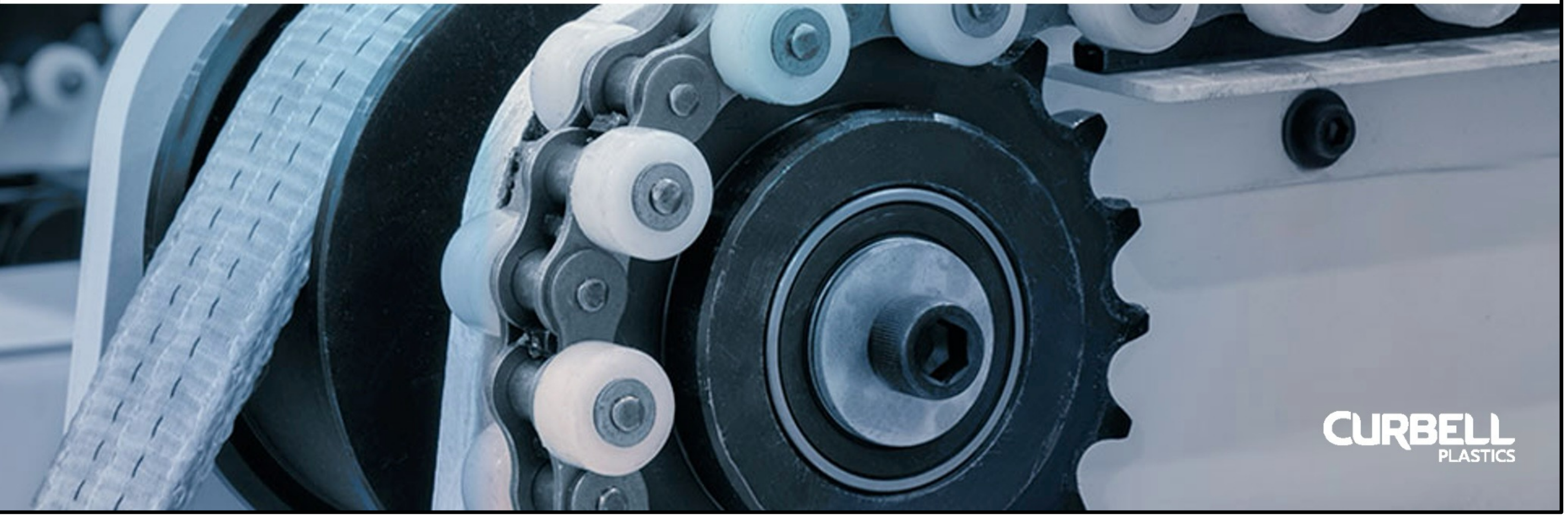
Solving Friction and Wear Challenges with Engineering Plastics

Webinar Presented by Curbell Plastics



Today's Presenter:

Dr. Keith Hechtel, DBA

Senior Director of Business Development

About Keith:

Dr. Hechtel is a recognized speaker on plastic materials and plastic part design. He has conducted numerous presentations for engineers, designers, and fabricators in both industrial and academic settings.

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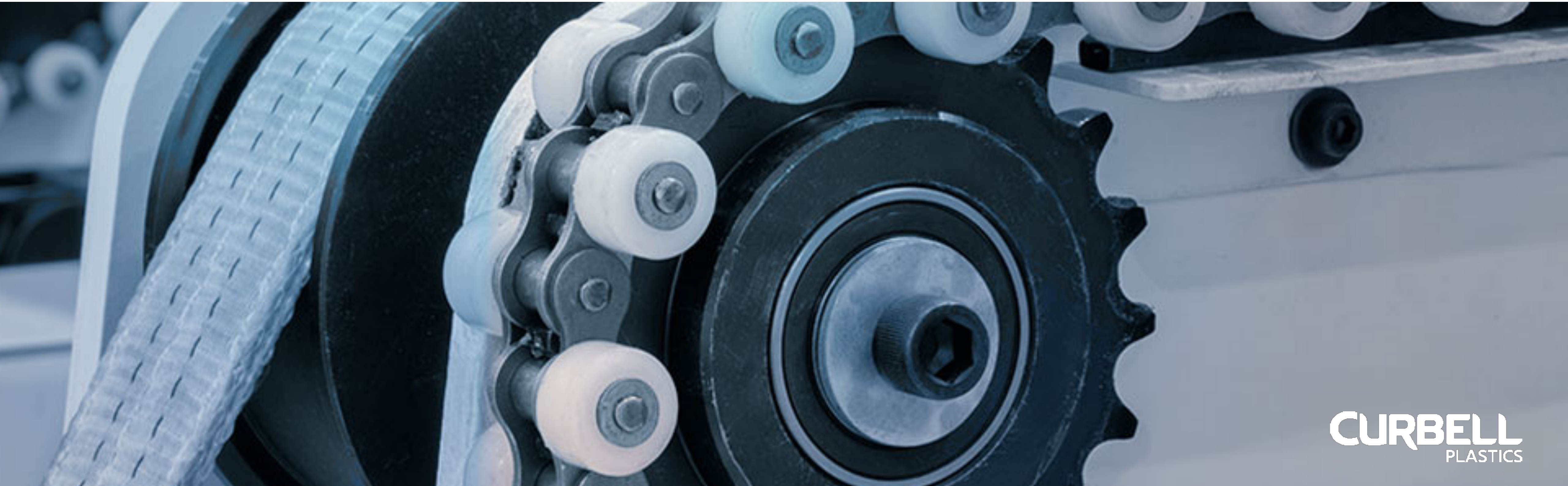

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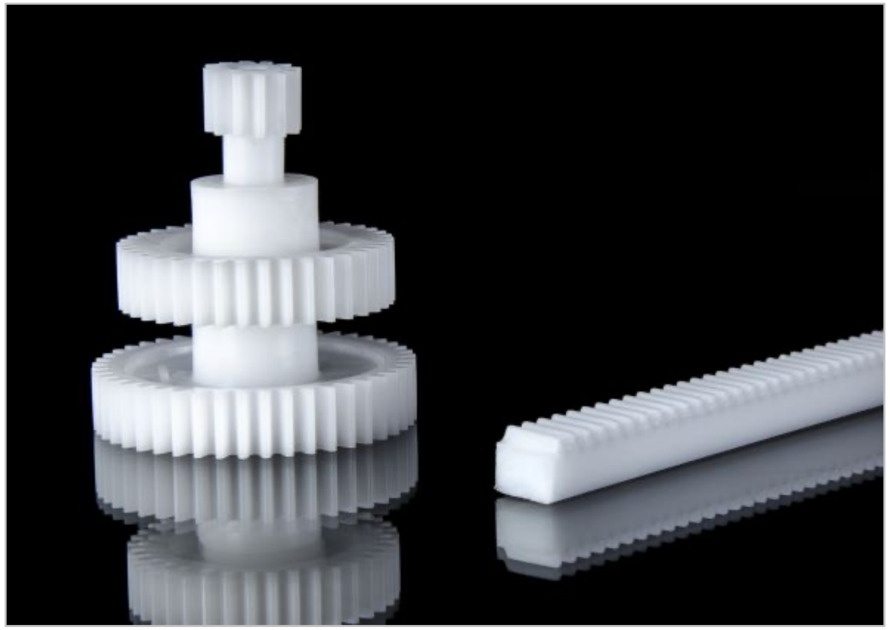
Agenda

- Overview of polymer wear
- Mechanisms of polymer wear
- Additives for enhanced friction and wear performance
- Selecting plastic materials for friction and wear applications



Some Notes on Polymer Wear

- Wear – a gradual removal of material eventually resulting in decreased performance
- There are different mechanisms of material removal – all referred to as "wear"
- Friction - the force required to cause or maintain motion divided by the normal force on the contacting surfaces

  Friction has important implications for machine design such as motor size, conveying capacity, or actuation torque on a valve.

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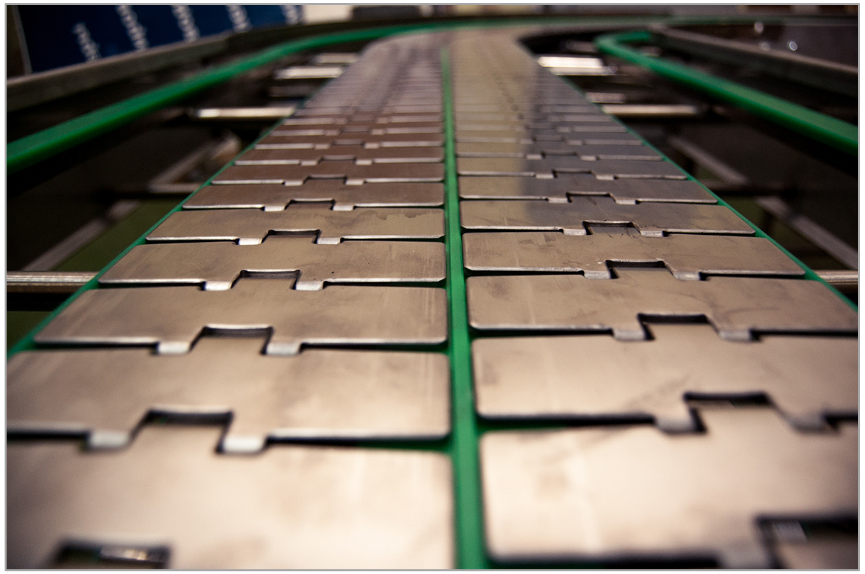
Some Notes on Polymer Wear

Generally trying to achieve three things

- Low friction for smooth operation
- Long wear life of the polymer
- Low wear on the mating parts

Some Notes on Polymer Wear

- Friction and wear are "system" properties – not material properties
- Both mating components (and in some cases additional materials) play a role in wear
  - Chemistry
  - Hardness
  - Surface finish



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Some Notes on Polymer Wear

- The environment plays an important role in polymer wear
  - Service temperature
  - Water, other chemicals
  - Vacuum conditions
- Additives can dramatically affect friction and wear behavior
- Friction and wear performance is very application-specific. Difficult to make generalizations.

