Wear Resistant Thermoplastic Compounds

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Product Development Engineer
RTP Company
Agenda

- RTP Company Introduction
- Definitions & Test Methods
- Morphology
- Additive Technologies
- Application examples
GLOBALIZATION STRATEGY

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Asia

• Scalability: Develop your solution on a small scale and produce your solution at larger quantities

• Plant-to-plant consistency

• Identical machinery, processing, QA testing

United States

• ISO 9001:2008 Registered Facilities

• Worldwide technical support

• Local customer service: real people, real time

France
Compounds formulated to meet your needs
Definitions
The Science of the mechanisms of friction, lubrication, and wear of interacting surfaces that are in relative motion.
Adhesive Wear

The primary mechanism for thermoplastic wear.
Characterized by transfer of material from one part to the other caused by frictional heat.
Mechanisms of Wear

Abrasive wear
Caused by a hard material scraping or abrading away at a softer material.
Characterized by grooves cut or gouged into the surface.
- Three Body
Friction is the natural resistance to the sliding motion of one surface over another.

- **Static Coefficient of Friction** \( (\mu_s) = \frac{Fx}{Fy} \)
  - \( Fx \) = Force to initiate motion
  - \( Fy \) = Normal force holding surfaces together

- **Dynamic Coefficient of Friction** \( (\mu_k) = \frac{Fx}{Fy} \)
  - \( Fx \) = Force to sustain motion
  - \( Fy \) = Normal force holding surfaces together
Thermoplastics Are Unique

- Static friction is typically less than dynamic friction
  - Can Lead To Slip/Stick
- Too large of difference leads to squeaking
• Sled Test
  – Coefficient of Friction Testing
  – Does not determine wear resistance
• Can Show Slip/Stick
Standard conditions

- Steel Thrust Washer
- 40 psi: 50 ft/min (2000 PV)
- Ambient Temp
- 100 hour test

Counter-surface (thrust washer) material, pressure, velocity and temperature are all adjustable

The best use of this test is to perform comparative screening of multiple candidate materials
Calculating Wear Factor (K)

Wear Factor (K)

\[ K = \frac{W}{(F \times V \times T)} \]

\( K \) = Wear Factor: \( (\text{in}^3\cdot\text{min}/\text{ft}-\text{lb}-\text{hr}) \cdot 10^{-10} \) or \( (\text{mm}^3/\text{N}-\text{m}) \cdot 10^{-8} \)

\( F \) = Force: lb or N

\( V \) = velocity: ft/\text{min} or m/sec

\( T \) = Elapsed Time: hr or sec

\( W \) = volume wear: in\(^3\) or mm\(^3\)

Wear factor per unit pressure can be calculated by multiplying the standard wear factor value by 0.35in\(^2\).

\( K_p = \text{Wear Factor: } (\text{in}^5\cdot\text{min}/\text{ft}-\text{lb}-\text{hr}) \cdot 10^{-10} \)

(Some companies report wear factors this way)
Additive Technologies
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Amorphous</th>
<th>Semi-Crystalline</th>
</tr>
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<tbody>
<tr>
<td>Low Shrinkage</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Low Warpage</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Tight Tolerances</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Transparency</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Mold Flow Ease</td>
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<td>X</td>
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<tr>
<td>Chemical Resistance</td>
<td></td>
<td>X</td>
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<tr>
<td>Response to Reinforcement</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Wear Resistance</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
1. **PTFE – Polytetrafluoroethylene (10-20%)**

- Workhorse additive – solid white powder
- Homogeneously distributed throughout the polymer matrix
- Forms a lubricious layer at polymer surface – Requires a “Break-in” period
- Compatible with nearly all thermoplastic resins

**Drawbacks**

- Fluorine content
- Die plate-out
- Relatively high loadings
Base Polymer Layer | Exposed PTFE | PTFE Layer

Part - As Molded | Part - After break-in period exposed PTFE shears to form layer
Application

- **Automotive Seat Adjustment Lever**
  - Needs good strength, stiffness and wear resistance. (Structural, wear, precolor)
  - Glass fiber reinforced PTFE lubricated and precolored PPA.
2. Silicone – Polydimethylsiloxane (1-3%)

- Boundary lubricant which migrates to the surface over time
- Migration rate is viscosity dependent
- Excellent friction reducer
- Best in high speed/low load applications
- Used with PTFE to eliminate “Break-in” period

Drawbacks

- Limited use in decorated parts
  - Poor adhesion of paint or print inks
- Bad for electrical applications
  - Can foul contacts
PTFE Break-In Period with Silicone

Base Polymer Layer

Exposed PTFE

PTFE Layer

Part - As Molded

Part - After break-in period
exposed PTFE shears to form layer
Food Handling conveyor rollers

- Antimicrobial, low friction. (Antimicrobial, Wear)
- PTFE and silicone lubricated POM with antimicrobial additive
Wear of POM, PA 6/6 and PC

Values per ASTM D3702 test method vs C1018 Steel

- Wear Factor Units: (in³/min/ft/lb/hr)E-10
3. **Graphite Powder (5-15%)**
   - Aqueous environments
   - Excellent temperature resistance
   - Black (Charcoal Gray) color

4. **Molybdenum Disulfide – MoS2 (1-5%)**
   - Nucleating agent innylons: creates harder surface
   - High affinity to metal: smoother mating metal surface = lower wear

