Novel Approach to Thermoplastic Composite Production Enables Localized Design Optimization

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WEAV3D
WEAV3D Inc. develops revolutionary fiber-reinforced plastic manufacturing processes and processing equipment.

- 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
J.L. Thomason has published extensively on the topic of short and long glass-fiber-reinforced polypropylene and polyamide plastics.

- 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
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 ($V_f$) 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
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
- Mass = 16.9 kg
CASE STUDY — SHEET REINFORCEMENT

CASE STUDY

SHEET REINFORCEMENT
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
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>
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<tr>
<td>Total Pallet Mass</td>
<td>16.9 kg</td>
<td>17.5 kg</td>
<td>17.1 kg</td>
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<tr>
<td>Mass Change</td>
<td>-</td>
<td>+3.6%</td>
<td>+1.2%</td>
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<tr>
<td>Total Material Cost</td>
<td>$35.49</td>
<td>$62.93</td>
<td>$42.37</td>
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<tr>
<td>Cost Change</td>
<td>-</td>
<td>+43.6%</td>
<td>+19.4%</td>
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Substantial stiffening can be achieved with controlled mass and cost change, further optimization could reduce cost or mass by tuning max deformation.
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.

A true Rebar for Plastics™ solution.
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