Light-Weighting with Engineered Thermoplastic Compounds Including Carbon Fiber Reinforced Polypropylene

Nolan Krause
Application Development Engineer
RTP Company
• **Compounder** = We blend thermoplastic resins with fillers, additives, and modifiers

• **Specialty** = We create compounds custom engineered to your meet specifications

• **Independent** = We are unbiased in our selection and use of raw materials
Compounding Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Raw Materials → Extruder → Cooling → Pelletizer → Classifier → Finished Product
Global R&D, Manufacturing, & Support

United States • Mexico • France • Germany • China • Singapore
Extensive Technology Portfolio To Solve Material Problems

- STRUCTURAL
- WEAR RESISTANT
- CONDUCTIVE
- THERMOPLASTIC ELASTOMERS
- FLAME RETARDANT
- COLOR
- SHEET/FILM
• Fuel economy and emissions regulations are driving mass reduction initiatives

• Reinforced plastics have a proven history of success in replacing traditional materials because of their excellent strength-to-weight performance

• RTP Company has the broad portfolio of products and support assistance needed for making material transitions
• Lightweighting technologies
  – Reinforced compounds
    • Glass fiber
    • Long glass fiber (VLF)
    • Carbon fiber
  – Hollow glass microspheres
  – Chemical foaming agents

• Design considerations
  – Resin selection
  – Fiber orientation effects
• Short glass fiber
  – Reinforcement theory
  – Resin selection

• VLF (Very Long Fiber)

• Carbon fiber
Short (Chopped) Glass Fiber and Reinforcement Theory
“As engineers who typically work with metal, we don't really know what plastics can do.”

– Quote from RTP Company customer
Property change determined by:

Aspect Ratio

Reinforcing
**Fibers (Glass)**

Aspect Ratio = 50-250

<table>
<thead>
<tr>
<th></th>
<th>PP</th>
<th>PP + 40% Glass Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>0.91</td>
<td>1.22</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>32 MPa</td>
<td>85 MPa</td>
</tr>
<tr>
<td>Notched Izod Impact</td>
<td>47 J/m</td>
<td>108 J/m</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>1.5 GPa</td>
<td>6.9 GPa</td>
</tr>
</tbody>
</table>
Fibers (Glass)  
Aspect Ratio = 50-250

<table>
<thead>
<tr>
<th></th>
<th>PA 6/6</th>
<th>PA 6/6 + 30% Glass Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>1.14</td>
<td>1.42</td>
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<tr>
<td>Tensile Strength</td>
<td>85 MPa</td>
<td>186 MPa</td>
</tr>
<tr>
<td>Notched Izod Impact</td>
<td>50 J/m</td>
<td>120 J/m</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>2.8 GPa</td>
<td>9.0 GPa</td>
</tr>
</tbody>
</table>
Bi-Directional Stress-Strain

Tensile Bar Test Data

Approximate Longitudinal Behavior

Approximate Transverse Behavior
Orientation Effects
Coring Thick Walls

Overall Flatness = 0.041"
On-Demand Recorded Webinars

**CAE SIMULATION TOOLS FOR INJECTION MOLDING**
Presented by Barb Matousek on May 15, 2012
Not all flow simulation analysis is the same. It’s important to understand what you’re getting and what it means. During this brief, yet detailed webinar Barb Matousek, CAE Analyst with custom compounder RTP Company, discusses the benefits and limitations of various analysis tools.

[View Recorded Webinar](http://www.rtpcompany.com/webinars)

**DESIGN PRINCIPLES FOR STRUCTURAL COMPOSITES**
Presented by Bob Sherman on May 17, 2012
Fibrous reinforcements are used to enhance the mechanical properties of thermoplastics, but they also change the nature of these materials from isotropic to anisotropic. This significantly affects the materials molding characteristics and understanding this behavior is critical to successfully integrating them into your design. This webinar is a must see for anyone who designs parts or builds injection molds for applications that use filled or reinforced thermoplastic composites.