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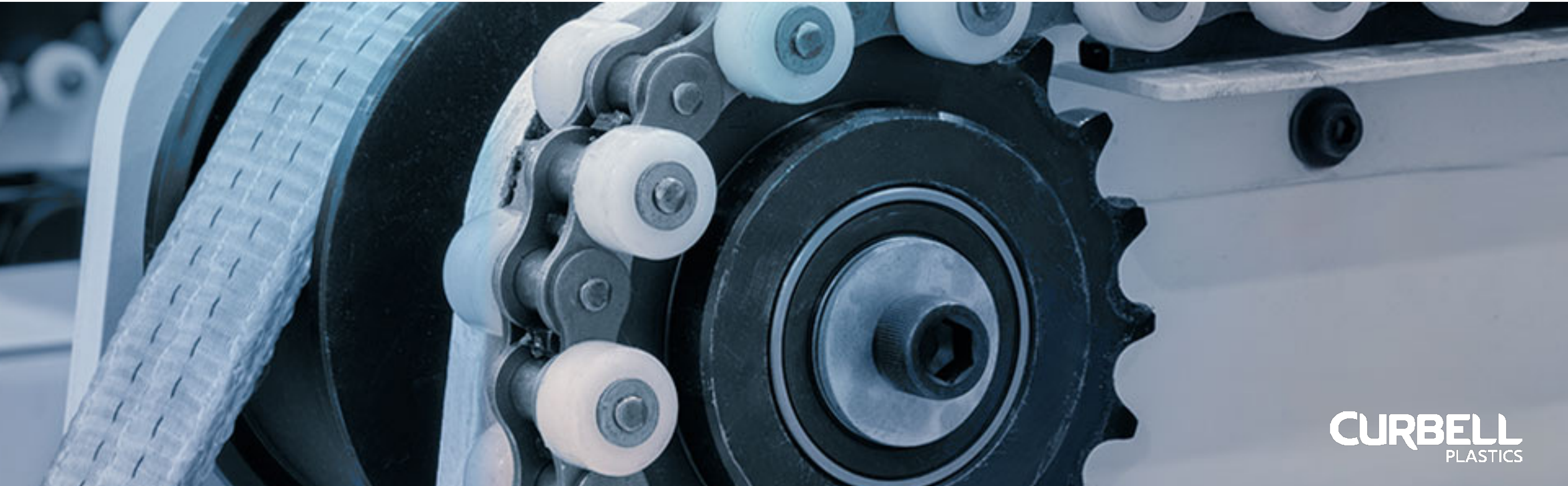
Mechanisms of Polymer Wear & Additives for Enhanced Friction and Wear Performance



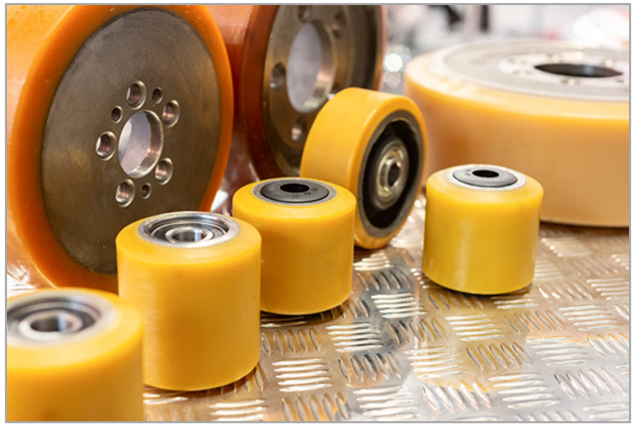
Mechanisms of Polymer Wear

Sliding Wear

Abrasive Wear

Impact Fatigue

Rolling Contact Fatigue



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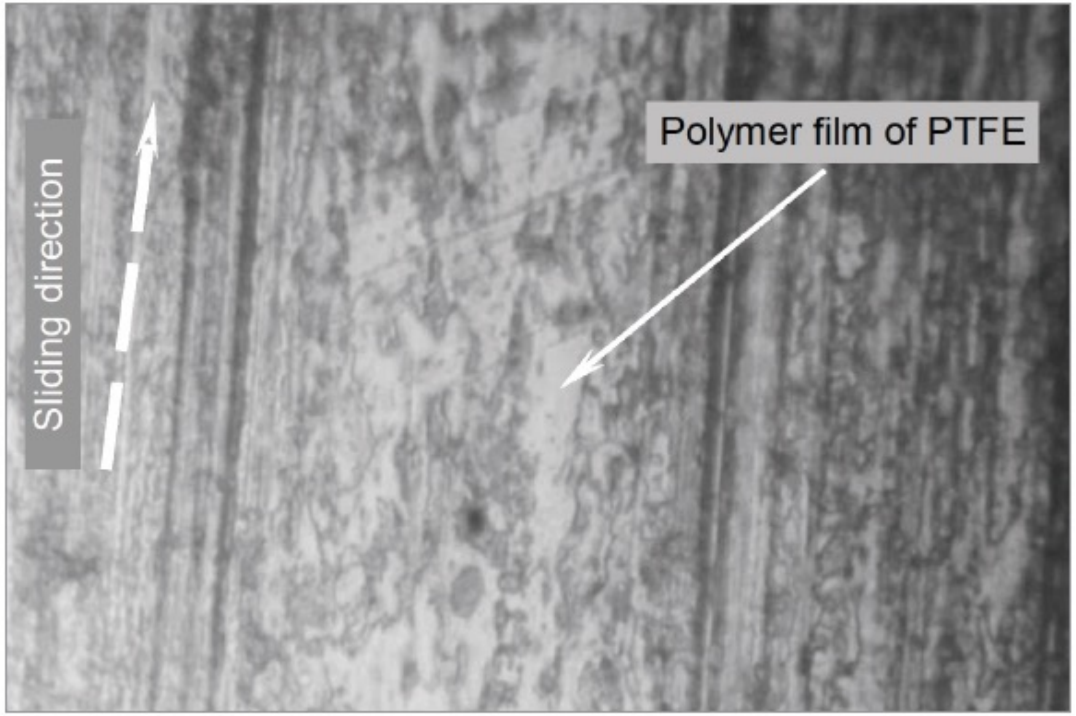
Sliding Wear Applications

Deposition of Polymer Wear Films



Source: Wieleba, 2007

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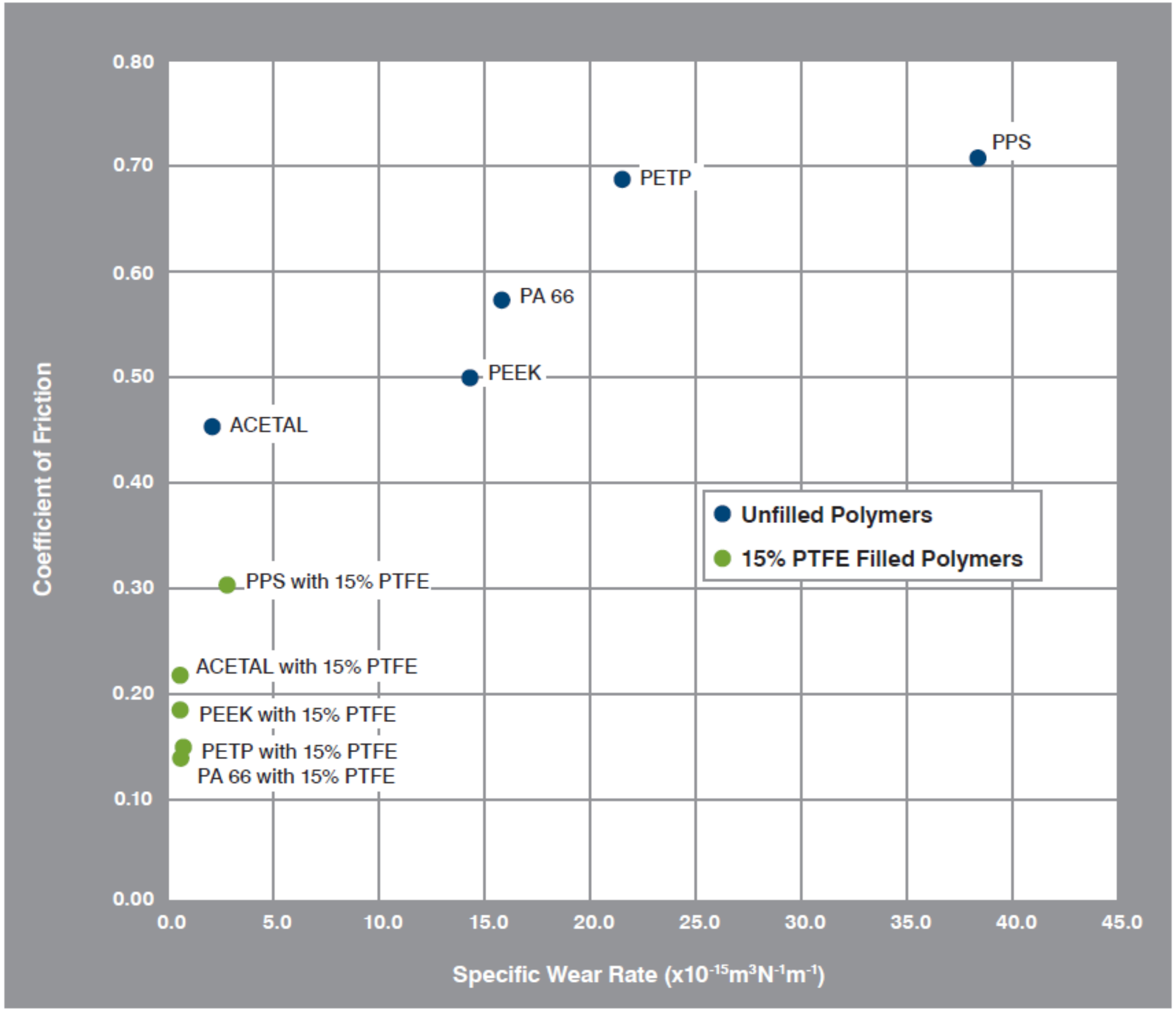
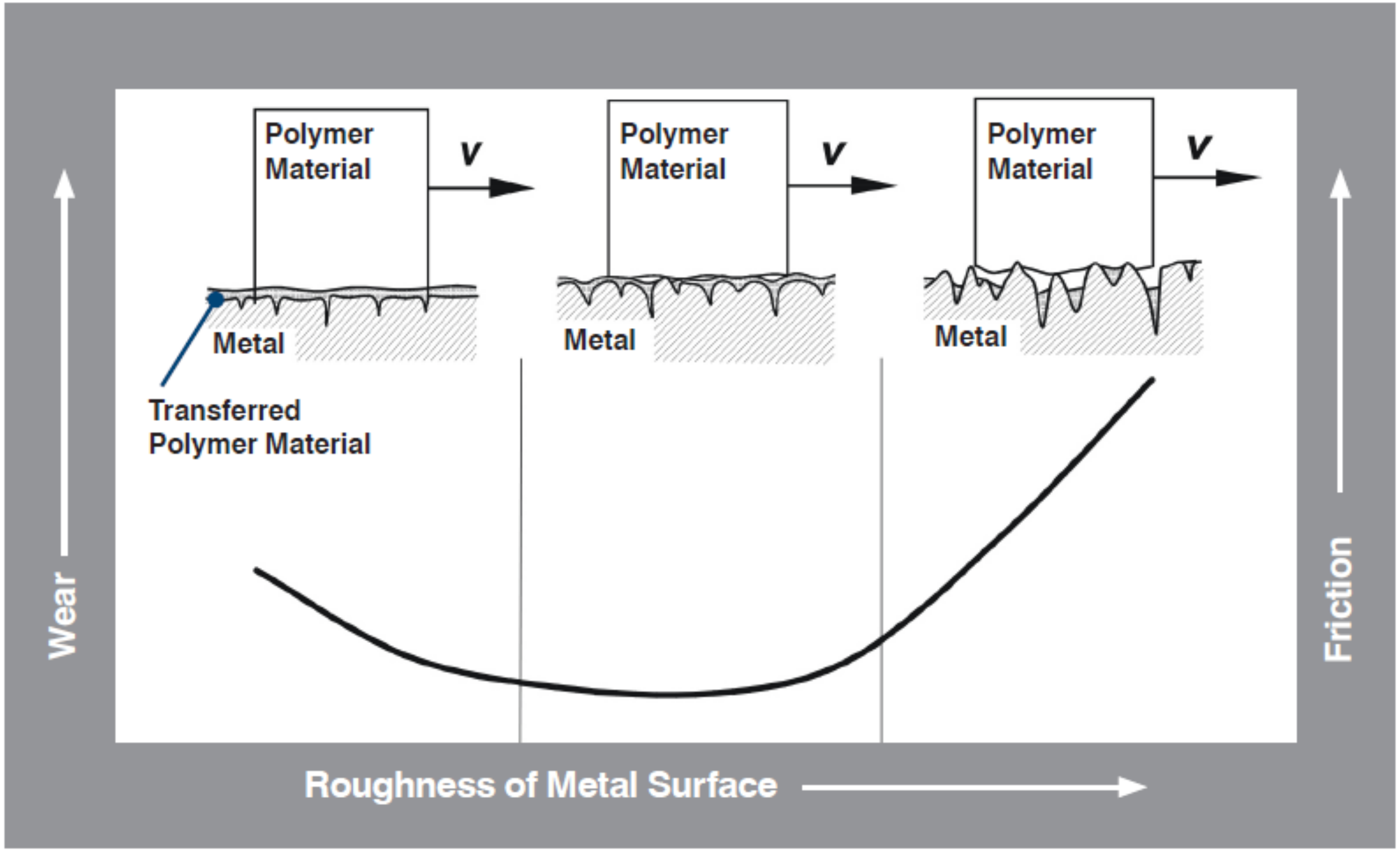
Effect of PTFE Additives on Friction and Wear Rate Sliding Against Hardened Steel



