Materials study
  - Liner-Metal interface design
  - Investigation of mass-production methods
- **Metal Fitting Development**
  - Metal fitting material investigation and redesign
  - Liner-Metal interface investigation
- **Composite Design Optimization**
  - Manufacturing process evaluation
  - Further optimization of composite design to improve fiber translation[1] and reduction of composite usage

[1] translation= reinforcing efficiency of carbon fibers

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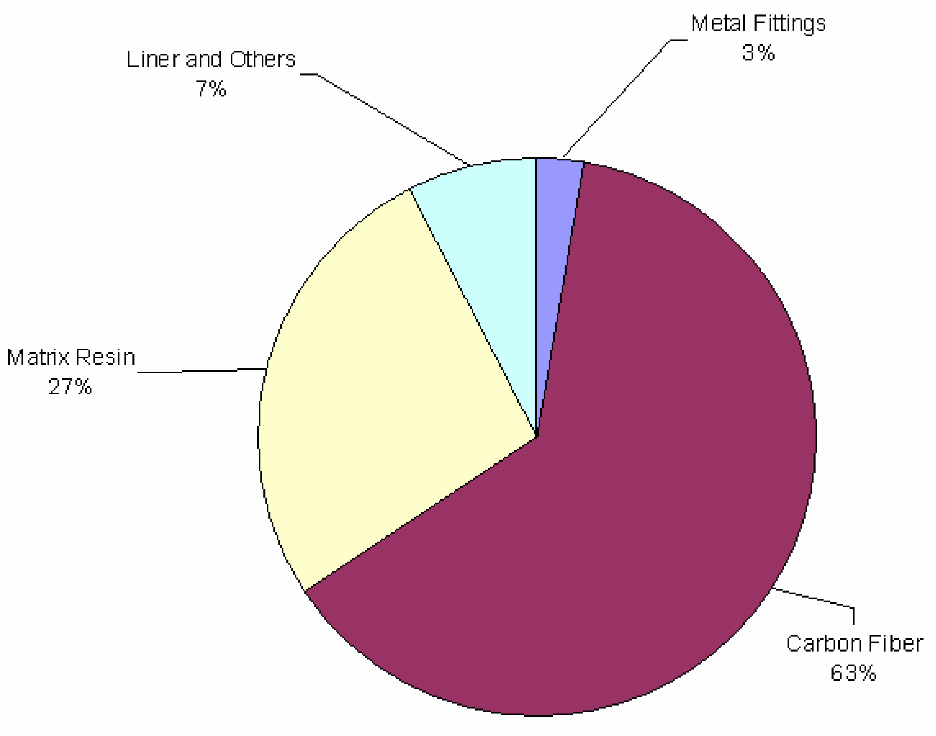
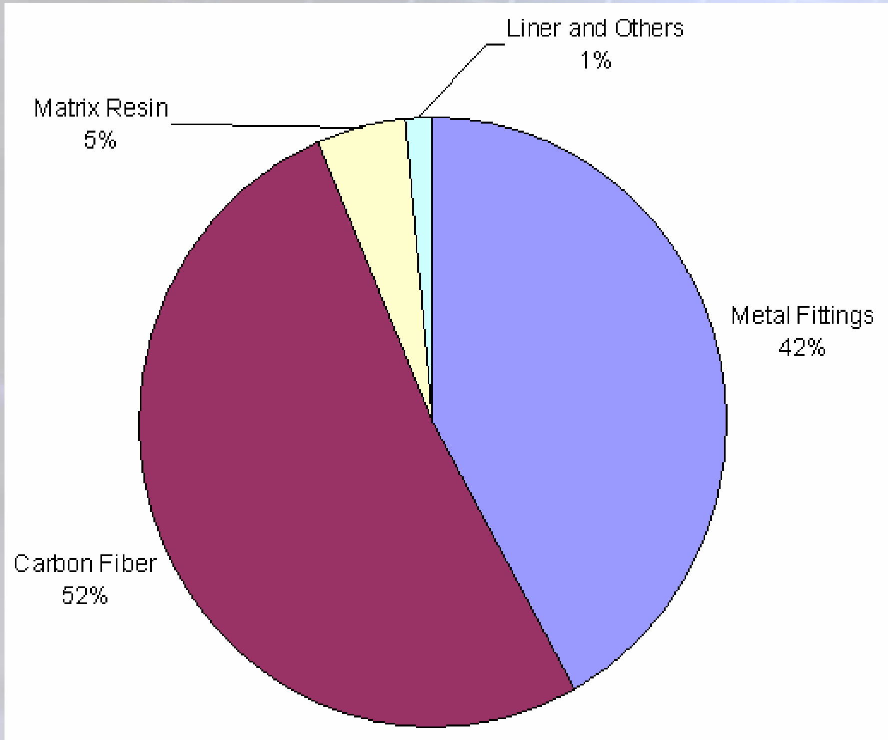
Accomplishments