[View Recorded Webinar](http://www.rtpcompany.com/webinars)
Short (Chopped) Glass Fiber and Resin Selection
The form and structure the molecules of a polymer take upon solidification

Amorphous

Semi-Crystalline
<table>
<thead>
<tr>
<th>Amorphous</th>
<th>Semi-Crystalline</th>
<th>Thermal Performance Increases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyetherimide (PEI)</td>
<td>Polyetheretherketone (PEEK)</td>
<td></td>
</tr>
<tr>
<td>Polyethersulfone (PES)</td>
<td>Polyphenylene Sulfide (PPS)</td>
<td></td>
</tr>
<tr>
<td>Polysulfone (PSU)</td>
<td>Polyphtalamide (PPA)</td>
<td></td>
</tr>
<tr>
<td>Amorphous Nylon</td>
<td>Polyamide (PA/Nylons)</td>
<td></td>
</tr>
<tr>
<td>Polycarbonate (PC)</td>
<td>Polyethylene Terephthalate (PET)</td>
<td></td>
</tr>
<tr>
<td>Acrylonitrile Butadiene Styrene (ABS)</td>
<td>Polybutylene Terephthalate (PBT)</td>
<td></td>
</tr>
<tr>
<td>Styrene Acrylonitrile (SAN)</td>
<td>Acetal (POM)</td>
<td></td>
</tr>
<tr>
<td>Polystyrene (PS)</td>
<td>Polylactic Acid (PLA)</td>
<td></td>
</tr>
<tr>
<td>High Impact Polystyrene (HIPS)</td>
<td>Polypropylene (PP)</td>
<td></td>
</tr>
<tr>
<td>Acrylic (PMMA)</td>
<td>Polyethylene (HDPE, LDPE, LLDPE)</td>
<td></td>
</tr>
</tbody>
</table>

Commodity  Engineered  High Performance
Comparison at Temperature

VLF 80107 CC Tensile Stress/Strain
(Molded Specimen Data)

- Stress - MPa
- Strain - mm/mm

Lines represent:
- Typical DAM, -40 C
- Typical DAM, 23 C
- Typical DAM, 65 C
- Typical DAM, 167 C
Comparison at Temperature

RTP 207 Tensile Stress/Strain
(Molded Specimen Data)

- **Typical DAM, -40 C**
- **Typical DAM, 23 C**
- **Typical DAM, 65 C**
- **Typical DAM, 121 C**

Stress - MPa

Strain - mm/mm
Comparison at Temperature

RTP 4007 Tensile Stress/Strain
(Molded Specimen Data)

- Typical DAM, -40 C
- Typical DAM, 23 C
- Typical DAM, 65 C
- Typical DAM, 176 C
Comparison at Temperature

VLF 80107 CC Tensile Stress/Strain
(Molded Specimen Data)

RTP 207 Tensile Stress/Strain
(Molded Specimen Data)

RTP 4007 Tensile Stress/Strain
(Molded Specimen Data)
<table>
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<tr>
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<th>Semi-Crystalline</th>
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</thead>
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<td>Polyethersulfone (PES)</td>
<td>Polyphenylene Sulfide (PPS)</td>
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<tr>
<td>Polysulfone (PSU)</td>
<td>Polynyphthalamide (PPA)</td>
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<td>Amorphous Nylon</td>
<td>Polyamide (PA/Nylons)</td>
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<td>Polyethylene (HDPE, LDPE, LLDPE)</td>
</tr>
</tbody>
</table>

### Commodity | Engineered | High Performance
---|-------------|-------------|

**Morphology vs. Cost**

**Amorphous**
- Polyetherimide (PEI)
- Polyethersulfone (PES)
- Polysulfone (PSU)
- Amorphous Nylon
- Polycarbonate (PC)
- Acrylonitrile Butadiene Styrene (ABS)
- Styrene Acrylonitrile (SAN)
- Polystyrene (PS)
- High Impact Polystyrene (HIPS)
- Acrylic (PMMA)

**Semi-Crystalline**
- Polyetheretherketone (PEEK)
- Polyphenylene Sulfide (PPS)
- Polylephthalamide (PPA)
- Polyamide (PA/Nylons)
- Polyethylene Terephthalate (PET)
- Polybutylene Terephthalate (PBT)
- Acetal (POM)
- Polylactic Acid (PLA)
- Polypropylene (PP)
- Polyethylene (HDPE, LDPE, LLDPE)

**Cost Increases**

- Commodity (<$1.50)
- Engineered ($1.50-$4.00)
- High Performance (>$4.00)
Resin Selection