Source: Adapted from Mens, 1991

Effect of Counterface Surface Finish for Sliding Wear Applications



Source: Adapted from Wieleba, 2007 and Bely, 1982

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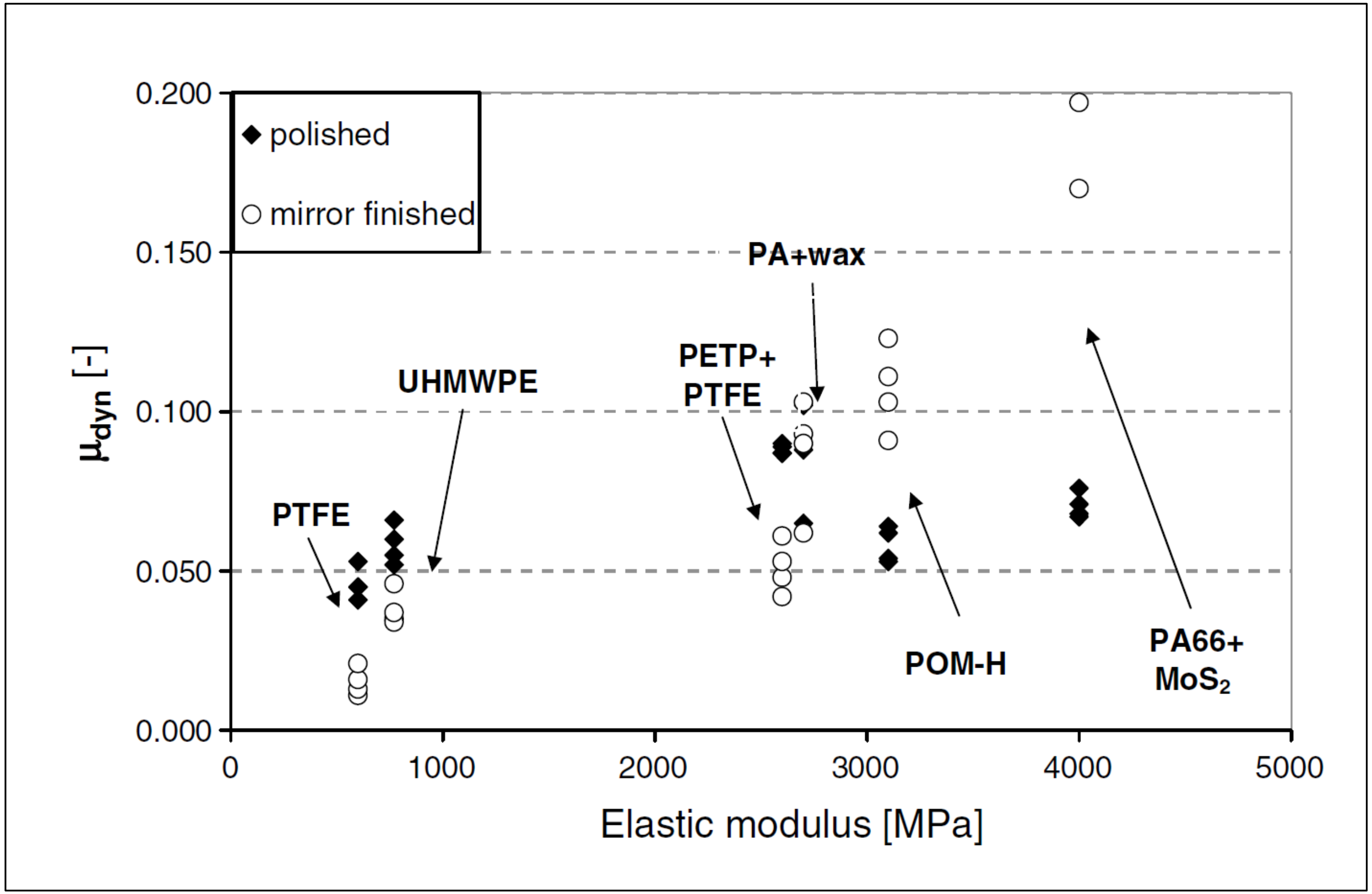
Effect of Counterface Surface Finish for Sliding Wear Applications



Steady-state coefficient of dynamic friction versus elastic modulus at 20 MPa contact pressure and different peak velocities (2.5, 12.5, 22, and 42 mm/s.

Surface Roughness:

- Mirror Finished: R_a = 0.02 to 0.08 µm
- Polished: R_a = 0.10 to 0.20 µm

Source: Quaglini

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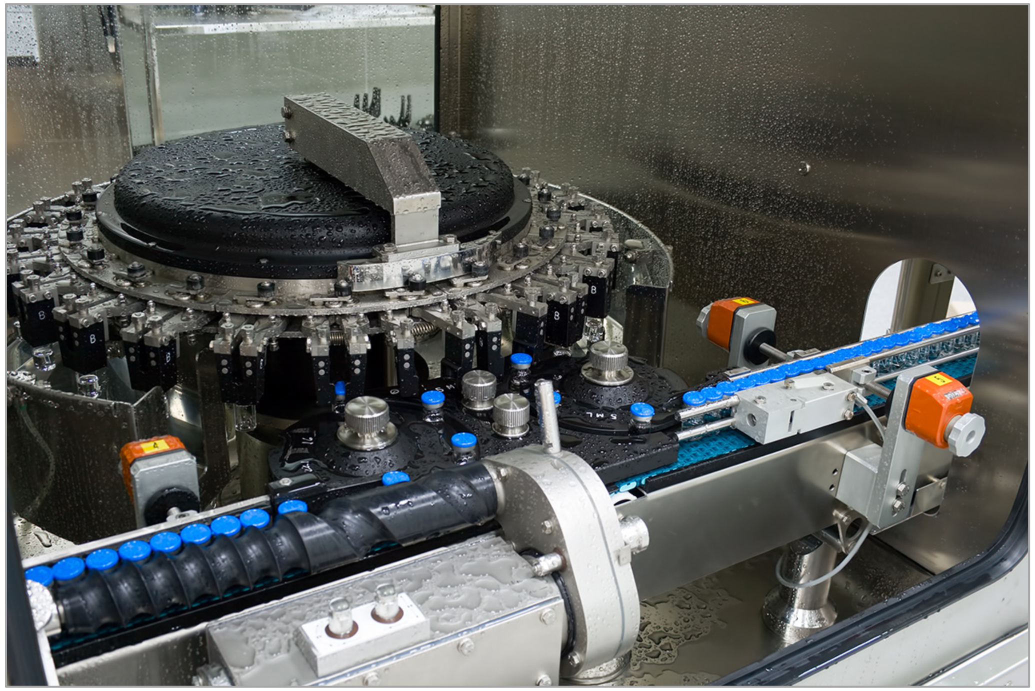
Effect of PTFE Additives in Wet Environments

The beneficial effects of PTFE additives on the friction and wear behavior of thermoplastics is generally less pronounced in wet environments.



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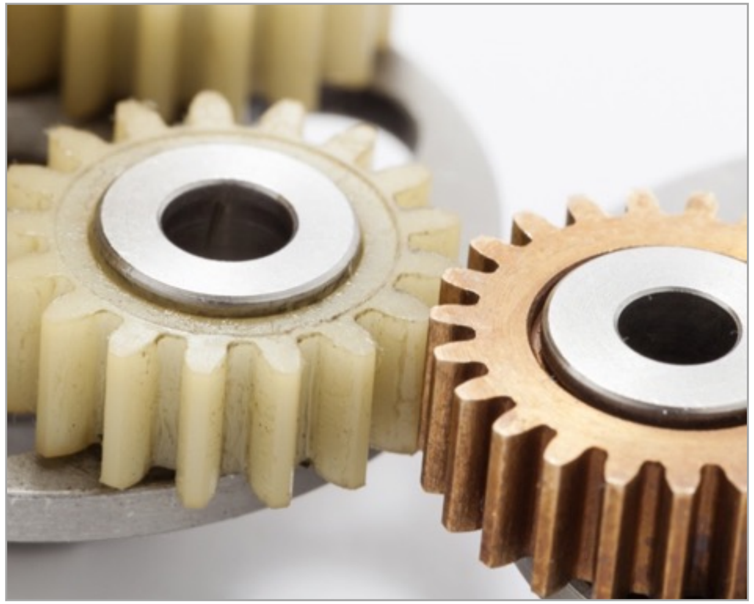
A Note on Liquid Lubricants

- Lubrication can lower friction and remove heat from a tribological system
- Lubricants should be selected carefully
  Example: Some oils can plasticize nylon, which can detract from its wear performance

Friction and Wear Additives

- **MoS2**
  Makes nylon harder and more crystalline. Offers some advantages in vacuum environments.
- **PTFE**
  Creates a wear film on the mating metal surface
- **Oil**
  Separates sliding surfaces with a liquid film
- **Graphite**
  Molecules slide over each other in humid environments. Is not good for dry or vacuum environments.
- **Carbon fibers**
  Lowers friction and increases thermal conductivity
- **Glass fibers**
  Increases strength, modulus, thermal conductivity. Improves creep resistance.



