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

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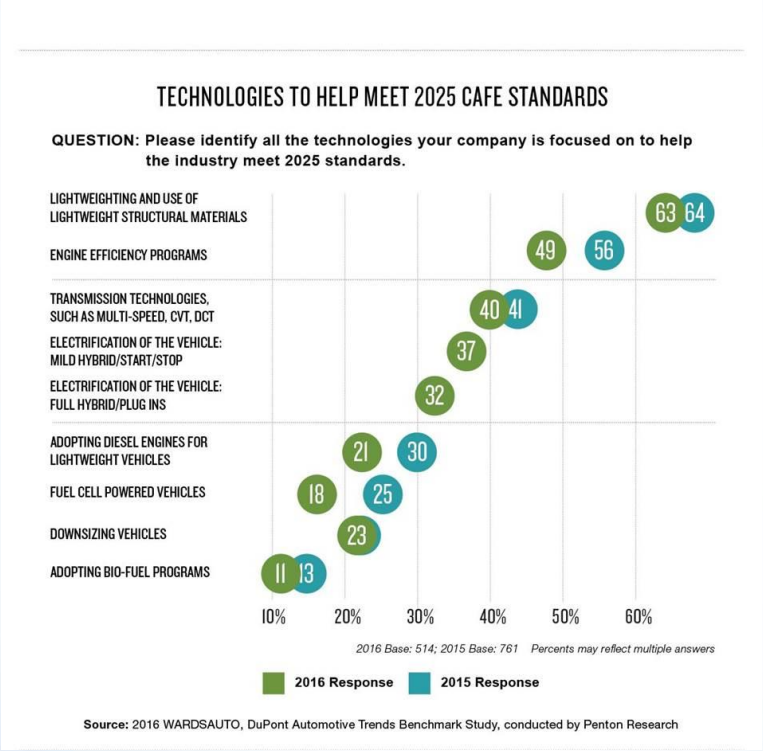
[4] Fibrtec

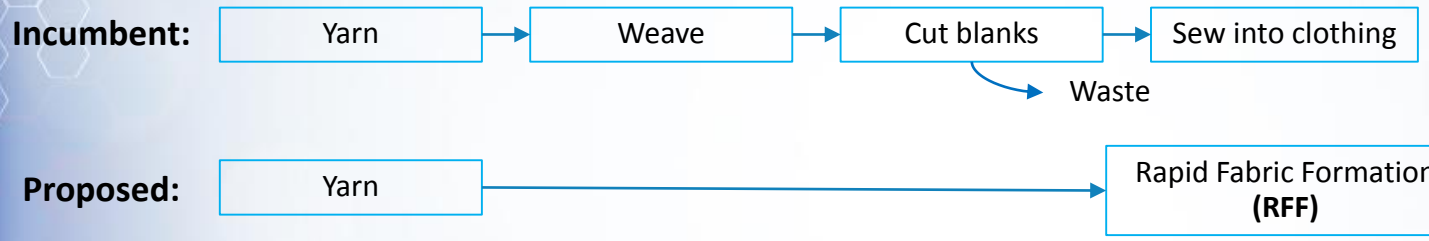
Automotive Lightweighting

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



Rapid Fabric Formation (RFF)

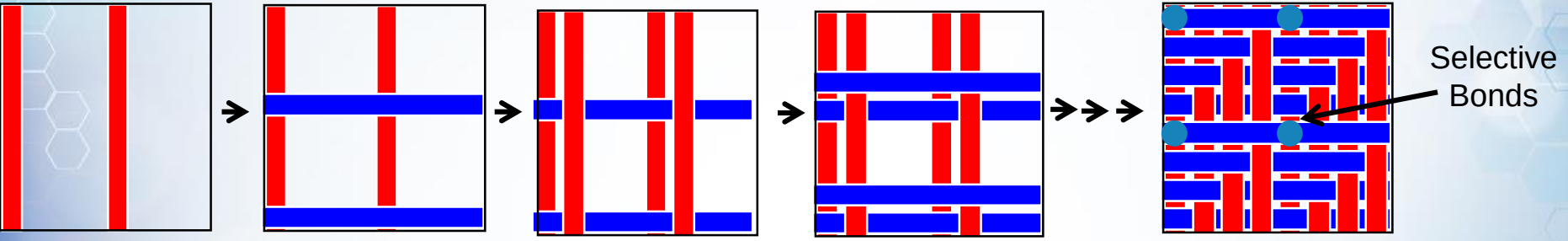
- DuPont Patented Technology
  - Intended to remove process steps and waste in textile manufacturing



