An Engineer’s Guide to Specifying the Right Thermoplastic

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11:10 a.m.
An Engineer’s Guide to Specifying the Right Thermoplastic

Jason Becker
Application Development Engineer

Define Compounding
Plastic Resin Selection Process
Application Case Studies
Compounding Performance
Engineered Thermoplastic Compounds

- Compounder → We blend thermoplastic resins with fillers, additives, and modifiers
- Specialty → We create engineered formulations
- Independent → We are unbiased in our selection of raw materials

Agenda

Compounding Process

- Raw Materials → Finished Product
- Blender → Extruder → Cooling → Pelletizer → Classifier
Compounding Objectives

- Mixing
  - Distributive
  - Dispersive

Compounding Extruders

- Single Screw
- Twin Screw
- Co-Kneader

Putting Compounding Into Perspective

- Conductive carbon black surface area = 130 m²/gram
- 34 grams carbon black = surface area of football field (4460m²)
- Dispensing a 20% carbon black compound is similar to evenly coating a football field with 136 grams of plastic!

Resin Selection

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Morphology Characteristics

<table>
<thead>
<tr>
<th>Morphology</th>
<th>Amorphous</th>
<th>Semi-Crystalline</th>
</tr>
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<tbody>
<tr>
<td>Low Shrinkage</td>
<td>✗</td>
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Morphology Of Thermoplastics

<table>
<thead>
<tr>
<th>Amorphous</th>
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<tbody>
<tr>
<td>Polyethersulfone</td>
<td>Polyetheretherketone (PEEK)</td>
</tr>
<tr>
<td>Polyphenylene Sulfide (PPS)</td>
<td></td>
</tr>
<tr>
<td>Polyamide (PA/Nylons)</td>
<td></td>
</tr>
<tr>
<td>Polytetrafluoroethylene (PTFE)</td>
<td></td>
</tr>
<tr>
<td>Polystyrene (PS)</td>
<td>Polyethylene Terephthalate (PET)</td>
</tr>
<tr>
<td>High Impact Polystyrene (HIPS)</td>
<td></td>
</tr>
<tr>
<td>Acrylic (PMMA)</td>
<td>Polypropylene (PP)</td>
</tr>
<tr>
<td>Polycarbonate (PC)</td>
<td>Polylactic Acid (PLA)</td>
</tr>
<tr>
<td>Amorphous Nylon</td>
<td>Polyethylene (HDP, LDPE, LLDPE)</td>
</tr>
<tr>
<td>Polysulfone (PSU)</td>
<td>Polypropylene (PP)</td>
</tr>
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Step 1 – Use Resin Morphology

Step 2 – Use Thermal & Cost Requirements

Step 3 – Fine Tune & Special Features

- Lens?
- Fuel Float?
- Lamp Housing?
- Tool Housing?
- Pulley?
- Precision Printer Chassis?
- Intake Manifold?
- Grease Fitting?
- Laptop Cover?
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**Morphology Vs Thermal/Cost**

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**Commodity (<$1.50) • Engineered ($1.50-$4.00) • High Performance (> $4.00)**

**Step 1 – Use Resin Morphology**

**Step 2 – Use Thermal & Cost Requirements**

**Step 3 – Fine Tune & Special Features**

**Engineered & Commodity Resins**

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**Commodity (<$1.50) • Engineered ($1.50-$4.00)**

**Plastic Selection Process**

**Step 1 – Use Resin Morphology**

**Step 2 – Use Thermal & Cost Requirements**

**Step 3 – Fine Tune & Special Features**

**Styrenic Features**

**Morphology Features** – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent (except HIPS & ABS), Poor Chemical & Abrasion

- **PS** → Good Transparency @ Low Cost, Brittle
- **HIPS** → Moderate Impact Resistance @ Low Cost
- **SAN** → Good Transparency, Slightly Better Chemical Resistance, Brittle, Low Cost
- **ABS** → Excellent Impact Resistance & Gloss, Slightly Better Chemical Resistance, Low-Moderate Cost
**Acryllic Features**

**Morphology Features** – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Chemical & Abrasion

PMMA → Optical Quality Transparency, Excellent UV Stability, Brittle, Low Cost

**Poly carbonate Features**

**Morphology Features** – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Chemical & Abrasion

PC → Optical Quality Transparency, High Impact Resistance, Moderate Cost

**Olefin Features**

**Morphology Features** – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections, Poor Dimensions

PP → Low Density, Better Thermal Resistance Than PE, Living Hinge Capable, Brittle @ Low Temperatures, Low Cost