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Tensile Strength (MPa)

- PP 40% VLF: 1.21 MPa
- PA66 40% GF: 1.46 MPa
- PPA 40% GF: 1.57 MPa
VLF (Very Long Fiber) Reinforced Thermoplastics
<table>
<thead>
<tr>
<th></th>
<th>Short Fiber Reinforced</th>
<th>Long Fiber</th>
<th>Impact Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tensile Strength</strong></td>
<td>90 MPa</td>
<td>120 MPa</td>
<td>155 °C</td>
</tr>
<tr>
<td><strong>Flexural Modulus</strong></td>
<td>6.90 GPa</td>
<td>8.25 GPa</td>
<td></td>
</tr>
<tr>
<td><strong>Notched Izod</strong></td>
<td>100 J/m</td>
<td>270 J/m</td>
<td></td>
</tr>
<tr>
<td><strong>HDT @ 1.8 MPa</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Polypropylene with 40% glass fiber**

- Increasing stiffness
- Increasing toughness

**Strength/Impact Advantage**

- Short fiber reinforced
- Long fiber
- Impact modified
PA 6/6 – 40 Glass Fiber%
PA 66 + 60% VLF
Seat Belt Tensioner Housings
Drop Impact Test

Increasing impact force

Short Fiber PA

VLF PA
### PA 6/6 vs. VLF PP

<table>
<thead>
<tr>
<th></th>
<th>30% Short Glass Polyamide 6/6</th>
<th>40% Long Glass PP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Dry as Molded)</td>
<td>(50% RH)</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>186 MPa</td>
<td>124 MPa</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>9.0 GPa</td>
<td>6.2 GPa</td>
</tr>
<tr>
<td>Izod Impact</td>
<td>120 J/m</td>
<td>135 J/m</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.38</td>
<td></td>
</tr>
<tr>
<td>HDT @ 1.8 MPa</td>
<td>250 °C</td>
<td></td>
</tr>
</tbody>
</table>
End User: Honda, GM, Toyota
Material: VLF Polypropylene

Benefits of choosing VLF PP vs. short glass PA

- Cost reduction
- Weight reduction
- Designed for the environment
  - more commonly recycled
## PBT vs. VLF PP

<table>
<thead>
<tr>
<th>Property</th>
<th>PBT + 30% SGF</th>
<th>PP + 40% LGF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>1.53</td>
<td>1.21</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>124 MPa</td>
<td>120 MPa</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>8.3 GPa</td>
<td>8.25 GPa</td>
</tr>
<tr>
<td>Notched Impact</td>
<td>96 J/m</td>
<td>270 J/m</td>
</tr>
<tr>
<td>HDT @ 1.8 MPa</td>
<td>213 °C</td>
<td>155 °C</td>
</tr>
<tr>
<td></td>
<td>PPA + 40% SGF</td>
<td>PA66 + 40% LGF</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.55</td>
<td>1.46</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>221 MPa</td>
<td>228 MPa</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>13.4 GPa</td>
<td>11.7 GPa</td>
</tr>
<tr>
<td>Notched Impact</td>
<td>107 J/m</td>
<td>320 J/m</td>
</tr>
<tr>
<td>HDT @ 1.8 MPa</td>
<td>279 ºC</td>
<td>254 ºC</td>
</tr>
</tbody>
</table>
• Reduce cost
• Reduce weight
• Design freedom
• Corrosion and chemical resistance
• Sound and vibration dampening
<table>
<thead>
<tr>
<th></th>
<th>Zamak 3</th>
<th>60% VLF PA 6/6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>6.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>282 MPa</td>
<td>275 MPa</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>85.5 GPa</td>
<td>19.3 GPa</td>
</tr>
</tbody>
</table>
VLF PA6/6 vs. ZAMAK 3

Tensile Strength (MPa) vs. Temperature (ºC)