Material Weight Distribution: 2008 Current 70 MPa Tank



Material Cost Distribution: 2008 Current 70 MPa Tank



Accomplishments

Tank Nominal Capacity: 129 Liter, 5 kg H_2

Raw Material Cost = Composite Usage (57%) + Liner (1%) + Metal Fittings (42%)

Tank Weight (118.0 kg) = Composite (90%) + Liner (7%) + Metal Fittings (3%)

Metal Fittings = Polar Boss + Adapter

Composite Usage = Carbon fiber + Matrix Resin

Efficiency:

0.048 kWh/$: Energy / Cost

1.42 kWh/kg: Energy / Mass

0.85 kWh/L: Energy / Volume

2007 DOE targets:

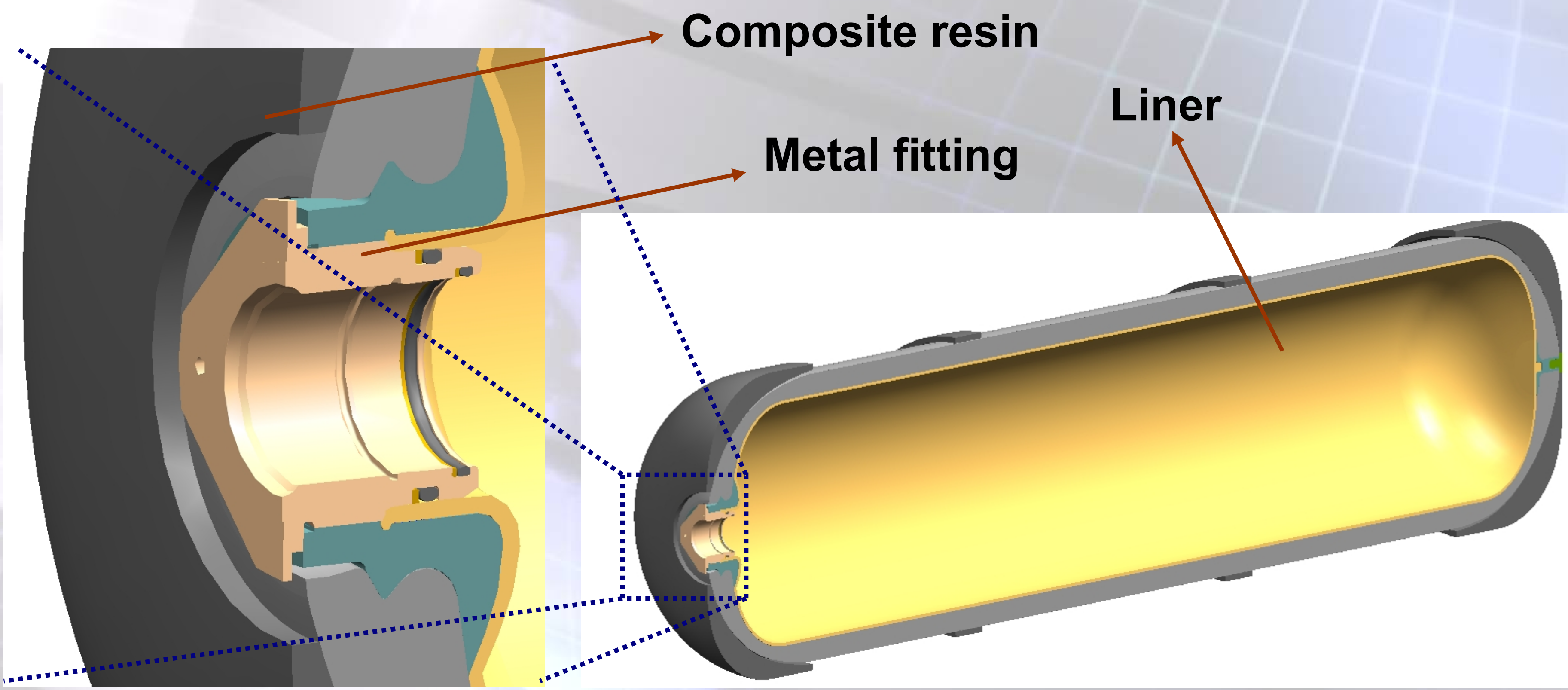
System energy cost= 0.167kWh/$

System gravimetric capacity= 1.5kWh/kg

System volumetric capacity= 1.2kWh/L

Data based on current manufacturing cost/mass/volume for a **single** tank. There are no components in addition to the one tank for this specific project.

Accomplishments



Close-up cross section of polar end of 129L tank

Cross section of 129L tank

Technical Accomplishments

Liner Development

- **Evaluated rotational molded plastics:**
  - Toughness
  - Tensile properties
  - Durability
  - Liner-Metal Interface Compatibility
  - -40 ºC to 85 ºC high pressure seal for hydrogen
  - Permeability
  - Process development
    - Moldability
    - Heat cycle
    - Post cure treatments

Technical Accomplishments

- **Composite optimization**
  - Investigated different fibers for translation efficiency
  - Changed from high-cost (Aerospace grade) to low-cost (Commercial grade) carbon fibers while keeping the translation efficiency unchanged throughout the design effort
  - Composite manufacturing process control & Improvement
  - Resin formulation and curing control to reduce residual stress
  - Validated to automotive OEM standards (15 year life)

Accomplishments

1st Generation (~2000)

T1000G Tow Preg = $100/lb

Translation ~ 65%

2nd Generation (~2003)

M30S Tow Preg = $35/lb

Translation ~ 65%

Cost reduction

3rd Generation (~2005)