Source: McKeen, 2010

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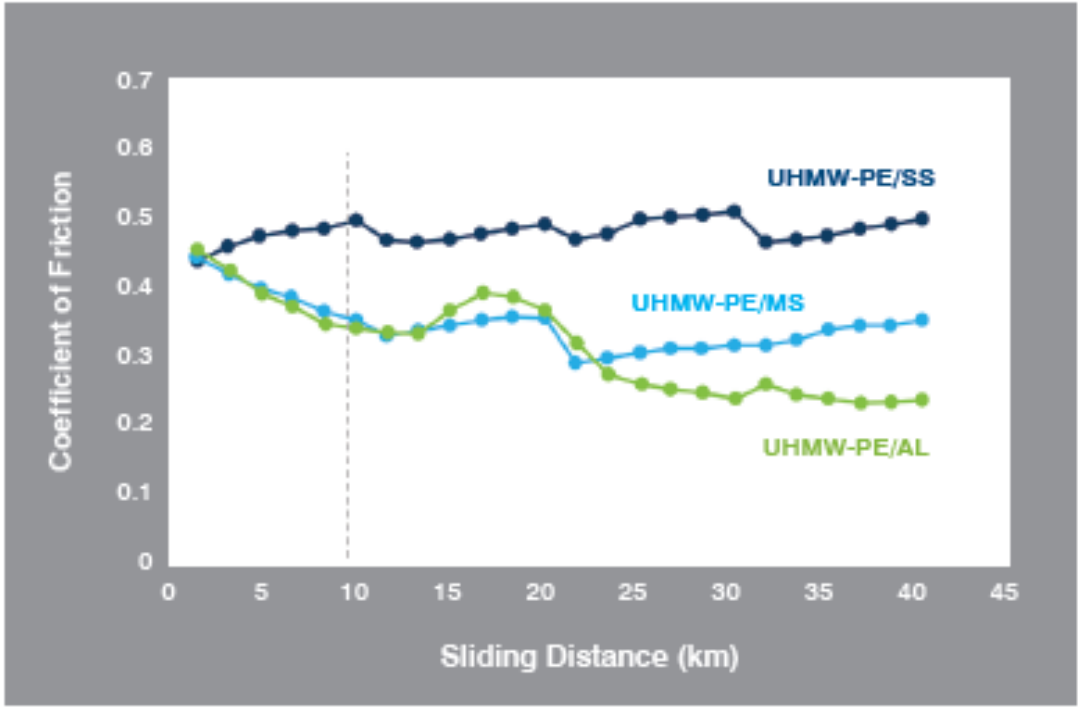
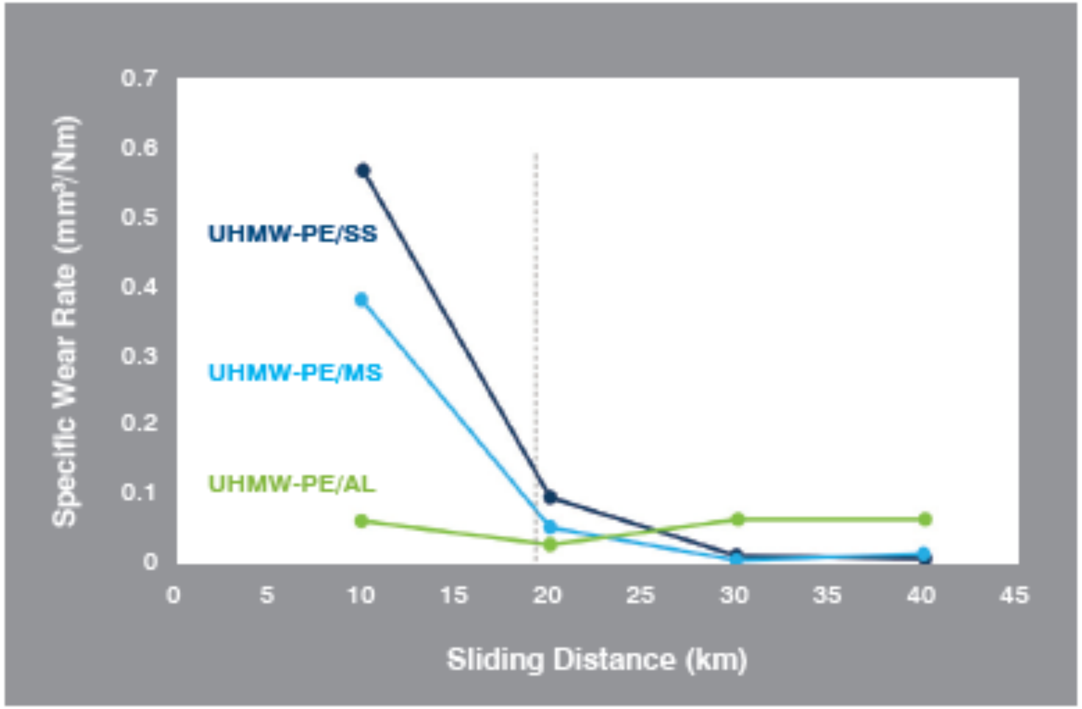
The Importance of the Counterface Material





Friction coefficients and wear rates for UHMW-PE sliding against stainless steel (SS), mild steel (MS), and aluminum (AL) in dry conditions. The vertical dashed line indicates the sliding distance where a steady state of wear is achieved.

Source: Yousif, 2010

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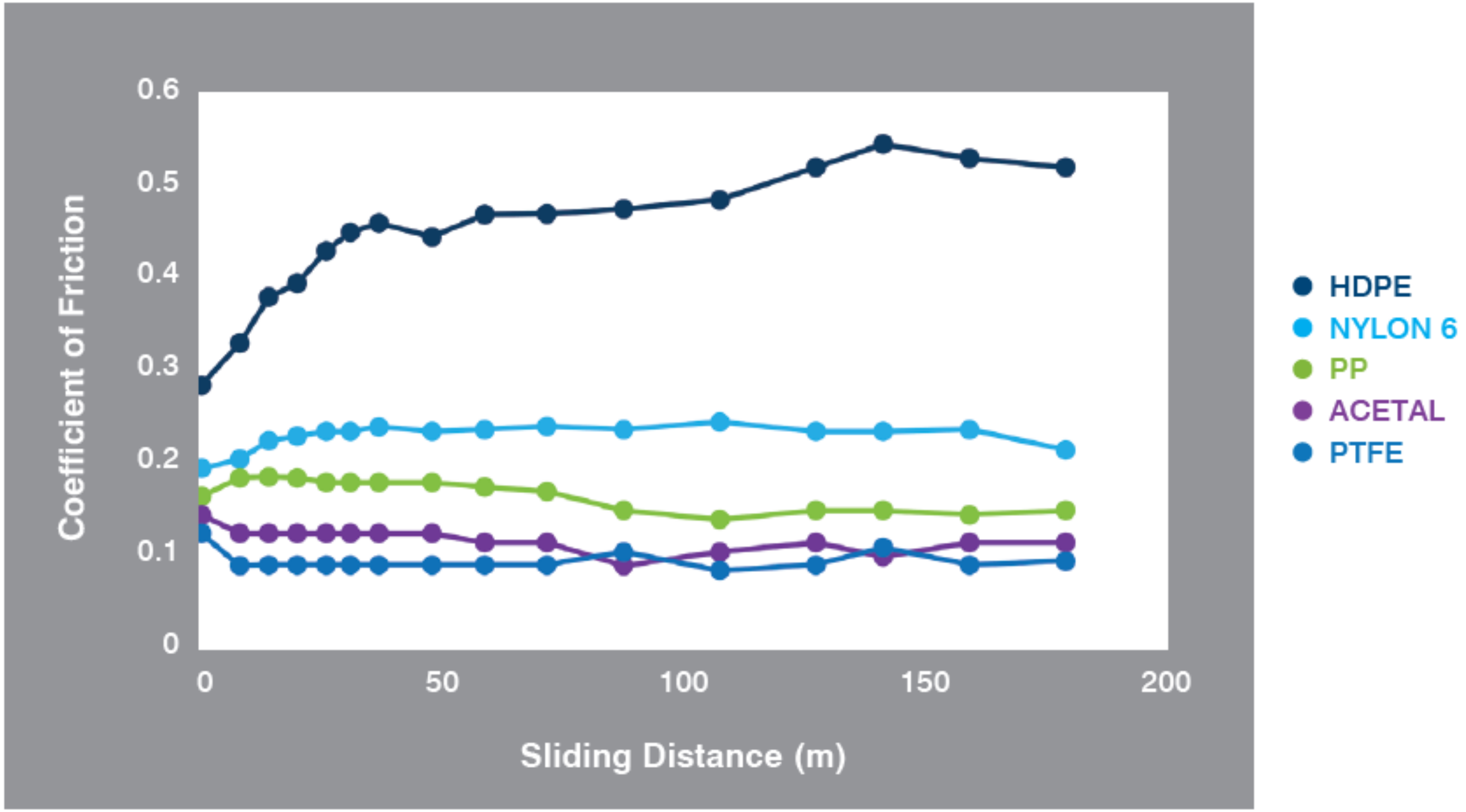
Plastic-on-Plastic Wear

- Low thermal conductivity makes it challenging to remove heat
- Difficult to deposit a wear film
- Specific plastics tend to wear poorly against themselves

Plastic-on-Plastic Wear

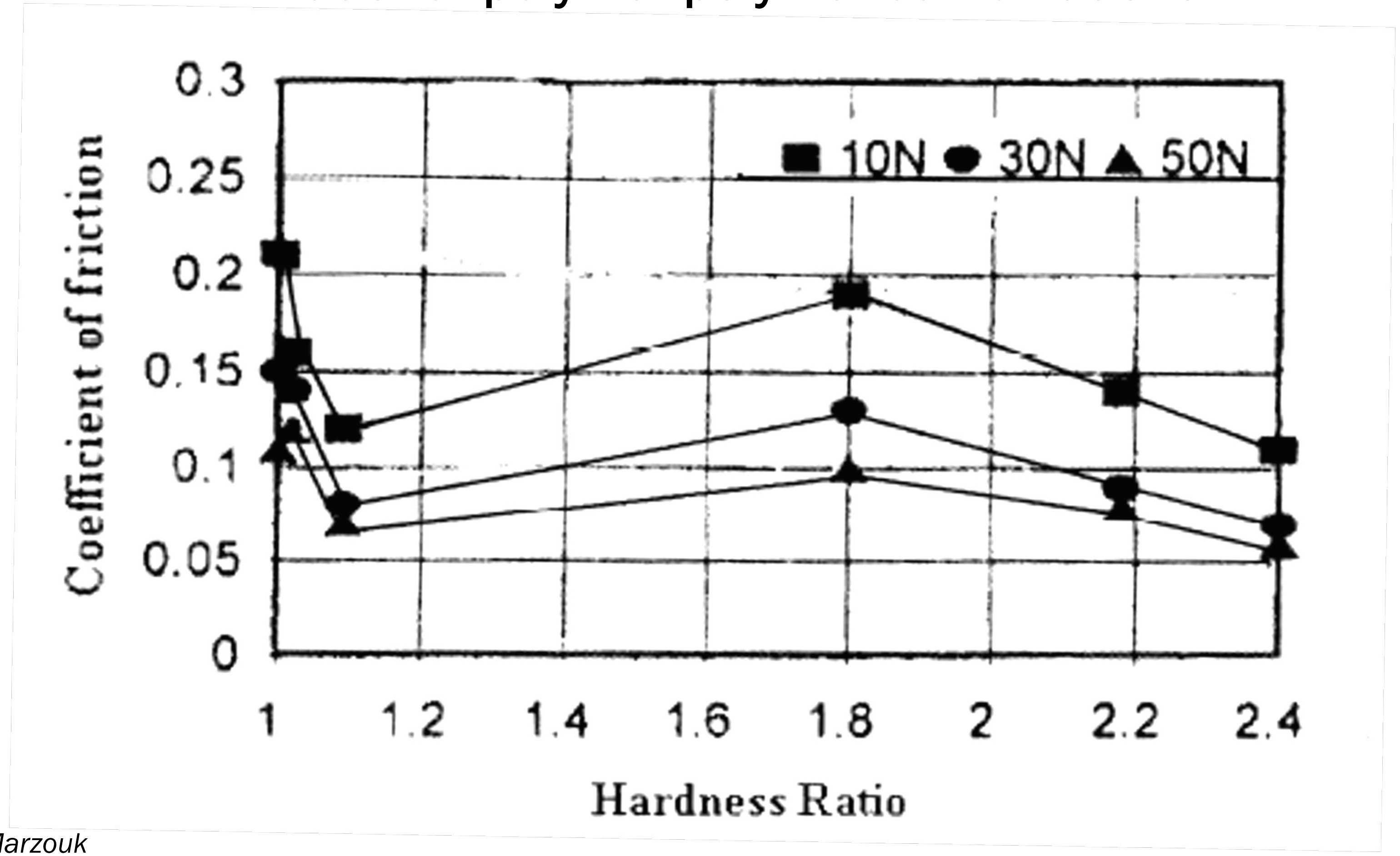
Figure 4. Friction coefficients for various polymers sliding against HDPE



