Wear in the World of Plastics

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WEAR AND FRICTION

“My application is wearing out!”

? Fatigue?

? Chemical Attack?

? Abrasion?

? Weather/UV Resistance?

Be Specific!

Wear – Sliding wear of thermoplastic compounds against a contact surface (steel, aluminum, other thermoplastics, etc.)

Friction – Reducing/controlling the friction in a sliding or moving system

Internally Lubricated Thermoplastics
I. Wear Definitions & Test Methods
II. Friction Definitions & Test Methods
III. Additive Technologies
IV. Application Examples
V. Extreme Conditions – Ultra Wear

WEAR DEFINITIONS

Tribology:
The Science of the mechanisms of friction, lubrication, and wear of interacting surfaces that are in relative motion

Recall: Sliding surfaces
Wear = Loss of material over time

Adhesive Wear Mechanism
- The primary mechanism for thermoplastic wear
- Characterized by transfer of material from one part to the other caused by frictional heat
WEAR DEFINITIONS

Adhesive Wear Mechanism
• Caused by a hard material scraping or abrading away at a softer material
• Characterized by grooves cut or gouged into the surface
  • Three body

WEAR TESTING

Question: How do you simulate an application and test a material for long-term wear resistance?

Answer: RTP uses ASTM D-3702 wear test to quantify the amount of material a sample loses over time under specific conditions (pressure, speed, temperature)

ASTM D-3702 “Thrust Washer” Wear Test

Adjustable:
• Counter-surface (thrust washer)
• Pressure
• Velocity
• Temperature

The best use of this test is to perform comparative screening of multiple candidate materials

• RTP Company has six thrust washer wear testing machines in our wear lab located in Winona, MN
• Equipment is available to perform customer requested testing
• A test isn’t always just a test
  • Conditions matter!
WEAR TESTING

Wear factor (K): Used to quantify wear resistance
Lower Value = Better Wear Resistance!

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

- \( K \) = Wear Factor: \( \text{in}^3\text{-min/ft-lb-hr} \cdot 10^{-10} \) or \( \text{mm}^3/N\text{-m} \cdot 10^{-8} \)
- \( W \) = Volume wear: \( \text{in}^3 \) or \( \text{mm}^3 \)
- \( F \) = Force: \( \text{lb} \) or \( N \)
- \( V \) = Velocity: \( \text{ft/min} \) or \( \text{m/sec} \)
- \( T \) = Elapsed time: \( \text{hr} \) or \( \text{sec} \)

100 Hour Test!

WEAR TESTING

Standard Conditions:
- Steel thrust washer
- 40 psi · 50 ft/min
- Ambient temp
- 100 hour test

2,000 PV = (40 psi · 50 ft/min)

Typical testing done at 2,000 to 10,000 PV

WEAR TESTING

Question: Does an equivalent PV always result in the same data?

Standard Conditions: PV = 2,000
- \( P = 40 \text{ psi} \)
- \( V = 200 \text{ ft./min} \)

Non-Standard Conditions:
- PV = 2,000
- \( P = 10 \text{ psi} \)
- \( V = 200 \text{ ft./min} \)

Answer: No…Wear factor will change based on individual conditions
**WEAR TESTING**

**Question:** What happens when PV is increased? Does Wear Factor (K) also increase?

![Graph showing wear factor vs PV for POM and POM + 20% PTFE](image)

Wear per ASTM D 3702 against C1018 Steel

**AGENDA**

I. Wear Definitions & Test Methods
II. Friction Definitions & Test Methods
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**FRICTION DEFINITIONS**

**Coefficient of Friction (μ)**
Ratio of the force of friction between two bodies and the force pressing them together

\[ \mu = \frac{F}{N} \]

**Static coefficient of friction (μs) = Fx/Fy**
- Fx = Force to initiate motion
- Fy = Normal force holding surfaces together

**Dynamic coefficient of friction (μk) = Fx/Fy**
- Fx = Force to sustain motion
- Fy = Normal force holding surfaces together
**FRICTION DEFINITIONS**