- Applying **RFF** to composite manufacturing
- Addresses IACMI goals
  - Reduce cost ✓
  - Reduce energy ✓
  - Increase recyclability (thermoplastic resin) ✓

RFF Fabric Production

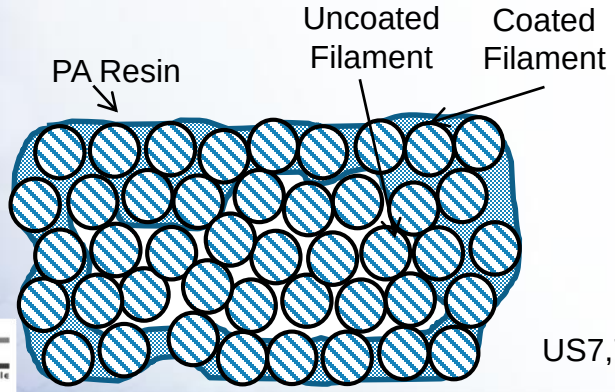
US 6,579,815 + others; DuPont



- 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

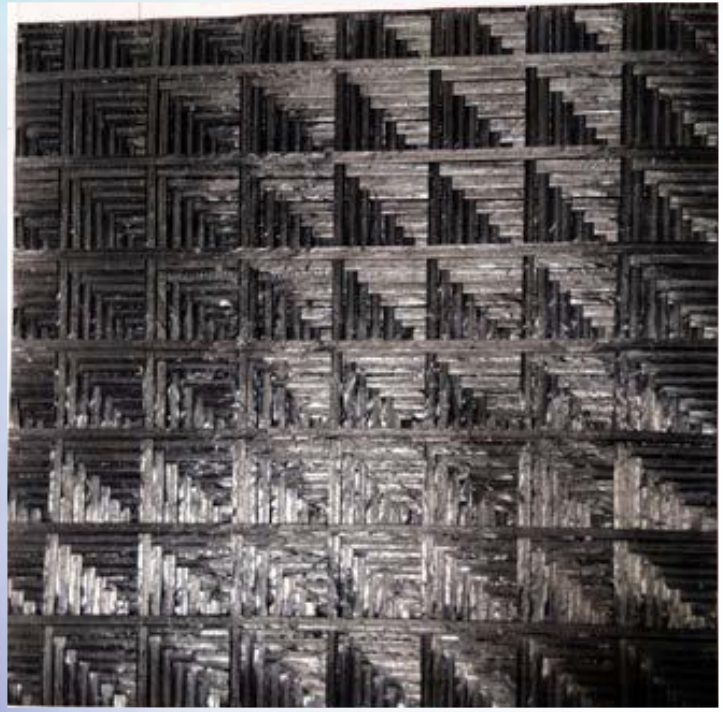
Coated Tow

- 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

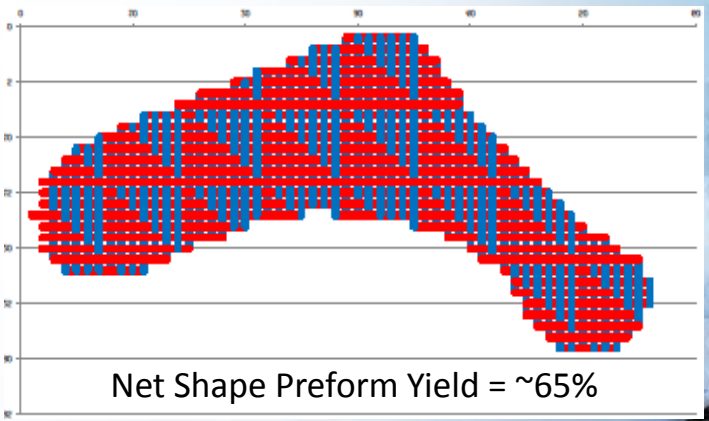