Source: Yamada, 1997

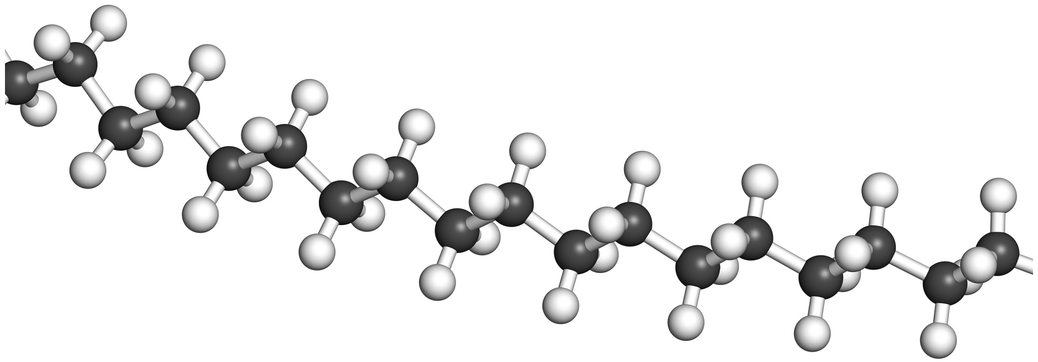
Hardness Ratio for Plastic-on-Plastic Wear

Dependence of coefficient of friction on hardness ratio for polymer-polymer combinations

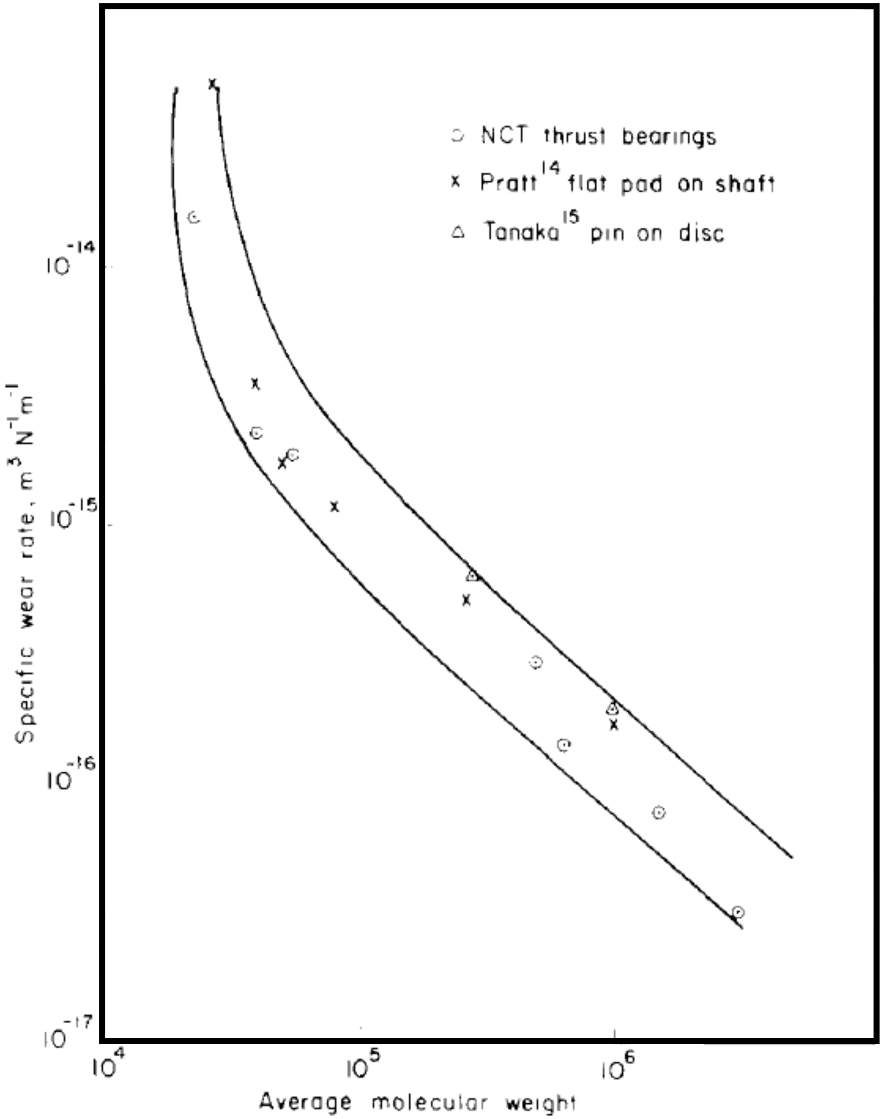


Source: Marzouk

The Effect of Molecular Weight on Wear Rate of Polyethylenes



Source: Anderson, 1982



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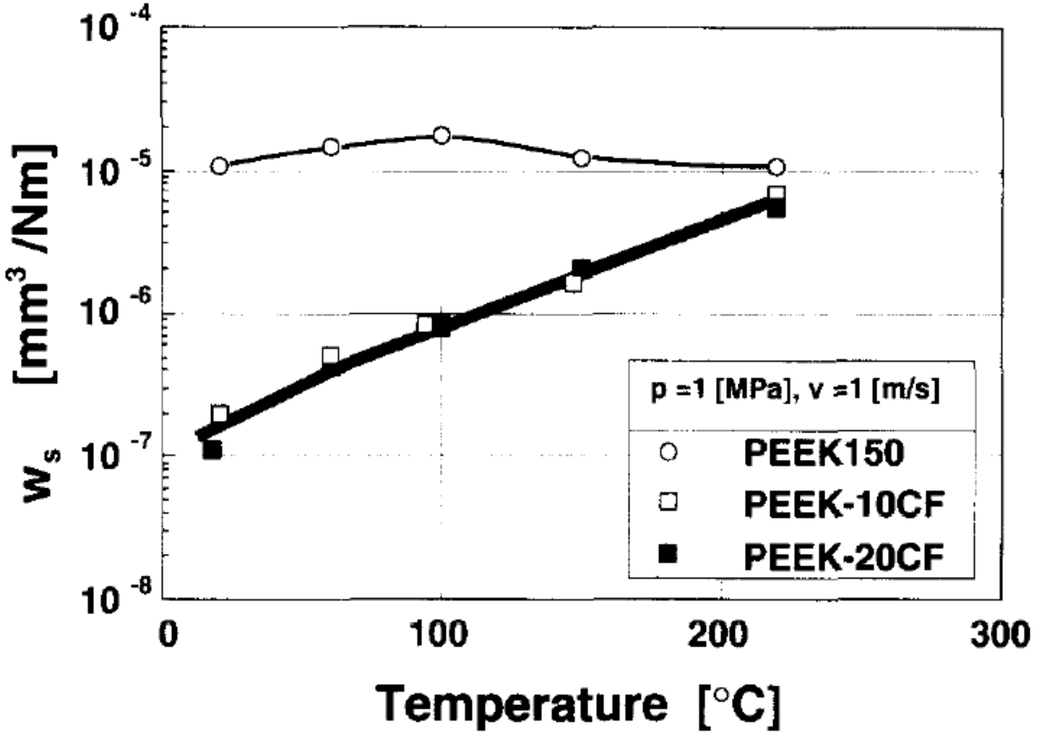
The Effect of Temperature on Wear Rate (important not to generalize)

Specific Wear Rate of PEEK and Short Carbon Fiber Reinforced PEEK Composites as a Function of Temperature



Source: Lu, Z., and Friedrich, K., (1995)