- In most non-plastic materials
  - $\mu_s > \mu_k$
- Thermoplastics are somewhat unique
  - $\mu_k > \mu_s$
- May cause “slip/stick” – *Glide Factor™*
- If $\mu_k >> \mu_s$ you may have squeaking

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**FRICTION TESTING**

ASTM D 1894 “sled test”

- Coefficient of friction testing
- Does not determine wear resistance
- Can show slip/stick

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**RTP Modified ASTM D3702 Friction Test**

- Oscillating motion used to measure friction coefficients and *Glide Factor™*
- *Glide Factor™* is used to quantify the difference between $\mu_s$ and $\mu_k$ in order to reduce/eliminate stick/slip
- Used to generate friction data for optimal material selection in medical devices

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**TESTING REVIEW**

**Question:** How does RTP measure wear resistance?

**Answer:** ASTM D3702 Thrust Washer wear test; Wear Factor (K)

**Question:** How does RTP measure Friction?

**Answer 1:** ASTM D1894 “Sled Test”

  (Static and Dynamic Coefficient of Friction)

**Answer 2:** Modified ASTM D3702 Thrust washer friction test.

  (*Glide Factor™*)
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ADDITIVE TECHNOLOGIES

PTFE – Polytetrafluoroethylene (5-20%)

Workhorse additive – solid white powder
Compatible with nearly all thermoplastic resins

Limitations:
- Fluorine content
- Die plate-out
- Relatively high loadings
- Cost fluctuation

PTFE Wear Mechanism

Base Polymer Layer  Exposed PTFE  PTFE Layer
Part – As Molded  Part – After break-in period Exposed PTFE shears to form layer
### Application Example

#### Laser Printer Fuser Gears

**Requirements:**
- High Operating Temperatures
- Good wear Resistance

**Solution:**
- Glass fiber reinforced and PTFE lubricated PPS

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#### 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

**Limitations:**
- Limited use in decorated parts
  - Poor adhesion of paint or print inks
- Bad for electrical applications
  - Can foul contacts
PTFE + Silicone Wear Mechanism

- SI Present as Molded
- Exposed PTFE
- SI + PTFE Layer

Part – As Molded
Part – After break-in period

Wear Resistance with PTFE and Silicone

- PC
- POM
- PA 6/6

Friction Reduction with PTFE and Silicone

- Dynamic μ

Specific Gravity Differences with PTFE and Silicone

- Specific Gravity
### Application Example

**Garage Door Opener Limit Switch**

**Requirements**
- Dimensional stability
- Good strength and stiffness

**Solution**
- Silicone lubricated PC

Not Transparent! More on this later…

### Application Example

**Drug Delivery Pen Components**

**Requirements**
- Good strength, dimensional stability, eliminate secondary lubricant application and no slip/stick

**Solution(s)**
- Optimal Plastic “Friction Pairs” with low Glide Factor

- Fiber reinforced and internally lubricated PC or PBT

- Internally lubricated POM or PBT
**ADDITIVE TECHNOLOGIES**

PFPE – Perfluoropolyether Oil (< 1%)
- Thermally stable up to PEEK processing temps
- Differentiates RTP Company from others
- Synergy with PTFE
- Specific gravity benefits

Limitations:
- Limited effectiveness in amorphous resins
- Needs PTFE “kick” to deliver optimum friction reduction

**APPLICATION EXAMPLE**

**Agricultural Pump**

Requirements
- Chemical and Wear Resistance

Solution
- PFPE lubricated PP

**Universal Conveyor Roller**

Requirements
- Strength, conductivity and wear resistance (must be silicone-free)

Solution
- Carbon fiber reinforced and PTFE/PFPE lubricated PPS
Additives Reduce Clarity!