0/90

60/120

RFF Fabric Value

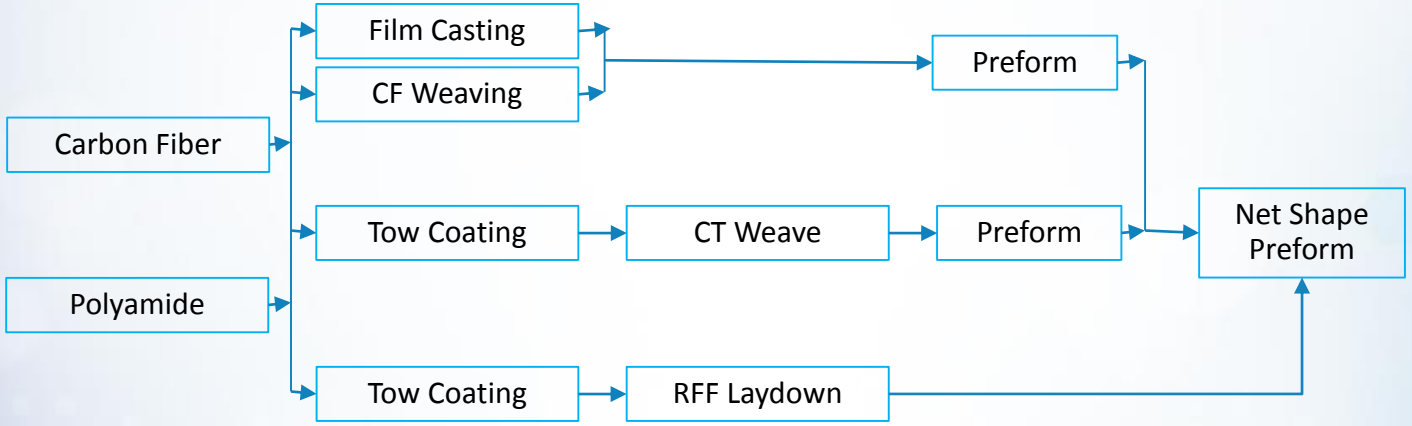
- Fibrflex® flexibility facilitates manufacturing
  - Easier to pack in molds ✓Reduced cost
  - Eliminates fibrillation ✓Reduced cost
- Selective bonding expected to allow for control of draping and fiber alignment
  - Purdue is performing draping and mechanical testing modeling
- Near net shape preforms
  - ✓Reduced cost ✓Reduced waste ✓Reduced energy