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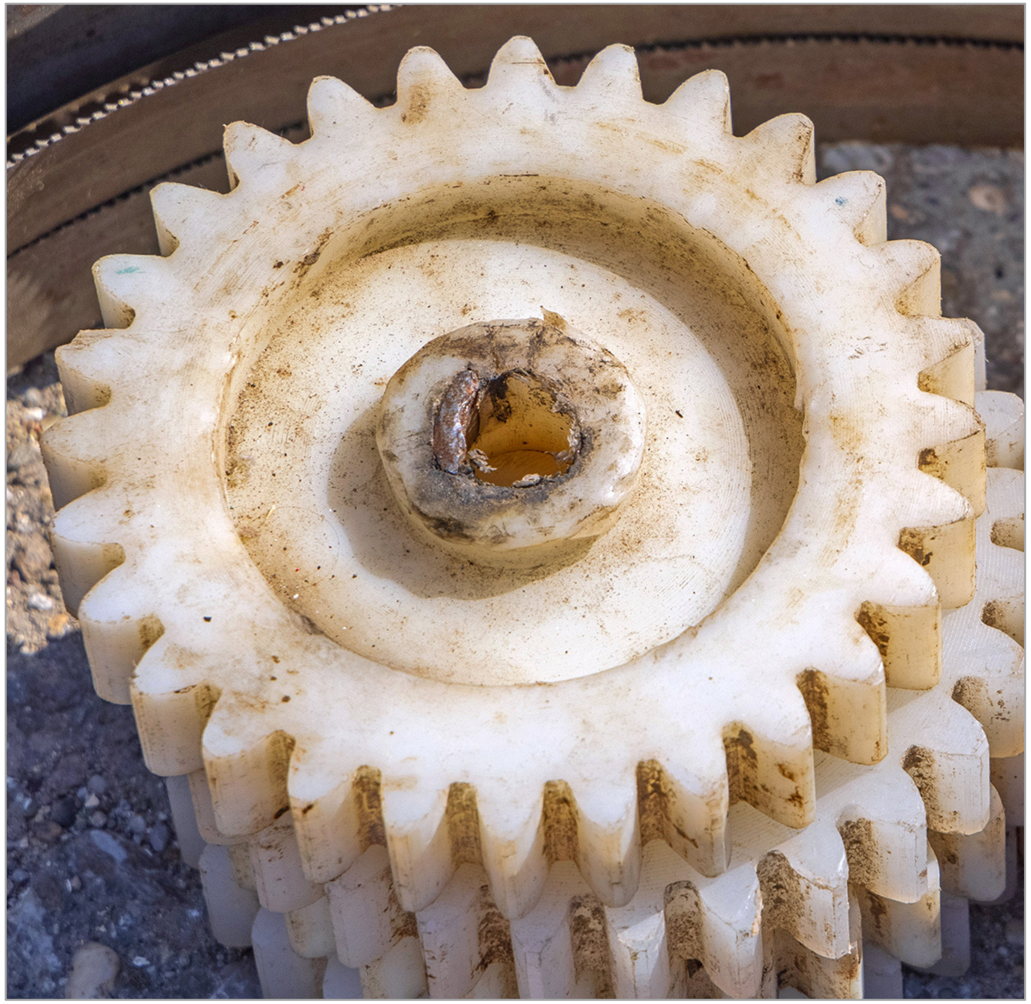
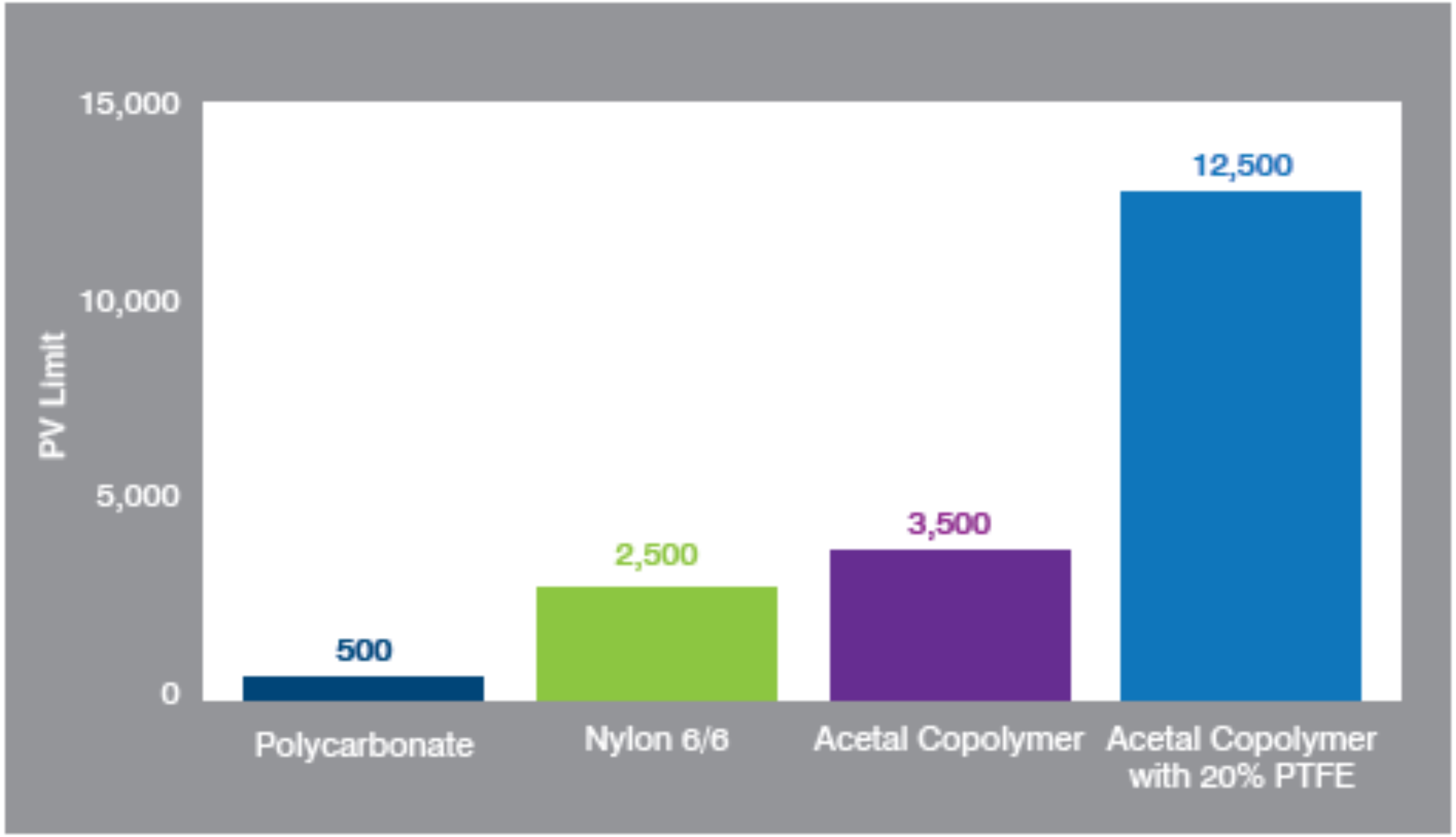
Limiting PV (Pressure-Velocity)



Limiting PV (Pressure-Velocity)

Figure 1. Limiting PV of Various Thermoplastics at 100 fpm
(Dry Wear Against 12 RMS SAE 1040 Steel)



Source: Adapted from Arkles, 1973

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Abrasive Wear

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Abrasive Wear

Abrasive Wear

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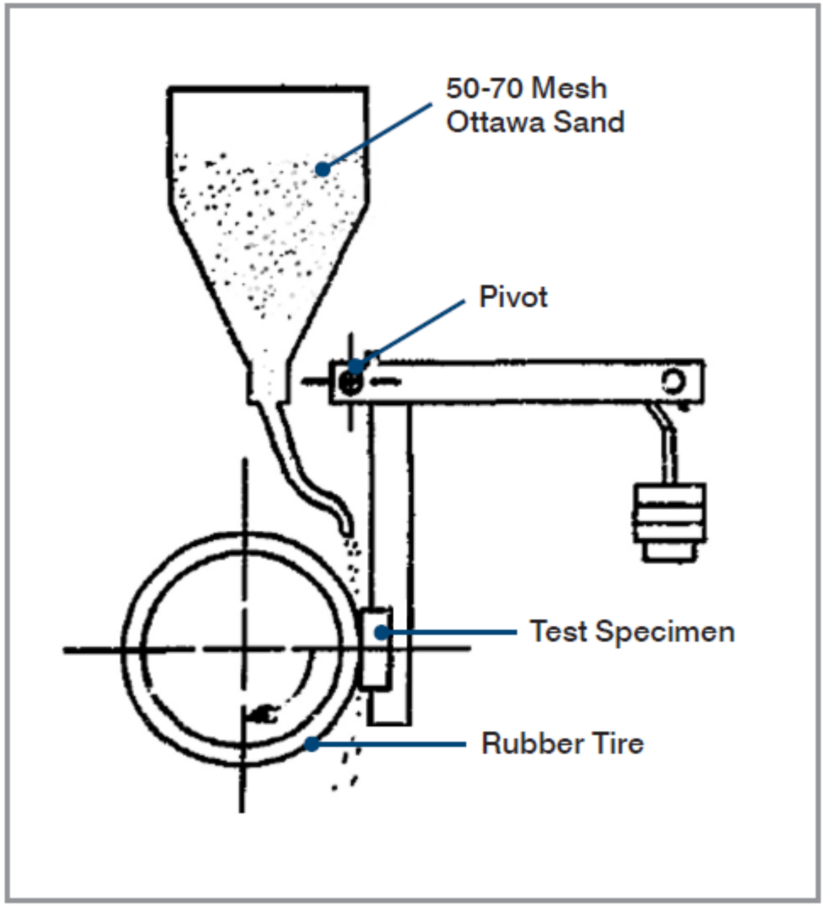
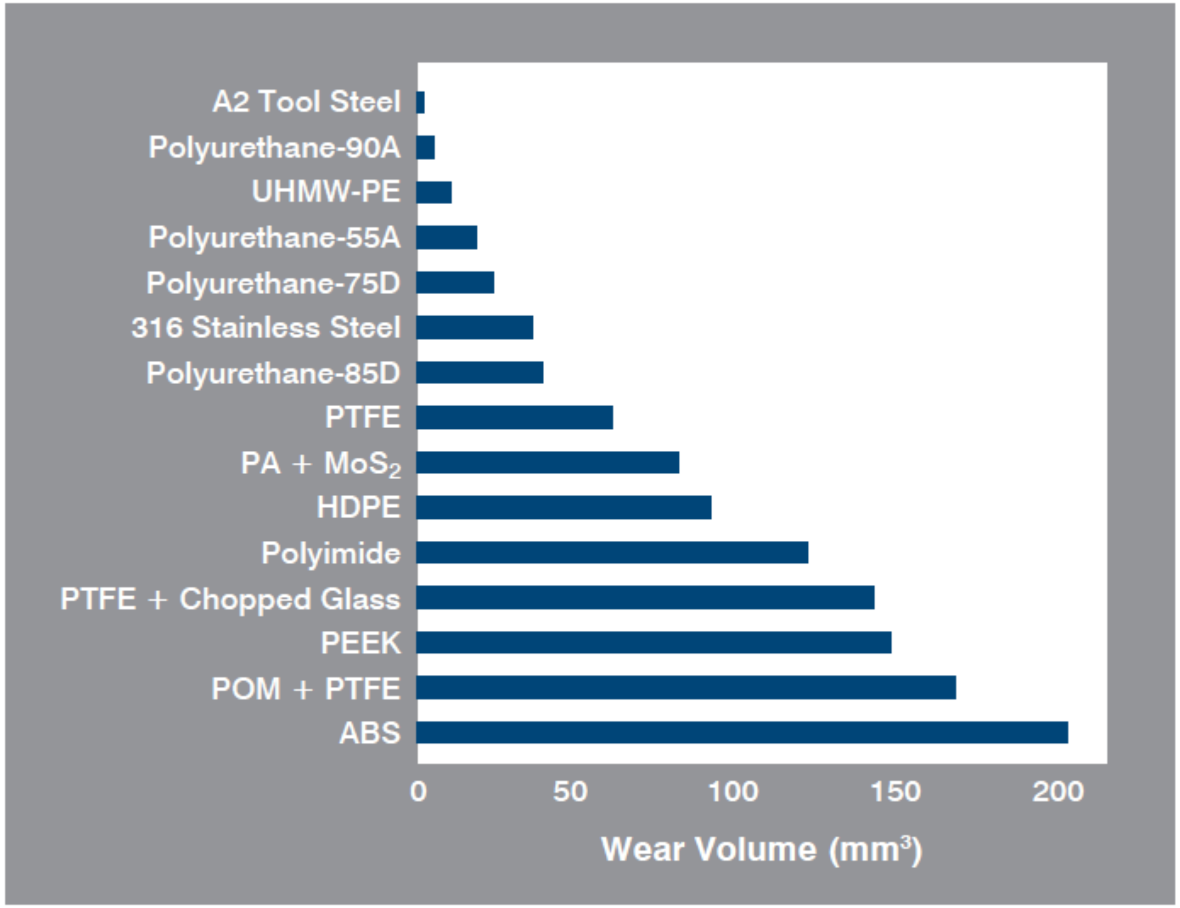
Abrasive Wear

Figure 9. Schematic of a Dry Sand-Rubber Wheel Abrasion Resistance Testing Machine and the Abrasive Wear Test Results for Various Plastic Materials





