ADDITIVE MANUFACTURING OF INNOVATIVE NEAR NET SHAPE CONTINUOUS FIBER THERMOPLASTIC COMPOSITE PREFORMS

John Ilkka, New Business Development Manager
Automotive Composites USA | Coats

Dr. Haibin Ning, Assistant Professor
Materials Processing and Application Development Center
University of Alabama at Birmingham
OVERVIEW

1. Thermoplastic composite program jointly carried out by:
   • Coats North America
   • University of Alabama at Birmingham (UAB)

2. Introducing Coats’ Synergex™ and Lattice™ Technology

3. Design Studies – Leaf Spring and Front end module

4. Results of testing comparing panels molded using Synergex™/Lattice™ Preforms and Thermoplastic composites in UD Tapes and Organosheet.

5. Conclusion: Near net shape thermoplastic preforms with similar mechanical properties and greater flexibility in fiber orientation as compared to alternative thermoplastic composite product formats.
1. **RAW MATERIAL TOW**

2. **FABRIC WITH PRESET LAYER ORIENTATION**

3. **THERMOPLASTIC PREPREG PROCESS**

4. **PATTERN CUTOUTS**

5. **PREFORM VIA STACKING OF PLYES/LAYERS BY MANUAL OR ROBOTIC PROCESS**
SYNERGEX™/LATTICE™

1. RAW MATERIAL TOW & THERMOPLASTIC FIBER

2. COMINGLING PROCESS
   - OPTIMIZED DESIGN FOR FIBER ORIENTATION AND LAYER COMPOSITION

3. AUTOMATED ADDITIVE MANUFACTURING
   - REDUCED WASTE
   - REDUCED LABOR
   - REDUCED COST

3D CAD - Part

2D Lattice™ CAD
COMMINGLED FIBERS - SYNERGEX™

- Commingled fibers
- Typically 2 fibers commingled in one final product
- Fiber content adjusted based on denier of input raw material
- Compression Molding
  - Made with thermoplastic fibers
- Overmolding
  - Overmold composite form with reinforced injection molding compounds
Synergex™ Commingling Technology

- SEM – Scanning Electron Microscopy scan of tested sample
- Shows excellent fiber wetting
- Superior wet-out of the fiber is what gives higher mechanical properties
TECHNOLOGIES FOR AUTOMOTIVE LIGHT WEIGHTING

Reinforcing Fiber(s)
- Carbon
- Glass
- Aramid

Matrix Fiber(s)
- Nylon 6
- Polypropylene
- PPS

Synergex™ Commingling process

Lattice™ Preform Process

Lattice™ Pre-consolidated (*)

Molding TP Compression

Molding TP Over Molding

Coats provides commingled fiber; converts CAD data to fiber path data & provides near net shape Lattice preforms to molders.

(*) Some customers utilized Lattice Preforms without Pre-consolidation
### COMINGLED FIBERS - SYNERGEX™

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>Reinforcing</th>
<th>Thermoplastic</th>
<th>% Fiber Volume Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nylon 6</td>
<td>62%</td>
<td>55%</td>
</tr>
<tr>
<td></td>
<td>Polypropylene</td>
<td>65%</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>PEEK</td>
<td>56%</td>
<td>45%</td>
</tr>
<tr>
<td></td>
<td>PPS</td>
<td>57%</td>
<td>52%</td>
</tr>
<tr>
<td>Carbon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nylon 6</td>
<td>63%</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>Polypropylene</td>
<td>63%</td>
<td>54%</td>
</tr>
<tr>
<td></td>
<td>PEEK</td>
<td>61%</td>
<td>56%</td>
</tr>
<tr>
<td></td>
<td>PPS</td>
<td>60%</td>
<td>54%</td>
</tr>
<tr>
<td>Aramid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nylon 6</td>
<td>61%</td>
<td>54%</td>
</tr>
<tr>
<td></td>
<td>Polypropylene</td>
<td>57%</td>
<td>54%</td>
</tr>
<tr>
<td>Basalt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nylon 6</td>
<td>59%</td>
<td>49%</td>
</tr>
<tr>
<td></td>
<td>Polypropylene</td>
<td>53%</td>
<td></td>
</tr>
</tbody>
</table>