HDPE → Good Low Temp Impact Performance (Tg = -77°C vs -9°C for PP), Low Cost

**Poly amide Features**

**Morphology Features** – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections (Except Amorphous Nylon), Poor Dimensions

Nylon 6 → Strong/Stiff (But Humidity Dependent), Good Surface Finish Even When Reinforced, Moderate Cost

Nylon 66 → Strong/Stiff (But Humidity Dependent), Higher Thermal Than 6, Moderate Cost

Nylon 6/12, → Less Sensitive to Humidity, High Cost
**Amorphous Nylon Features**

- **Morphology Features** – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Abrasion

  - **Amorphous Nylon** → Good Chemical Resistance for Amorphous Morphology, Moderate-High Cost

**Polyester Features**

- **Morphology Features** – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections, Poor Dimensions

  - **PET** → Difficult to Mold (Poor Nucleation & Hydrolysis), Good Electrical Resistance, Mod. Cost
  - **PBT** → Easy to Mold, Good Electrical Resistance, Properties & Dimensions Do Not Fluctuate With Humidity (Same For PET), Moderate Cost
  - **PLA** → “Green” Polymer, Poor Impact, Poor Heat Resistance, Difficult to Mold (Poor Nucleation & Hydrolysis), Low Cost

**Polyoxymethylene (Acetal) Features**

- **Morphology Features** – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections, Poor Dimensions

  - **Acetal** → Low Friction & Wear, Excellent Resiliency & Fatigue Endurance, Moderate Cost

**Putting It All Together**

- **Step 1** – Use Resin Morphology
- **Step 2** – Use Thermal & Cost Requirements
- **Step 3** – Fine Tune & Special Features

*Test Your Knowledge With Application Examples*
**CD Jewel Case**
- Transparent
- Flat & Dimensionally Stable
- Low Cost
- PS

**Gas Tank**
- Good Chemical Resistance
- Good Low Temperature Impact
- Low Cost
- HDPE

**Auto Tail Lamp Cover**
- Transparent Colors
- Dimensionally Stable
- Excellent UV
- Low Cost
- PMMA

**Plastic Glass Tumblers**
- Transparent
- Reasonable Thermal & Chemical Resistance (Dishwasher Cycles)
- Low Cost
- SAN
### Case Study
- **Sump Pump Housing**
  - Chemical Resistance
  - Reasonable Thermal Resistance
  - Low Cost
- **PP + GF**

### Case Study
- **Safety Glasses**
  - Optical Transparency
  - High Impact
  - Moderate Cost OK
- **PC**

### Case Study
- **Truck Wheel Odometer Lens**
  - Transparent
  - Good Chemical Resistance
  - Moderate-High Cost OK
- **Amorphous Nylon**

### Case Study
- **Chemical Beakers**
  - Excellent Chemical Resistance
  - Low Cost
  - Transparent
- ????????
Case Study

- Nail Gun Housing
  - Good Chemical Resistance
  - Excellent Strength, Stiffness & Impact
  - Good Surface Finish When Reinforced
  - Moderate Cost OK

- Nylon 6 + GF

Case Study

- Automotive Intake Manifold
  - Chemical Resistance
  - Excellent Strength, Stiffness & Impact
  - Moderate Heat Resistance
  - Moderate Cost OK

- Nylon 66 + GF

Case Study

- Oil Pan
  - Chemical Resistance
  - Excellent Strength, Stiffness & Impact
  - Moderate Heat Resistance
  - Moderate Cost OK
  - Extremely Tight Dimensions & Flat

Case Study

- Electrical Connectors
  - Good Flow in Thin Walls
  - Excellent Electrical Properties
  - Dimensionally Stable in Humidity
  - Moderate Cost OK

- PBT (PET) + GF + FR

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Case Study

- **Conveyor Rollers**
  - Good Abrasion Resistance
  - Low Wear & Friction
  - Moderate Cost OK

- **Acetal**

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Case Study

- **Printer Gears**
  - Extremely Tight Dimensions
  - Moderate Cost OK
  - Good Abrasion Resistance
  - Low Wear & Friction

- ?????????