PC with APWA+
PC with PTFE
PC with PFPE
PC with Silicone
Natural PC

Graphite Powder (5-30%)
- Aqueous environments
- Excellent temperature resistance
- Black color

Molybdenum Disulfide – MoS₂ (1-5%)
- Nucleating agent in nylons: creates harder surface
- High affinity to metal:
  - Smoother mating metal surface = lower wear

Limitations:
- Limited use
- Dark color limits colorability
- Sloughing type additives

Water Meter Valve
Requirements
- Dimensional stability, potable water contact - NSF listed

Solution
- Graphite lubricated PS and SAN
ADDITIVE TECHNOLOGIES

Reinforcing Fibers and Wear Resistance

- Glass Fiber
  - Improved bearing capabilities/wear resistance
  - Very abrasive

- Carbon Fiber
  - Higher bearing capabilities
  - Excellent thermal resistance
  - Conductive
  - Less abrasive

- Aramid Fiber
  - Little strength improvement
  - Very gentle to mating surface

Fibers protect the polymer, but may be abrasive against the mating material

- Glass
- Carbon
- Aramid

Copier Bushings

Requirements
- High HDT and good wear resistance

Solution
- Aramid fiber reinforced and PTFE lubricated PPA
APWA^PLUS: All Polymeric Wear Alloy

A Unique Polymer Alloy Technology Offering:

- Improved wear and friction performance
- Especially effective in plastic vs. plastic wear
- Good retention of base resin physical properties
- Lower specific gravity than PTFE
- Reduction/Elimination of plate-out associated with PTFE

Additive Synergies

10/10/10 – Carbon Fiber/Graphite Powder/PTFE
Typical additive package for high load bearing/high temp. applications

Aramid Fiber/PTFE
Excellent wear package that is gentle on the mating surface

Carbon Fiber/Ceramic Additive
Non-PTFE solution, good for very demanding conditions

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What happens when your application has a PV higher than 10,000?

High Temperature
High Loads (500+ psi)
High Speeds
Chemical Resistance

Excellent Mechanical Properties
Injection Molded Parts

100 ft/min tests
200 ft/min tests

10,000 PV: 100 psi
10,000 PV: 50 psi

25,000 PV: 250 psi
25,000 PV: 125 psi

50,000 PV: 500 psi
50,000 PV: 250 psi

Ultra Wear Products Developed for Demanding applications

Transmission Seal
High Load Thrust Washers
Pipe Gaskets

Off-Shore Drilling
Construction Vehicles
Oil and Gas Industry

1. Develop a series of high performance RTP products ideal for “Ultra” testing

- **Resins**
  - PEEK
  - PPS
  - PPA

- **Additives**
  - Carbon Fiber
  - Graphite
  - Aramid Fiber
  - PTFE
  - Ceramic
  - MoS₂

2. Compare RTP Ultra Products with industry leading wear resistant materials

- Rulon® J
- Rulon® LR
- Torlon® 4301
- Torlon® 4630
- Vespel® SP-21
- Vespel® SP-211
- Stanyl® TW371

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**PV=50,000 (500psi @ 100 ft/min)**

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<th>Wear Factor (in3-min/ft-lb-hr)</th>
<th>Dynamic µ</th>
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<td>PA 46 - TFE Wear Limit</td>
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Wear per ASTM D-3702 against Steel
EXTREME CONDITIONS

APPLICATION EXAMPLE

AC Compressor Scroll Seal
- Requirements
  - High temperature, chemical and wear resistance
- Solution
  - Carbon fiber reinforced and PTFE/Graphite lubricated PEEK

APPLICATION EXAMPLE

Transmission Seal Rings/Thrust Washers
- Requirements
  - Ability to survive extremely high PV conditions with external lubrication
- Solution
  - Carbon fiber reinforced, internally lubricated PEEK
WEAR AND FRICTION

Thank You!

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WEAR FACTOR (K) AND FRICTION COEFFICIENT (μK) FOR COMMON TRIBOLOGICAL COMPOUNDS:

Wear Factor (K) and friction coefficient (μK) for common tribological compounds:

www.rtpcompany.com/info/wear