Net Shape Preform Yield = ~65%

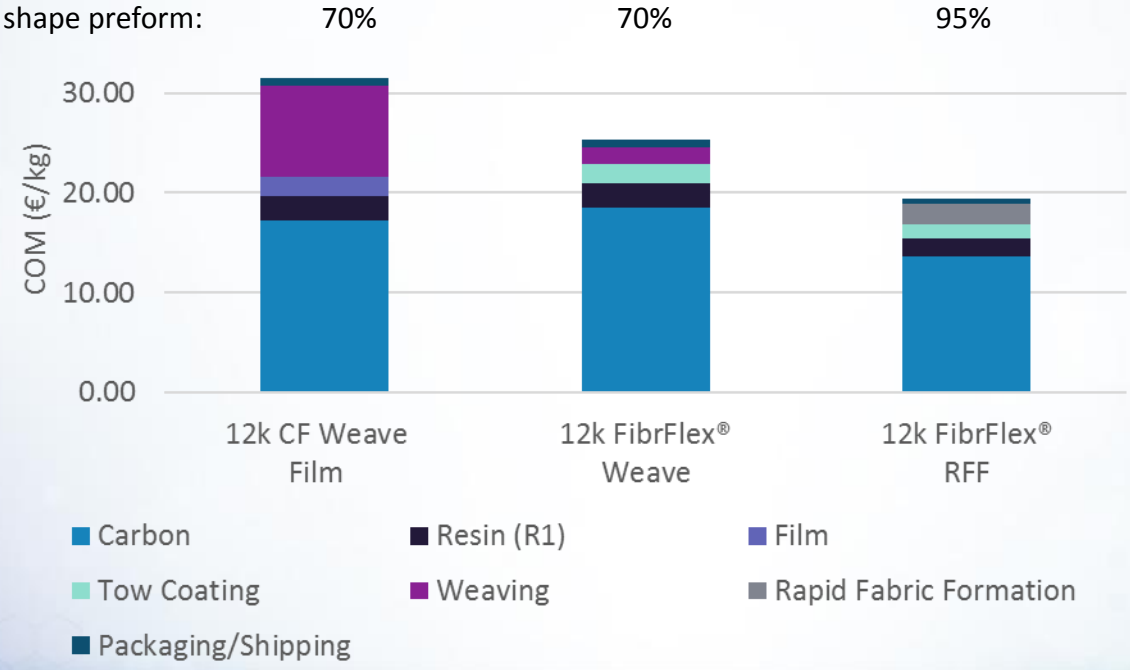
Techno-Economic Analysis

- 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



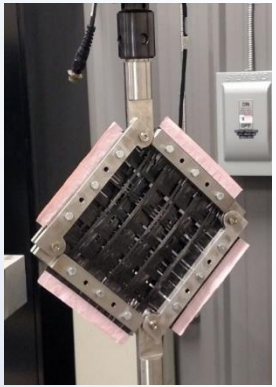
Net Shape Preform Cost

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

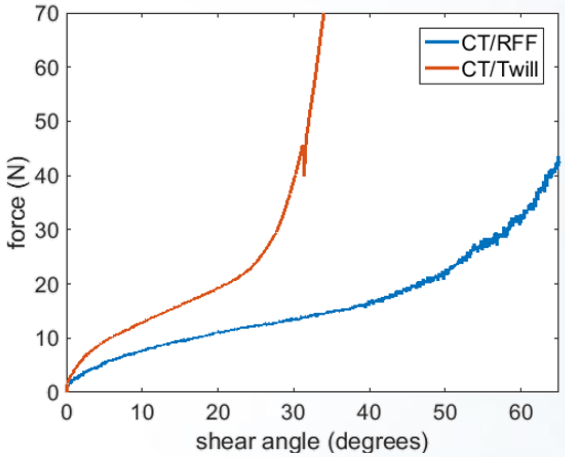


Increased Flexibility of the RFF

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



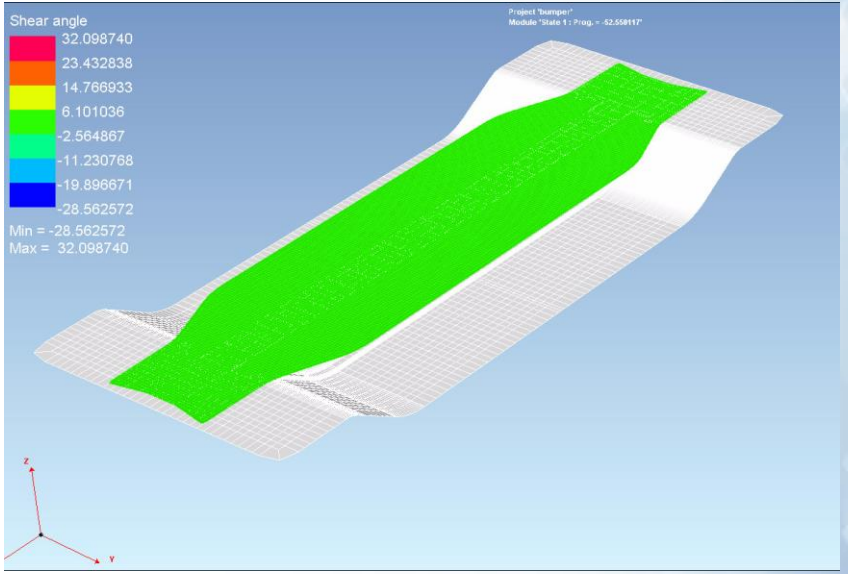
RFF Picture Frame Test conducted at the Indiana Manufacturing Institute



Comparison of RFF Shear Locking vs. Twill Weave

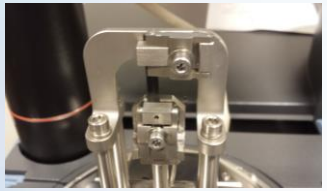
Modeling and Simulation of RFF

- 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.