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Case Study

- **Lawn Tractor Hood**
  - Tight Dimensions & Low Warp
  - Moderate Cost OK
  - Chemical Resistance
  - Good Mold Flow
  - High Impact

- ?????????

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**Overcoming Morphology Deficiencies Via Compounding**
**Morphology Deficiencies**

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<td>D</td>
<td>✓</td>
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**Dimensional Stability**

- Can We Reduce Shrink Rate & Improve Dimensional Stability of Semi-Crystalline Resins?

**Fiber Reduces Shrink**

Shrink Rate X ≠ Shrink Rate Y → Warp

**Warp Control**

Shrink Rate X = Shrink Rate Y → Flat Part
But Low Strength!
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Strength & Warp Control

Common Loading = 15% Glass Fiber & 25% Mineral or Beads

Case Study

- Oil Pan
  - Chemical Resistance
  - Excellent Strength, Stiffness & Impact
  - Good Heat Resistance
  - Moderate Cost OK
  - Extremely Tight Dimensions & Flat

Nylon 66 + 15% GF + 25% Mineral

Transparency

- Can We Make A Semi-Crystalline Resin Transparent?

Nucleation/Clarification

- Compounding nucleator into PP or PE controls crystal size to less than wavelength of light = Transparency

Lunch & Learn: Greene Tweed

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**Case Study**

- Chemical Beakers
  - Excellent Chemical Resistance
  - Low Cost
  - Transparent

- PP + Nucleator

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**Chemical Resistance/Mold Flow**

- Can We Improve Chemical Resistance & Mold Flow of Amorphous Resins?

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**Alloying**

- Alloy PC with ABS
  - RTP 2500 A Series

<table>
<thead>
<tr>
<th>Property</th>
<th>PC</th>
<th>PC/ABS</th>
</tr>
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<tbody>
<tr>
<td>Tensile Strength, psi</td>
<td>9000</td>
<td>8900</td>
</tr>
<tr>
<td>Flexural Mod, E6 psi</td>
<td>0.34</td>
<td>0.40</td>
</tr>
<tr>
<td>Izod Impact, ft lb/in</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>HDT @ 264 psi/°F</td>
<td>270</td>
<td>210</td>
</tr>
<tr>
<td>Fuel Resistance</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Melt Flow, gm/10 min</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Clarity</td>
<td>Transparent</td>
<td>Opaque</td>
</tr>
</tbody>
</table>

- Alloy PC With Polyester (PBT or PET)
  - RTP 2099 X 63578 B

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Case Study

- Lawn Tractor Hood
  - Tight Dimensions & Low Warp
  - Moderate Cost OK
  - Chemical Resistance
  - Good Mold Flow
  - High Impact

- PC/PBT Alloy

Case Study

- GPS Housing
  - Tight Dimensions & Low Warp
  - Moderate Cost OK
  - Good Mold Flow
  - High Impact

- PC/ABS or PC/PBT Alloy
  - Want Sustainability

- PC/PLA Alloy (30% Bio)
  - Want More Sustainability

- Recycled (PCR) PC/PLA Alloy
  (30%Bio + 60% PCR = 90% Sustainable)

Wear Resistance

- Can We Make An Amorphous Resin Wear Resistant?

PTFE Lubricated

- Compound PTFE Into PC
  - RTP 300 TFE 15

<table>
<thead>
<tr>
<th></th>
<th>PC</th>
<th>PC/15 PTFE</th>
<th>Acetal</th>
</tr>
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<tbody>
<tr>
<td>Wear Factor</td>
<td>560</td>
<td>130</td>
<td>90</td>
</tr>
<tr>
<td>Dynamic Coef. of Friction</td>
<td>0.60</td>
<td>0.33</td>
<td>0.40</td>
</tr>
</tbody>
</table>
**Case Study**

- **Printer Gears**
  - Extremely Tight Dimensions
  - Moderate Cost
  - Good Abrasion Resistance
  - Low Wear & Friction

PC + PTFE

**Questions?**

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**Intro To Compounding**

- **The Dilemma**
- **Resin Selection Procedure**
  - Resin Morphology
  - Resin Performance (including cost)
  - Unique Resin Features
- **Application Case Studies**
- **Compounding in Performance**
  - Overcoming Resin Deficiencies