- Zamak 3
- GF60 LONG, PA66
Carbon Fiber
<table>
<thead>
<tr>
<th>Fiber</th>
<th>E-Glass Fiber</th>
<th>Std. Modulus Carbon Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Diameter</td>
<td>10-17 µm</td>
<td>5-10 µm</td>
</tr>
<tr>
<td>Density</td>
<td>2.55 g/cm³</td>
<td>1.81 g/cm³</td>
</tr>
<tr>
<td>Est. Tensile Strength</td>
<td>3400 MPa</td>
<td>4100 MPa</td>
</tr>
<tr>
<td>Est. Tensile Modulus</td>
<td>73 GPa</td>
<td>240 GPa</td>
</tr>
</tbody>
</table>
### Fiber Comparison – PA 6/6

<table>
<thead>
<tr>
<th></th>
<th>PA 6/6 60% VLF (Long Fiber)</th>
<th>PA 6/6 35% Carbon Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Modulus</td>
<td>19.3 GPa</td>
<td>19.0 GPa</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>275 MPa</td>
<td>244 MPa</td>
</tr>
<tr>
<td>Tensile Elongation</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.71</td>
<td>1.29</td>
</tr>
</tbody>
</table>
### Fiber Comparison – PPS

<table>
<thead>
<tr>
<th></th>
<th>PPS 40% Glass</th>
<th>PPS 20% Carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Modulus</td>
<td>15.1 GPa</td>
<td>15.8 GPa</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>169 MPa</td>
<td>172 MPa</td>
</tr>
<tr>
<td>Tensile Elongation</td>
<td>1.5%</td>
<td>1%</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.68</td>
<td>1.40</td>
</tr>
<tr>
<td></td>
<td>PP 40% GF</td>
<td>PP 40% VLF</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------</td>
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</tr>
<tr>
<td>Specific Gravity</td>
<td>1.21</td>
<td>1.21</td>
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</table>
On-Demand Recorded Webinars

**INCREASING MECHANICAL PERFORMANCE OF PLASTICS**

Presented by Karl Hoppe on October 11, 2011

Modified and reinforced plastics provide increased mechanical performance and allow plastics to be used to solve the unique and challenging material requirements of today's leading product development efforts. See how structural compounds could be the key to your next successful application.

[View Recorded Webinar](http://www.rtpcompany.com/webinars)

**VERY LONG FIBER COMPOSITES**

Presented by Karl Hoppe on November 15, 2011

Does the idea of replacing metal parts with light-weight and easy to fabricate reinforced plastics seem appealing but you are not sure how to get started? The impressive performance benefits of "stiff and tough" very long fiber reinforced composites will be explained.

[View Recorded Webinar](http://www.rtpcompany.com/webinars)
• Lightweighting where properties are less demanding
Hollow Glass Spheres

Specific Gravity

- Unfilled PA 6/6: 1.14
- PA 6/6 w/ Glass Bubbles: 0.89
- High Impact PA 6/6 w/ Glass Bubbles: 0.85
- PA 6/6 w/ 40% mineral: 1.50
- PA 6/6 w/ 30% glass fiber: 1.36

RTP Co. - YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS
Hollow Glass Spheres

Tensile Strength (MPa)

- Unfilled PA 6/6
- PA 6/6 w/ Glass Bubbles
- High Impact PA 6/6 w/ Glass Bubbles
- PA 6/6 w/ 40% mineral
- PA 6/6 w/ 30% glass fiber
• Achieve up to 20% density reduction
• Added as masterbatch
• Loading levels of 2-5% for foaming
• Two types:
  – Exothermic
  – Endothermic
• “Exothermic” = generate heat during decomposition

• Release Nitrogen gas (N$_2$)

• Base color is somewhat yellow
• “Endothermic” = removes heat during decomposition

• Produces CO$_2$

• Mostly colorless
• Activation temperature

• Compatibility of masterbatch carrier

• Tweak based on other requirements:
  – Cell structure
  – Surface finish
  – Color
• Reinforced thermoplastics
  – Used in place of other materials for many years

• VLF (Long Fiber) thermoplastics
  – Wider range of applications with stiffness/toughness combination

• Carbon fiber
  – Best combination of weight reduction and properties, but at a premium

• Hollow glass spheres, chemical foaming agents
  – Reduced density where mechanical performance is less critical
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(248) 207-8224
dpahl@rtpcompany.com
RTP Company is your global compounder of custom engineered thermoplastics

- Color
- Conductive
- Flame Retardant
- Structural
- Wear Resistant

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- 60+ Resins
- Independent & Unbiased
- Local Support
- Worldwide Manufacturing

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