Alternative Thermoplastic Materials
<table>
<thead>
<tr>
<th>Standard Matrix Resins</th>
<th>Reinforcement Fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polypropylene (PP)</td>
<td>Carbon</td>
</tr>
<tr>
<td>Polyamide (N6)</td>
<td>E-Glass</td>
</tr>
<tr>
<td>Polyphenylene Sulfide (PPS)</td>
<td>S2-Glass</td>
</tr>
<tr>
<td>Polyetherimide (PEI)</td>
<td>Aramid</td>
</tr>
<tr>
<td>Polyetheretherketone (PEEK)</td>
<td>Hybrids</td>
</tr>
</tbody>
</table>

Other (PMMA, PET, PC, N11, N12, N6/6, TPI, etc.)
Product Forms

- Flexible Towpreg
- Woven Fabric
- Braided Sleeving
- Unidirectional Tape
- Chopped Compression Molding Compound
- Molded Plates
- Thermoformable Laminates
Product Focus

*TowFlex Continuous Fiber Reinforced Thermoplastic Materials (CFRTP) fill a cost and performance gap between long-fiber reinforced thermoplastics and thermoset advanced composites*
Mechanical Properties

Flexural Strength (KSI)

- N6
- PP

Unfilled Resin
- 30% SF EG
- TF EG Fabric
- TF EG UD
- TF C Fabric
- TF C UD
- Aluminum
- Steel
Mechanical Properties

Flexural Modulus (MSI)

- N6
- PP
Mechanical Properties

Notched Izod (ft-lb/in)

- Unfilled Resin
- 30% SF EG
- TF EG Fabric
- TFC Fabric

Comparison between N6 and PP materials.
Mechanical Properties

Heat Deflection Temperature (F)

- Unfilled Resin
- 30% SF EG
- TF EG Fabric

- N6
- PP
BMW M3 Bumper System

Advanced Composite Bumper-Beams
BMW M3 - Sportscoupe

Front-Bumper-Beam

Rear Bumper-Beam

HEXCEL Composites
Applied Fiber Systems
BMW M3 Bumper System

- Selected E-glass/Nylon 6 vs. E-glass/PP due to:
  - Higher service temperature (>100F increase)
  - Improved flexural/tensile/compressive strength properties (>25% increase)

- Processing:
  - Continuous sheet produced from TowFlex® fabric
  - Bumper beams and crush column boxes matched-mold thermoformed from sheet
  - Crush column profiles continuously produced from TowFlex® fabric
  - Beams, crush columns, boxes assembled via HF welding
Value Points

• Performance
  – Crash Performance @ High Under-Hood Temperatures

• Reduction in Part Numbers
  – Sub-Assembled

• 60% Weight Savings (2.8 kg/6.2 lbs total)
  – Fuel Economy/Emissions/Weight Distribution

• Recyclable

• M3 Volume/Specialty Vehicle
  – Reduced Tooling Cost
Continuous Sheets and Profiles

• Produced by AC.S from TowFlex fabric

• Multiple fabric rolls for multi-layer sheets and profiles

  • Sheets used for beam and crash box thermoforming

  • Profiles used for crush columns
Matched–Mold Thermoforming

- Parts produced by Jacob Composites
- Beams and Crash Boxes formed from consolidated sheet
- Beams, crash boxes, and crush column profiles assembled via HF welding
Compression Molding

- Use unconsolidated fabrics/tapes (vs. preconsolidated sheets)
- Use flat preforms
- Matched molds form and consolidated preforms (no hand-layup)
- Heated and cooled molds or shuttle press
Compression Molding Concept

Figure 5.1: Three rotating mold-shuttle system
Co-molding Concepts

• Use TowFlex as a stiffening element combined with unreinforced or discontinuous reinforced TP resins

• Overmold using “conventional” TP molding processes
  ➢ Injection Molding
  ➢ Compression Molding
  ➢ Thermoforming
  ➢ Blow Molding
Co-molding Preliminary Data

N6 Overmolding: Tensile/Compressive Strength Comparison (KSI)

- Untilled Resin
- 100% Chopped
- 50% Chopped/Fabric
- 50% Chopped/UD
- [100% Fabric]
- [100% UD]

Tensile Strength (KSI)
Compression Strength (KSI)
Co-molding Preliminary Data

N6 Overmolding: Tensile/Compressive Modulus Comparison (MSI)
Injection Overmolding

**Step 1**: TowFlex IR heating

**Step 2**: forming in molding press

**Step 3**: Resin injection for overmolding

**Step 4**: demolding
Co-Forming

With GMT Sheet

With Unreinf. Sheet

HEXCEL Composites
Applied Fiber Systems
Joining Processes

Standard TP Joining Processes Evaluated

• Adhesive Bonding
• Vibration Welding
• Ultrasonic Welding
• Spin Welding
• Hot Plate Welding
Application Development Support

- Material recommendations and data
- Part and tooling design support
- Prototype parts development
- Materials and molded parts testing/analysis
- Production molding technology transfer and support
Summary

• Solutions in Fiber Reinforced Thermoplastics
  – Multiple Resin & Fiber Combinations
  – High Temperature
  – High Stiffness and/or Strength Requirement
  – Maintain/Reduce Design Weight
  – Utilize and Expand Existing Thermoplastic Processes