**Drawbacks**
- Limited use
- Dark color limits colorability
- Sloughing type additives
- **Water Meter Valve**
  - Dimensional stability, potable water contact - NSF listed. (Structural, Wear)
  - Graphite lubricated SAN & PS
1. **Glass Fiber (5-50%)**

- Improved bearing capabilities and wear resistance
- Low cost

**Drawbacks**

- Extremely abrasive to mating surface
2. Carbon Fiber (5-50%)

- Greatly improved bearing capabilities
- Electrically and thermally conductive
- Less abrasive than glass

Drawbacks

- High cost
- Black color
1. 10/10/10 – Carbon fiber/Graphite Powder/PTFE

- Typical additive package for high load bearing applications.
- Prevalent in hi temp resin systems
- PPS, PEEK and PPA versions available from RTP
- Available from some resin producers
AC Compressor Scroll Seal

- High temperature, chemical and wear resistance
- Carbon fiber reinforced and PTFE/Graphite lubricated PEEK
3. Aramid Fiber (5-20%)
   - Very gentle to mating material
   - Improves wear and friction

**Drawbacks**
- Difficult to process
- Minimal physical property enhancement
- High cost
Fibers vs. Metal

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS
APWA – All Polymeric Wear Additive (5-15%)

- Alloys with host polymer
- Excellent Plastic vs. Plastic performance (Great for business machines)
- Completely halogen free
- Physical properties maintained
- No die plate-out
- Specific gravity benefits (more parts per lb or kg)

Drawbacks
- Limited thermal resistance
- Higher cost
- Not FDA
APWA Plastic vs. Plastic wear

Wear Factor (K): APWA vs. PTFE

Values per ASTM D3702 test method.

- PV = 1000 ft·lb/in²min
- Wear Factor Units: (in³/min/ft/lb/hr)E-10
- **Thermal Printer Frame**
  - High Impact, ESD, wear resistance.
  - (Conductive, Structural, Wear)
  - Impact modified, conductive PC with APWA for improved wear resistance
PFPE – Perfluoropolyether Oil (< 1%)

- Thermally Stable up to PEEK processing temps
- Differentiates RTP Company from others
- Physical properties maintained
- Minimized die plate-out (improved production efficiencies)
- Synergy with PTFE
- Specific gravity benefits
- Improved fatigue resistance

Drawbacks

- Limited effectiveness in amorphous resins
- Needs PTFE “kick” to deliver optimum friction reduction
Wear Factor (K) against Steel

Values per ASTM D3702 test method vs. C1018 Steel

- PV = 2000 ft·lb/in²·min
- Wear Factor Units: (in³/min/ft/lb/hr)E-10
- **Agricultural Pump**
  - Chemical and Wear Resistance (Structural, Wear)
  - PFPE lubricated PP
• Thank you for your attention.
• Any questions?
Friction of POM, PA 6/6 and PC

Dyanamic Coefficient of Friction

Values per ASTM D3702 test method vs C1018 Steel
Wear Factor (K): APWA vs. PTFE

Values per ASTM D3702 test method vs. C1018 Steel.

• PV = 2000 ft-lb/in²min
• Wear Factor Units: (in³/min/ft/lb/hr)E-10
- **Fluid Handling Pump**
  - Chemical resistance, high strength & stiffness. (Structural, Wear)
  - Glass fiber reinforced, PTFE lubricated PP
- Digital Printer Cartridge Holder
  - ESD, high strength/stiffness, low friction/wear. (Conductive, Structural, Wear)
  - Carbon fiber reinforced, PTFE lubricated PEI
Copier Bushings

- Extremely high temperature resistance (~260°C), wear resistance. (High Temperature, Wear)
- Aramide fiber reinforced, PTFE lubricated TPI
## Physical Property Comparison

<table>
<thead>
<tr>
<th></th>
<th>POM</th>
<th>PA 6/6</th>
<th>PC</th>
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<tbody>
<tr>
<td></td>
<td>Unfilled</td>
<td>PTFE (20%)</td>
<td>Silicone (2%)</td>
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<tr>
<td><strong>Specific Gravity</strong></td>
<td>1.41</td>
<td>1.52</td>
<td>1.40</td>
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<tr>
<td><strong>Tensile Strength (psi)</strong></td>
<td>8700</td>
<td>6500</td>
<td>7800</td>
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<tr>
<td><strong>Flexural Modulus (psi)</strong></td>
<td>350,000</td>
<td>300,000</td>
<td>350,000</td>
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<tr>
<td><strong>Notched Impact (ft-lb/in)</strong></td>
<td>1.5</td>
<td>1.0</td>
<td>1.5</td>
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Testing per ASTM test methods.
## Physical Property Comparison

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<tr>
<td></td>
<td>PTFE/SI</td>
<td>PTFE/ PFPE</td>
<td>PTFE/SI</td>
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<tr>
<td>Specific Gravity</td>
<td>1.44</td>
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<tr>
<td>Tensile Strength (psi)</td>
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<tr>
<td>Flexural Modulus (psi)</td>
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<td>340,000</td>
<td>300,000</td>
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<tr>
<td>Notched Impact (ft-lb/in)</td>
<td>1.2</td>
<td>1.5</td>
<td>1.2</td>
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Testing per ASTM test methods.