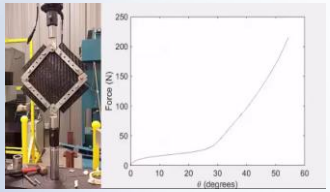


Modeling the Forming Process

Fiber Modulus

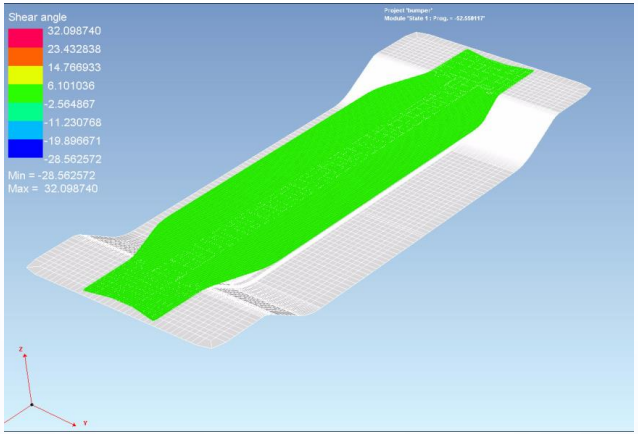


Picture Frame Test



Fabric Bending

Composites PAM-FORM 2G



Shearing Angle

Fiber Orientation

Consolidation

Part thickness

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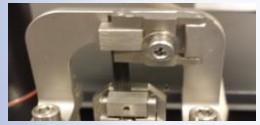
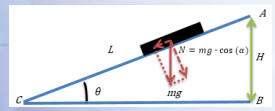
Using Simulation to Speed up Development

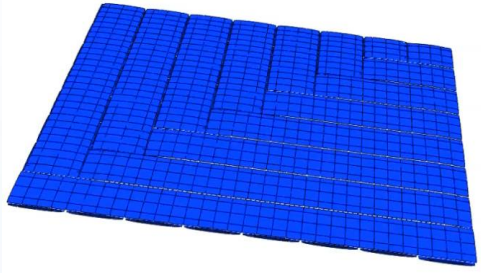
- The RFF process offers a great deal of design flexibility in tow alignment and selective bond density.
- Simulation eliminates the need to examine all orientations.
- Use micromechanical model to replace picture frame test.

Tow Modulus



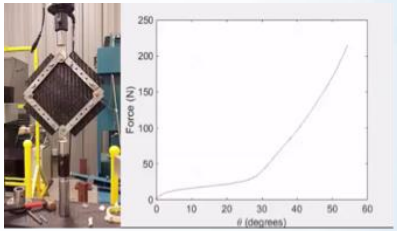
Tow Friction





Unconsolidated RFF Unit Cell Model

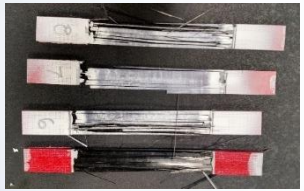
Picture Frame Test



Using Simulation to Predict Performance

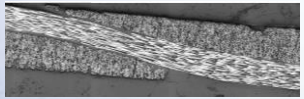
- Part performance is driven by the manufacturing process.
- Utilize the fiber orientations output from the forming simulation.
- Micromechanics simulation to predict composite properties.

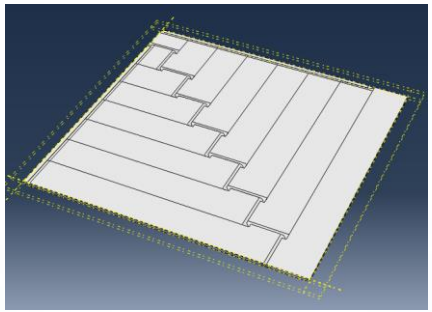
Consolidated Tow Properties



Fiber Orientation

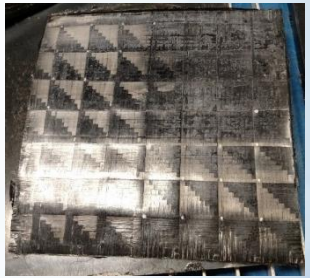
Microscopy





Consolidated RFF Unit Cell Model

Consolidated Composite Properties



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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

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FIBRTEC composite materials made simple for advanced applications

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

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