Source: Adapted from Budinski, 1997

Rolling Contact Fatigue

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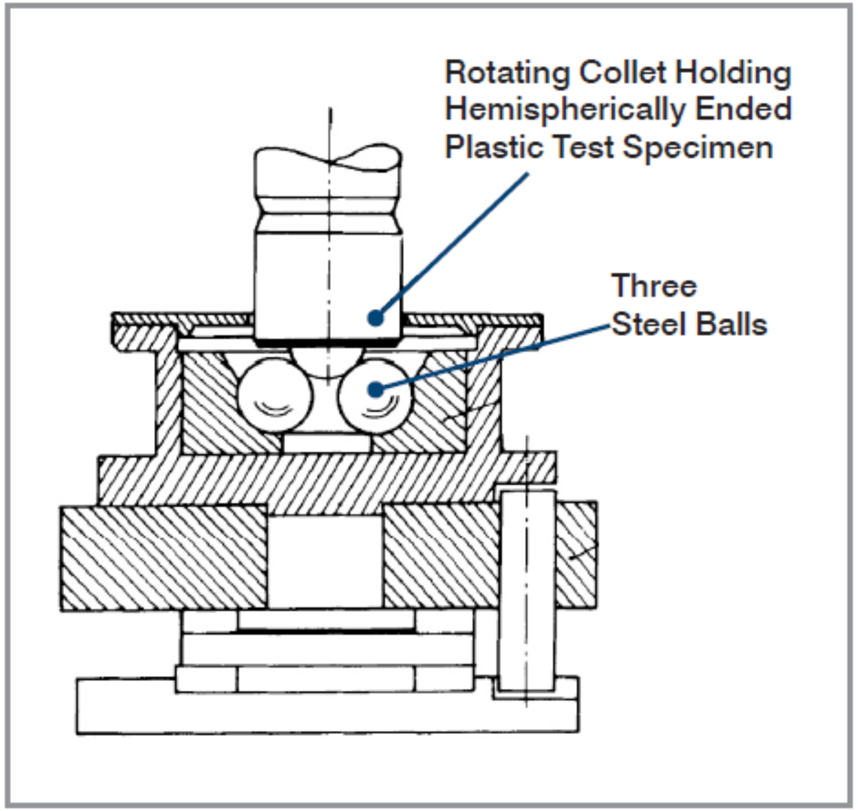
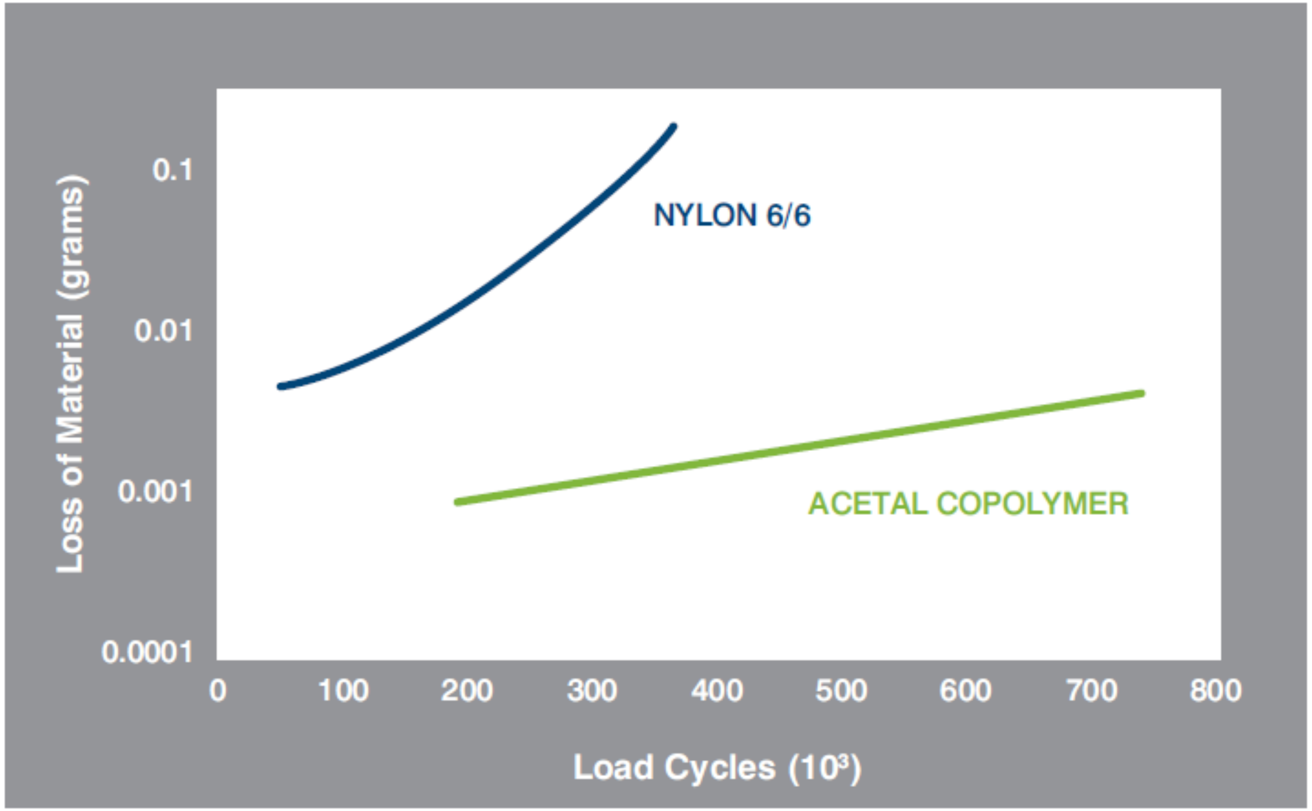
Rolling Contact Fatigue

Figure 10. Schematic of Rolling Contact Fatigue Testing Machine and Material Loss from Rolling Contact 400 RPM, 10N Load, Dry Conditions





Source: Adapted from Stolarski, 1993

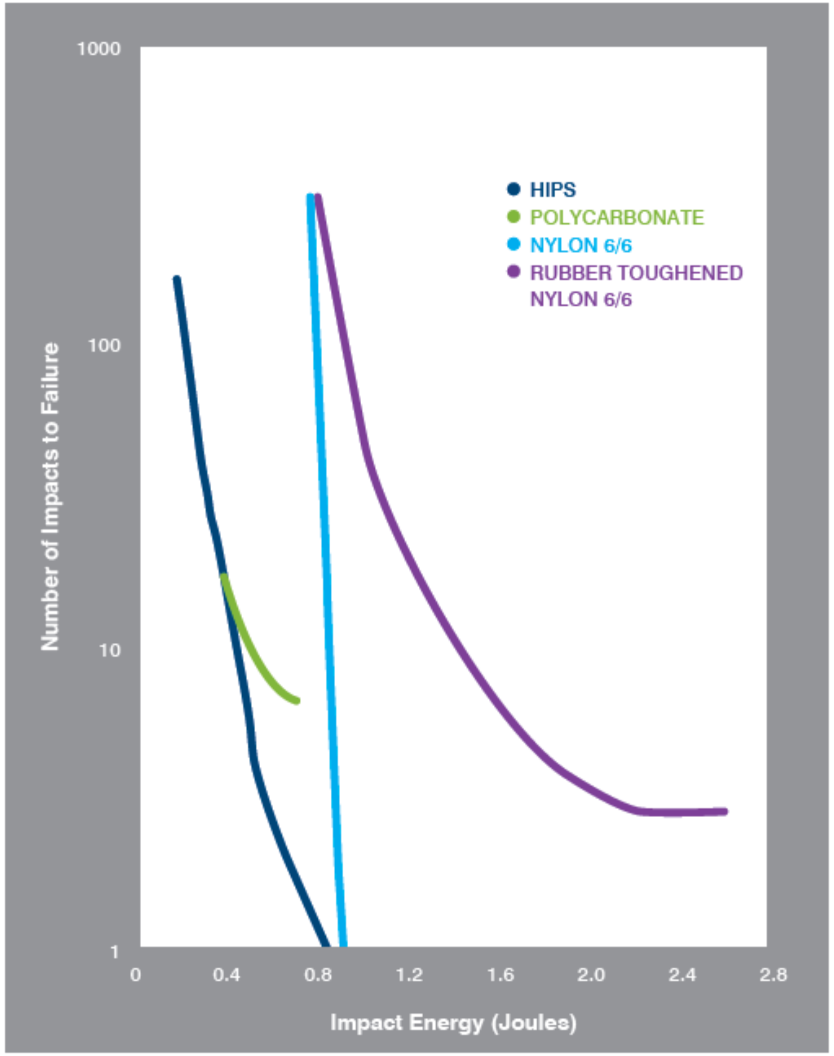
Note: PEEK exhibited no measurable material loss under the test conditions.

Impact Fatigue

White plastic berry picker bars on a harvesting machine experience repeated impacts as the machine harvests fruit.

Impact Fatigue

Figure 11. Impact Fatigue Resistance



Source: Adapted from Adams, 1983

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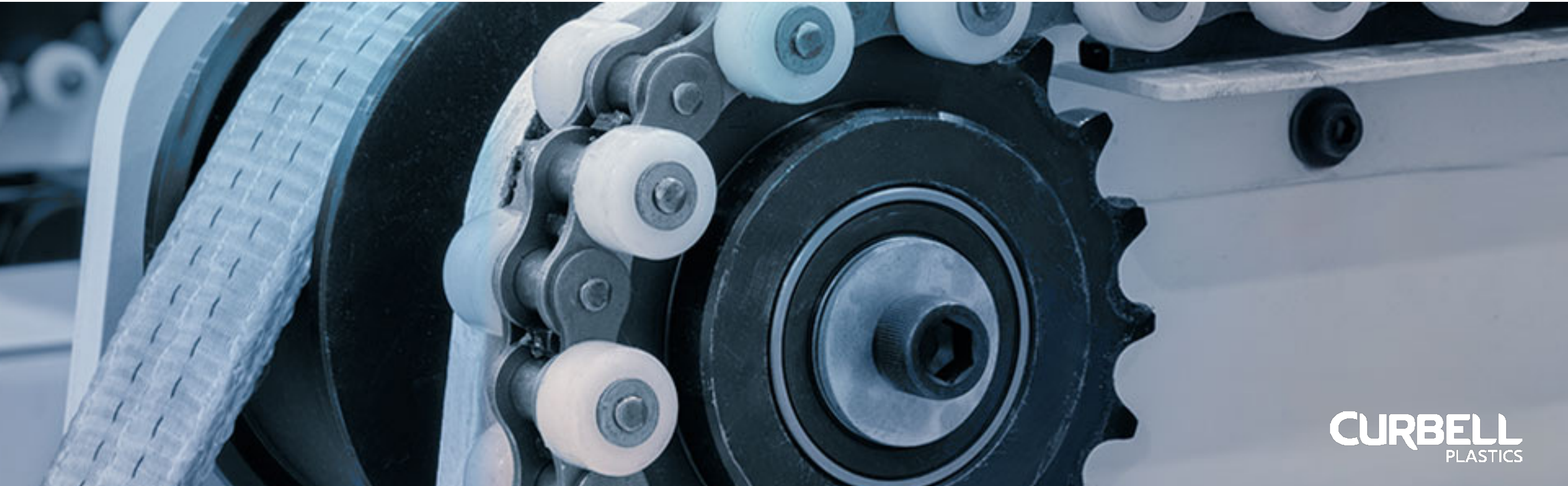
Plastic Materials for Friction and Wear Applications



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UHMW Polyethylene

Advantages

- Low friction
- Outstanding abrasion resistance
- Gentle on mating surfaces
- Tough and durable

Limitations

- Low strength and stiffness
- High rate of thermal expansion makes it difficult to hold tight tolerances