T700S Wet wind = $15/lb

Translation ~ 65%

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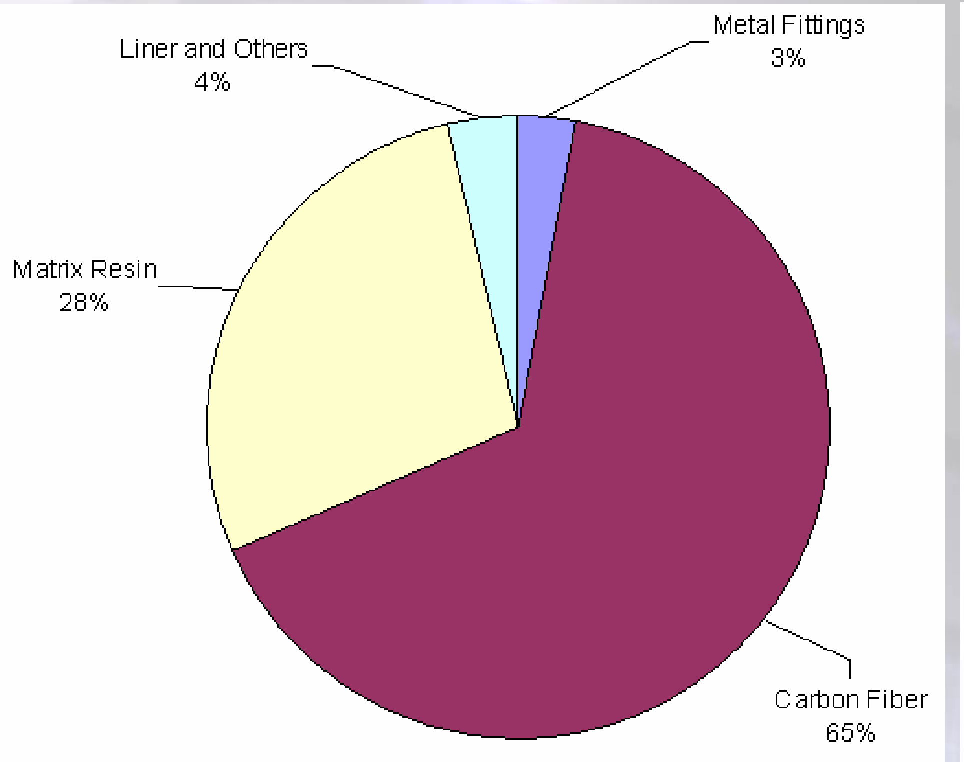
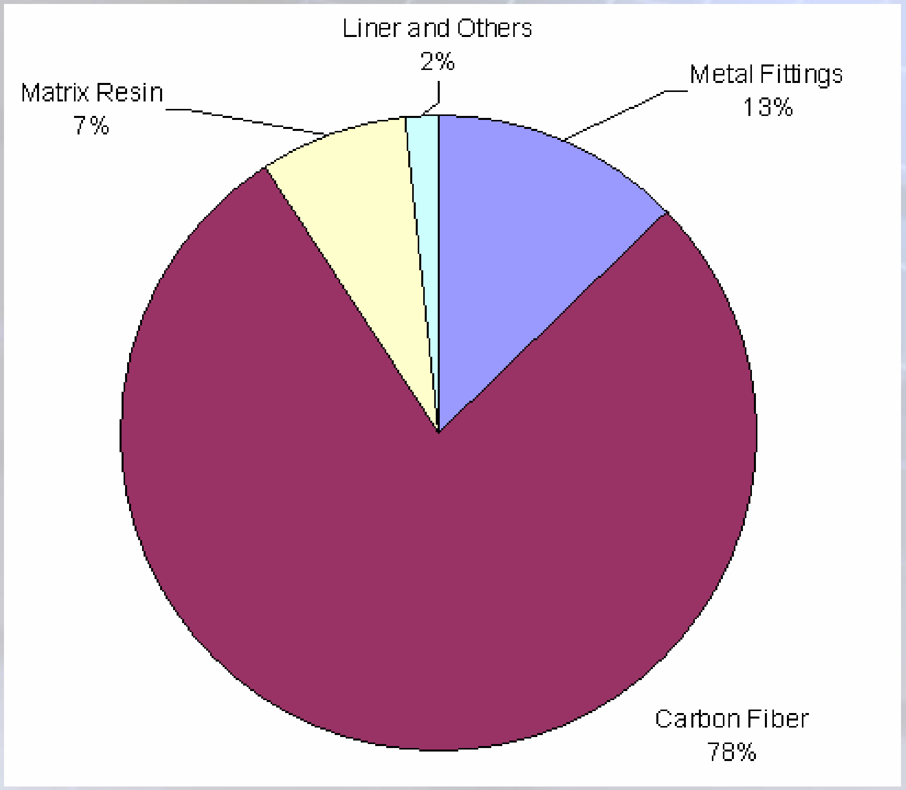
Pictures courtesy of GM

Future Work

Material Weight Distribution: 2010 Proposed 70 MPa Tank



Material Cost Distribution: 2010 Proposed 70 MPa Tank



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Future Work

Tank Nominal Capacity: 129 Liter, 5 kg H_2

Raw Material Cost (66% of current tank) = Composite Usage (85%) + Liner (2%) + Metal Fittings (13%)