- Table shows the spectrum of Synergex Commingled Fibers that have been made in Sevier, NC and Bursa, Turkey for various applications.
- Not shown in the database is the commingled Carbon-Glass Fibers that have also been prepared for RTM evaluations.
DESIGN STUDIES
### CF LATTICE™ VS CONVENTIONAL TECHNOLOGY

<table>
<thead>
<tr>
<th></th>
<th>Conventional Technology</th>
<th>Coats Technology</th>
<th>CF-Lattice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aluminum</td>
<td>Magnesium</td>
<td>Steel</td>
</tr>
<tr>
<td>Tensile Strength, MPa</td>
<td>137</td>
<td>130</td>
<td>215</td>
</tr>
<tr>
<td>Tensile Modulus, GPa</td>
<td>69</td>
<td>40</td>
<td>210</td>
</tr>
<tr>
<td>SPG</td>
<td>2.7</td>
<td>1.74</td>
<td>7.8</td>
</tr>
<tr>
<td>Weight Reduction vs. Aluminum</td>
<td>0.0%</td>
<td>22.7%</td>
<td>-99.4%</td>
</tr>
</tbody>
</table>

- Generic design assuming modulus driven thickness/weight.
- Typically SMC uses a 35% safety factor on properties.
- Thickness values on all materials assume a 0% safety factor.
- CF Lattice™ provides the greatest weight reduction material option.
THERMO-PLASTIC LEAF SPRING

Tapered leaf spring
Glass/Polypropylene
Thickness from .55” to 1.2”
Molded using 10 Lattice Preforms
GOR APPLICATION REDESIGNED WITH SYNERGEX™

Typical Vehicle GOR

<table>
<thead>
<tr>
<th>Material</th>
<th>Part Weight (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium</td>
<td>2.7</td>
</tr>
<tr>
<td>CF Composite / CF PP</td>
<td>2.05</td>
</tr>
<tr>
<td>FG Composite / LGPP</td>
<td>2.57</td>
</tr>
</tbody>
</table>

CAE Design Weights of GOR Based on Bending and Torsional Load Cases
COATS SYNERGEX™/LATTICE™

**Process:**
- Additive Manufacturing
- Automated via Machine Programming
- Flexible Fiber/Thermoplastic Combinations via Comingling
- Optimized solutions for custom fiber orientations and layering

**Benefits:**
- Reduced material waste
- Increased laminate lay-up quality and repeatability
- Consistent fiber fractions based on denier of inputs
- Reduced cost & weight of final part
**COATS SYNERGEX™/LATTICE™**

**PP-Fiberglass Flexural Properties**

- Unidirectional and Organosheet for Lattice and Commercial products for PP/Fiberglass Laminates
- Test Method: ISO 14125
- Data indicates that the Synergex™ /Lattice™ has properties similar to UD Tape and Organosheet
• Unidirectional PA6/CF Laminates for both Lattice and Commercial products
• Test Method: ASTM D3039M
• Data indicates that the Synergex™/Lattice™ has properties similar to UD Tape
PA6-Carbon Fiber Flexural Properties

- Lattice (0/90/90/0) and Organosheet (2x2 Twill): PA6/CF Laminates
- Test Method: ISO 14125
- Data indicates that the Synergex™/Lattice™ has properties similar to Organosheet
CONCLUSIONS

• The PP/FG and PP/CF Synergex™/Lattice™ design study showed comparable mass for GORs versus magnesium.
• Synergex™/Lattice™ PP/FG composite had comparable flexural strength and modulus compared with the PP/FG organosheet and UD tape.
• Synergex™/Lattice™ PA6/FG composite had comparable tensile strength and modulus compared with the PA6/FG UD tape.
• Synergex™/Lattice™ PA6/CF composite had comparable flexural strength and modulus compared with the PA6/CF organosheet composite.
• Lattice™ inherently has
  • Better fiber utilization (no wastage) than textile based preforms
  • Process lends itself to faster preform preparation time
• Synergex™/Lattice™ near net shape preforms are a viable alternative for organosheet and UD tape thermoplastic composites.
QUESTIONS?

John Ilkka | New Business Development Manager – Automotive | Coats
John.ilkka@coats.com
248-797-9245

Dr. Haibin Ning | Assistant Professor, University of Alabama at Birmingham, Materials Processing and Applications Development Center
ning@uab.edu

THANK YOU