3.4 Thermoplastic Composite Parts
Manufacturing Enabling High Volumes, Low Cost, Reduced Weight with Design Flexibility

Doug Anton¹,², Mike Bogdanor³, Robert Davies⁴, Jake Dickinson², Tim Harper², Tao Huang², Ryan Martin², Byron Pipes³, Penelope Salmons⁴, Jan Sawgle², Nathan Sharp³, Tian Tang³

¹ Technical Team Leader
² DuPont Performance Materials
³ Purdue University
⁴ Fibrtiec
Automotive Lightweighting

- Desire to lightweight driven by regulations (e.g., CAFE, EURO 6)

**Technologies to Help Meet 2025 CAFE Standards**

**Question:** Please identify all the technologies your company is focused on to help the industry meet 2025 standards.

- Lightweighting and use of lightweight structural materials
- Engine efficiency programs
- Transmission technologies, such as multi-speed, CVT, DCT
- Electrification of the vehicle: mild hybrid/start/stop
- Electrification of the vehicle: full hybrid/plug-in
- Adopting diesel engines for lightweight vehicles
- Fuel cell powered vehicles
- Downsizing vehicles
- Adopting bi-fuel programs

**Source:** 2016 WARD'S AUTO, DuPont Automotive Trends Benchmark Study, conducted by Penton Research
Rapid Fabric Formation (RFF)

- DuPont Patented Technology
  - Intended to remove process steps and waste in textile manufacturing

**Incumbent:**
- Yarn
- Weave
- Cut blanks
- Sew into clothing
  - Waste

**Proposed:**
- Yarn
- Rapid Fabric Formation (RFF)

- Applying RFF to composite manufacturing
- Addresses IACMI goals
  - Reduce cost ✓
  - Reduce energy ✓
  - Increase recyclability (thermoplastic resin) ✓
Fabric is formed with a laydown procedure not weaving
- Faster than weaving dry fiber
- Position and number of binding points can be controlled
- Crossover angles can be controlled
Fibrflex® from Fibrtec

- Flexible coated tows are **conformable** to tooling and automated processes
- Process is an order of magnitude faster than spread-tow processes for making UD tapes
- Exterior filaments fully coated to make fabric formation easier
- No fibrillation issues
- Low cost process
- Results in homogeneous, **well consolidated composites**!

US7,790,284 B2 (R. M. Davies, Fibrtec)
Crossover Angle

0/90

60/120
Fibrflex® flexibility facilitates manufacturing
• Easier to pack in molds ✓Reduced cost
• Eliminates fibrillation ✓Reduced cost

Selective bonding expected to allow for control of draping and fiber alignment
• Purdue is performing draping and mechanical testing modeling

Near net shape preforms
• ✓Reduced cost ✓Reduced waste ✓Reduced energy

Net Shape Preform Yield = ~65%
Purpose: Build a model of the estimated cost of different routes to producing thermoplastic composite automotive parts

Comparison of different routes from raw materials (carbon fiber and polyamide) to net shape preforms
Net Shape Preform Cost

- Net shape preforms
  - RFF allows for production of near net shape preforms

Yield to net shape preform:
- 70%
- 70%
- 95%

<table>
<thead>
<tr>
<th></th>
<th>12k CF Weave Film</th>
<th>12k FibrFlex® Weave</th>
<th>12k FibrFlex® RFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM (€/kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Carbon
- Resin (R1)
- Film
- Tow Coating
- Weaving
- Packaging/Shipping
- Rapid Fabric Formation
Increased Flexibility of the RFF

- RFF material exhibits a low resistance to shearing.
- Better surface conformation than traditional woven fabrics.
- Reduced wrinkle formation.

RFF Picture Frame Test conducted at the Indiana Manufacturing Institute

Comparison of RFF Shear Locking vs. Twill Weave
Modeling and Simulation of RFF

- Use simulation to leverage the advantages of the RFF material.
- Part performance is dictated by the manufacturing process.
- Forming simulation to anticipate wrinkling and obtain accurate fiber orientations.
- Local material mechanical properties are determined by the fiber orientation.
Modeling the Forming Process

- Fiber Modulus
- Picture Frame Test
- Fabric Bending
- Shearing Angle
- Fiber Orientation
- Consolidation
- Part thickness
Using Simulation to Speed up Development

- The RFF process offers a great deal of design flexibility in tow alignment and selective bond density.
- Simulation eliminates the need to examine all orientations.
- Use micromechanical model to replace picture frame test.
Part performance is driven by the manufacturing process.
Utilize the fiber orientations output from the forming simulation.
Micromechanics simulation to predict composite properties.
Path Forward

- Transitioning from Stage I to Stage II in March 2017
  - Expected to meet all Stage I Milestones
  - Models and mechanical property data being collected
- Working with Ford in Stage II on production car part
  - Forming process modeling critical to design parts
Conclusion

- TEA indicates RFF fabrics are a cost effective route to produce TPC parts
- RFF fabrics from Fibrflex® bring unique control of fiber orientation and draping
- Modeling and simulation critical to successful Stage II