Tank Weight (82.6 kg, 70% of current tank) = Composite Usage (93%) + Liner (4%) + Metal Fittings (3%)

Metal Fittings = Polar Boss Only

Composite Usage = Carbon fiber + Matrix resin

Efficiency:
0.10 kWh/$: Energy / Cost
2.09 kWh/kg: Energy / Mass
0.90 kWh/L: Energy / Volume

2010 DOE targets:
System energy cost= 0.25kWh/$
System gravimetric capacity= 2.0kWh/kg
System volumetric capacity= 1.5kWh/L

Data based on current manufacturing cost/mass/volume for a **single** tank. There are no components in addition to the one tank for this specific project.

Future Work

Why Liner Development:

Liner material is related to metal fittings development and carbon fiber optimization:

- Required for liner-boss interface Study after redesign to lower metal material cost and eliminate metal component usage

- Thin-wall liners allow reduction of composite usage

  Example: a 90% reduction in liner thickness results in 3.2% less composite usage for a 129 liter tank

Future Work

- Liner Development:
  - Reduce thickness by 90% which subsequently reduces composite usage

  Investigate polymer materials for:

    - Lower permeability and higher impact toughness
    - Larger tensile elongation at break
    - Better thermal-shock resistance
    - Longer fatigue life in tension
    - Better environmental durability

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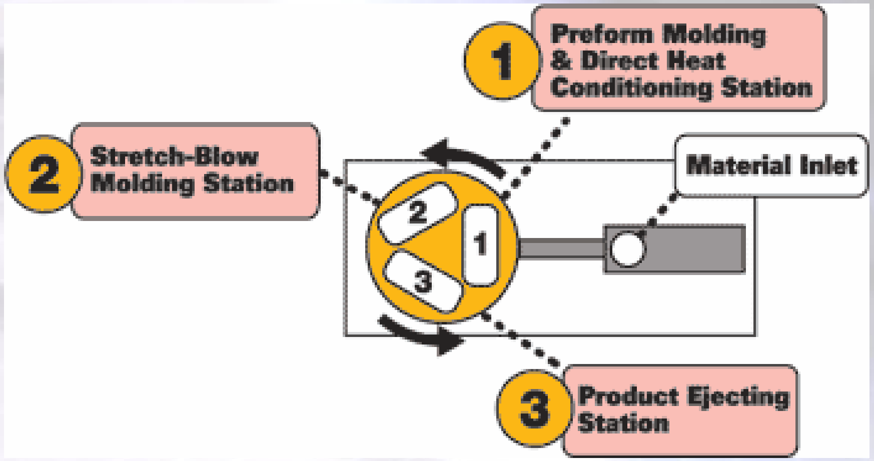
Future Work

- Liner Development:
  - Investigate liner-metal interface to reduce valve-interface size and eliminate metal adapter usage
  - Investigate injection molding or blow molding mass-production, which reduces cycle time and cost, and offers more precise liner quality control



Typical Stretch Blow Molding Process

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Future Work

- Metal Fitting Development:
  - Design and Investigate the liner-metal interface through FEA analysis. The goal is to remove the metal adapter and therefore save ~50% in both metal fitting material cost and weight.
  - Evaluate polar boss lower-cost hydrogen compatible metals to reduce an additional 30% material cost.

Target = 80% total metal fitting material cost saving; 50% weight savings

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Future Work

- Improvement of Composite Usage Translation Efficiency:
  - Translation Efficiency is a function of both manufacturing process and fiber lay-out
  - Evaluate the effect of manufacturing parameters on fiber translation efficiency and optimize them correspondingly
  - Further optimize fiber lay-out through design to improve fiber translation and reduce carbon/composite usage

Target= 25% reduction in composite usage

Project Summary

Relevance	Optimizaton of current manufacturing technologies for low cost hydrogen storage vessels
Approach	Liner and metal fittings material development Carbon fiber translation optimization
Proposed Work	Liner material development Metal fitting material and interface development Design of Experiment on carbon fiber tank manufacturing processes

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