Novel Approach to Thermoplastic
Composite Production Enables
Localized Design Optimization

Presented By: Chris Oberste, Ph.D.
Founder and CEO
WEAV3D
WEAV3D Inc. is an innovator in thermoplastic composite materials and manufacturing processes.

- Patent-pending technology produces low-density, continuous-fiber-reinforced lattice structures
- Continuous manufacturing process reduces cost and enables high-volume production
- Ideal approach for optimizing structural plastics design for automotive, aerospace, construction and other uses
• Focused on the effects of fiber length and fiber volume fraction on the tensile modulus, tensile strength and impact resistance of these materials
• Key findings include:
  ○ The critical fiber lengths for tensile strength, tensile modulus and impact resistance differ significantly
  ○ Fiber volume fraction is linearly correlated to stiffness
  ○ Fiber volume fraction is quadratically correlated to strength and toughness

J.L. Thomason has published extensively on the topic of short and long glass-fiber-reinforced polypropylene and polyamide plastics.
Effect of fiber length on mechanical properties, normalized against continuous-fiber properties. Original figure modified to label short and long-fiber length scales. (Thomason, 2002)
Plot of Young’s modulus vs. fiber volume fraction. Values for flexural (triangle) and tensile (circle) modulus are offset to show deviation. (Thomason, 2005)
A plot of tensile strength (light blue) and flexural strength (dark blue) vs. fiber weight fraction. (Thomason, 2005)
A plot of Charpy (light blue) and Izod (dark blue) impact resistance vs. fiber weight fraction. Charpy and Izod data is offset to more clearly show the data. (Thomason, 2005)
Modulus - Load transfer and distribution between fiber and matrix

• Fiber alignment
• Fiber volume fraction
• Fiber modulus

Strength - Failure mode (fiber, matrix, interface)

• Critical length
• Interfacial adhesion
• Fiber distribution/wetting

Toughness - Fracture mechanics (propagation, deflection, arrest)

• Reinforcement-induced stress concentrations
• Fiber volume fraction driven ductile-brittle transition
• Crack deflection length
(Left) Stress-strain curve for reinforcement fiber and plastic matrix. (Right) Relationship between fiber volume fraction (Vf) and strength of CFRP, developed from figure on the left.
Weav3D Process Overview

Rebar for Plastics™

Composite Lattice

Injection/Compression Molding or Thermoforming

Lightweight Structural Composite Part
Rebar for Plastics™

• Combination of:
  ○ Continuous fiber-reinforced tapes
  ○ Overmolded fiber-reinforced thermoplastic

• Independent tuning of:
  ○ Stiffness
  ○ Strength
  ○ Toughness

• Localized performance and cost optimization
CASE STUDY — POLYPROPYLENE PALLETON 1
Finite element analysis of 14,000 lb load over top surface of long fiber-reinforced polypropylene pallet
Baseline case using generic model, adjusted for realistic wall thickness and internal structure

- Long Glass PP (Vf = 16%)
- 4.9 GPa isotropic modulus
- Maximum deflection of 40.64 mm
- Yield stress exceeded
- Mass = 16.9 kg
CASE STUDY

SHEET REINFORCEMENT
Simulate pallet under same load with organo sheet reinforcement laid evenly across top surface of pallet

- Glass/PP organo sheet (Vf = 47%)
- 20 GPa in-plane modulus (X-Y)
- Maximum deformation: 26.16 mm
  - 2-layer sheet
- Mass = 2 kg organo sheet + 15.5 kg plastic
CASE STUDY — LATTICE REINFORCEMENT

LATTICE REINFORCEMENT
Optimized design with lattice reinforcement

- Glass/PP UD Tape Lattice (Vf = 45%)
- Unidirectional tape modulus: 37 GPa
- Maximum deformation: 10.06 mm
  - 2-layer lattice configuration
- Mass = 0.73 kg lattice + 16.37 kg plastic
## Results Comparison

<table>
<thead>
<tr>
<th></th>
<th>Long Glass Reinforced</th>
<th>Long Glass plus Organo Sheet</th>
<th>Long Glass plus Lattice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Deformation</td>
<td>40.64 mm</td>
<td>26.16 mm</td>
<td>10.06 mm</td>
</tr>
<tr>
<td>Deformation Change</td>
<td>-</td>
<td>-35.6%</td>
<td>-75.2%</td>
</tr>
<tr>
<td>Total Pallet Mass</td>
<td>16.9 kg</td>
<td>17.5 kg</td>
<td>17.1 kg</td>
</tr>
<tr>
<td>Mass Change</td>
<td>-</td>
<td>+3.6%</td>
<td>+1.2%</td>
</tr>
<tr>
<td>Total Material Cost</td>
<td>$35.49</td>
<td>$62.93</td>
<td>$42.37</td>
</tr>
<tr>
<td>Cost Change</td>
<td>-</td>
<td>+43.6%</td>
<td>+19.4%</td>
</tr>
</tbody>
</table>

Substantial stiffening can be achieved with controlled mass and cost change, further optimization could reduce cost and/or mass by tuning max deformation.
A true Rebar for Plastics™ solution

- For non-aerospace applications, traditional composite laminates are overkill and not justifiable for the cost
- Laminate back-injection is a step in the right direction, but:
  - Relies on laminate for all mechanical properties, only using molded plastic to adjust section properties
  - Conventional laminates are expensive and unsuitable to high-volume mass production
- WEAV3D process enables low cost, high volume production of optimized lattices
  - Molded plastic remains the dominant material in the part
  - Use of continuous material is optimized to meet performance properties while minimizing cost and weight
Contact

WEAV3D Inc. is seeking partners interested in developing new product offerings for the automotive market using WEAV3D lattice preforms. For more information about partnering opportunities, please contact me at chris.oberste@weav3d.com.

www.WEAV3D.com