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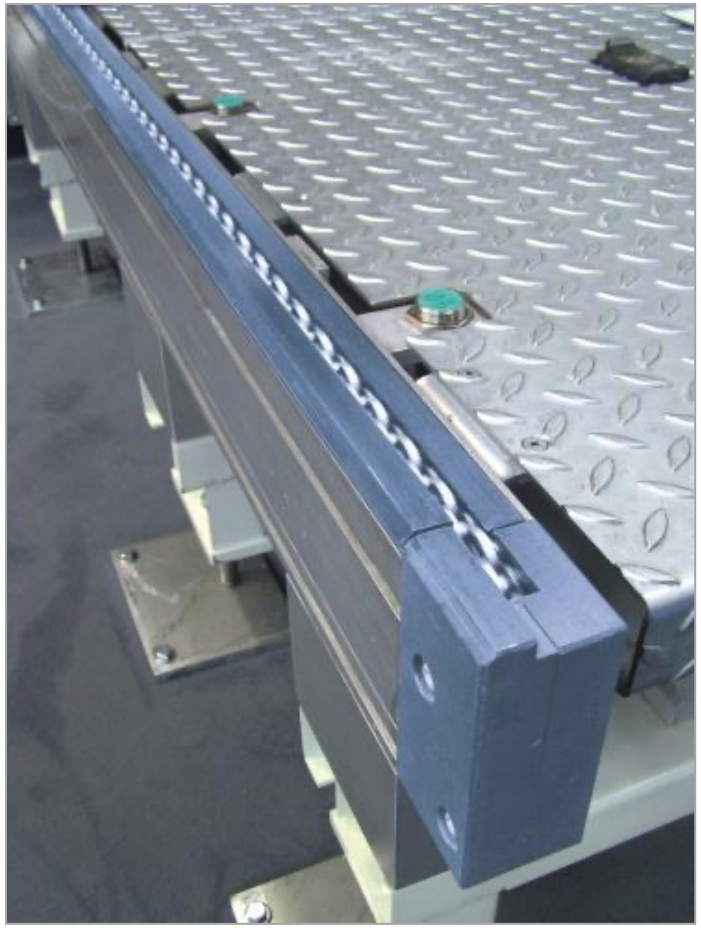
LubX® C

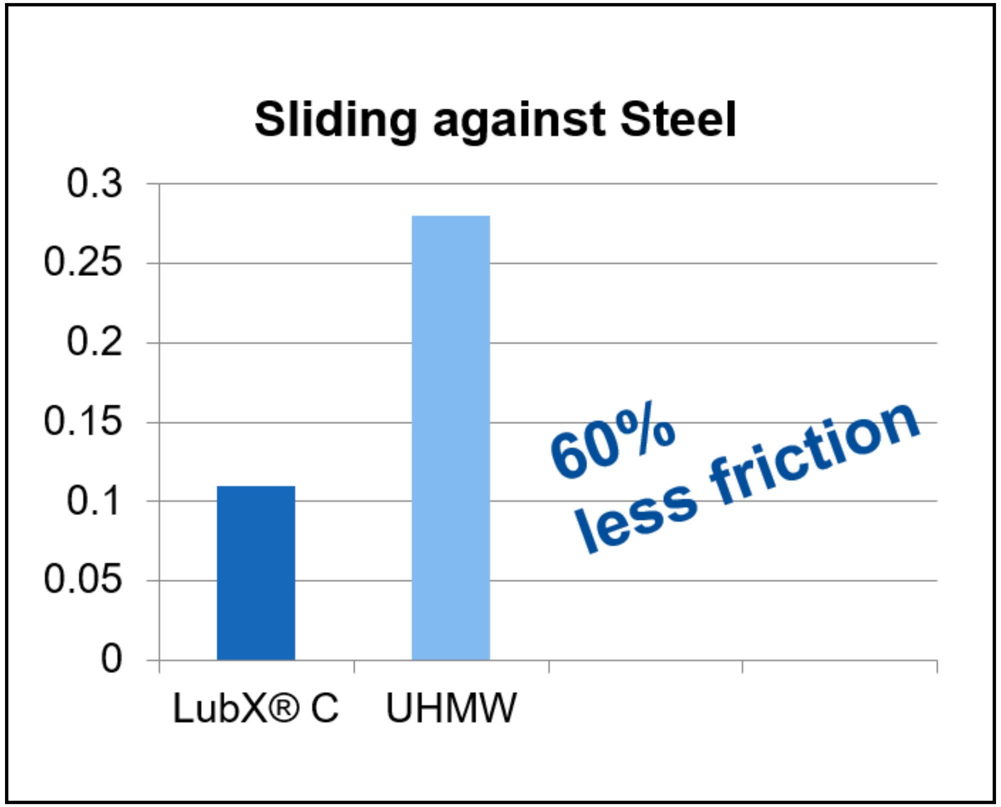
Special grade of UHMW-PE with reduced friction manufactured by Röchling Group

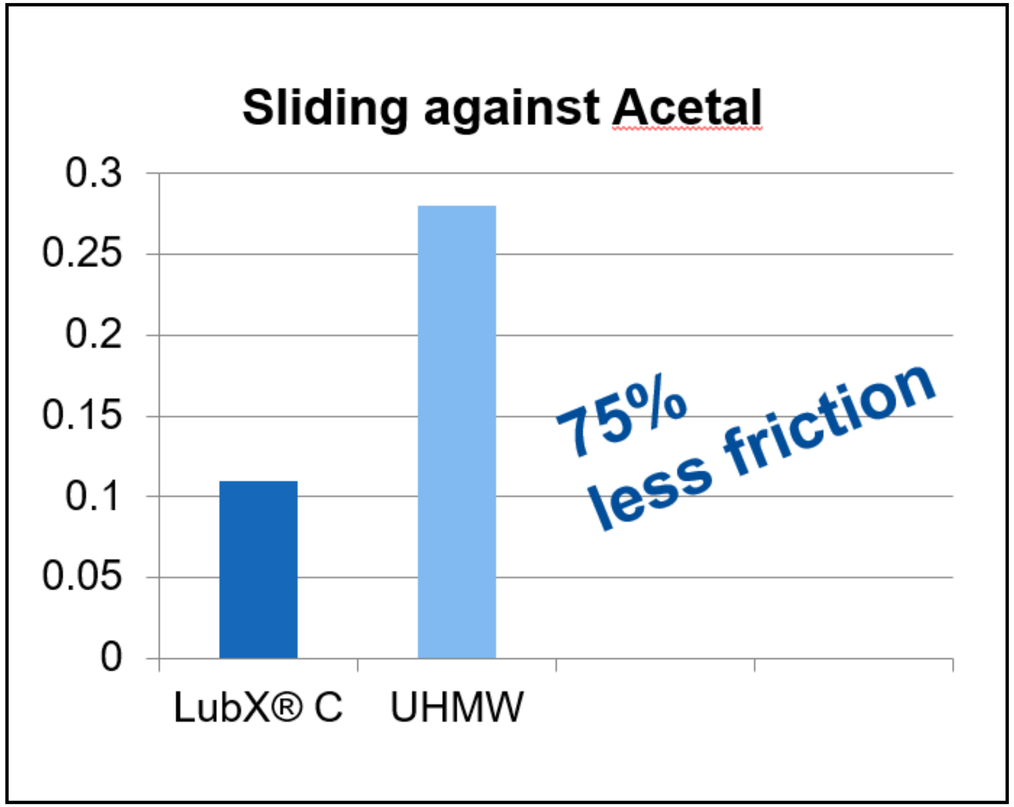


Source: Röchling Group

LubX® C – special grade of UHMW-PE with reduced friction

Coefficient of sliding friction under dry conditions





Source: Röchling Group

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Acetal (including Delrin®)

Advantages

- Easy to machine
- Stronger and stiffer than UHMW-PE
- Excellent friction and wear characteristics
- Good rolling contact fatigue characteristics
- PTFE filled grades available

Limitations

- Moderately high CTE makes it challenging to hold tight tolerances

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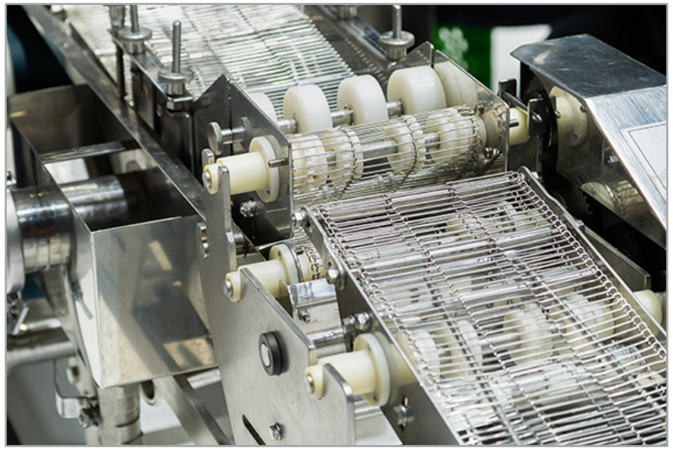
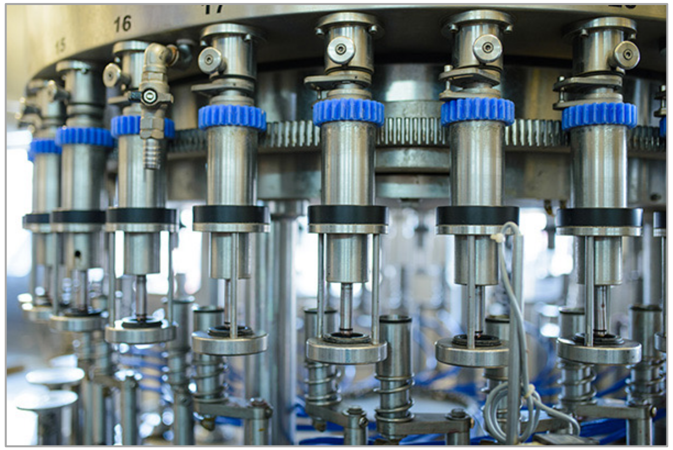
Nylon

Advantages

- Can be cast into large sheets, rods, tubes, and near net shapes
- Available in many different colors and grades
- Good friction and wear characteristics
- Stronger than UHMW-PE or acetal





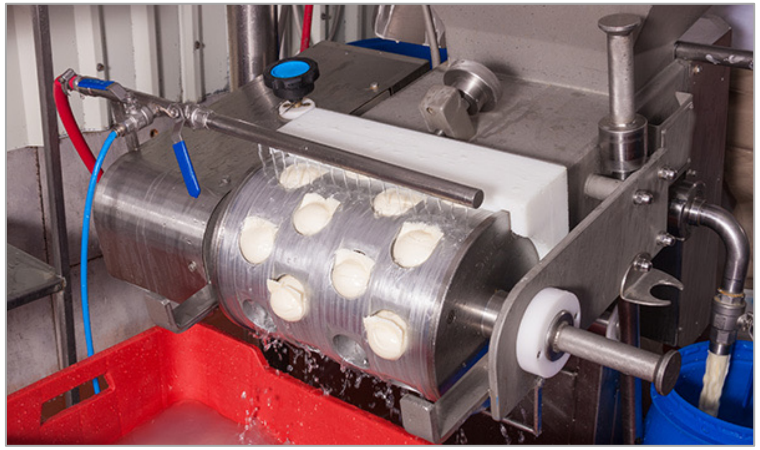
Limitations

- High water absorption makes it challenging to hold tight tolerances
- Becomes softer when it absorbs moisture
- Can be plasticized by certain liquid lubricants

Semicrystalline PET

Advantages

- Very low rate of thermal expansion as well as low water absorption allows for tight tolerances
- Good friction and wear characteristics
- Available in lubricated grades

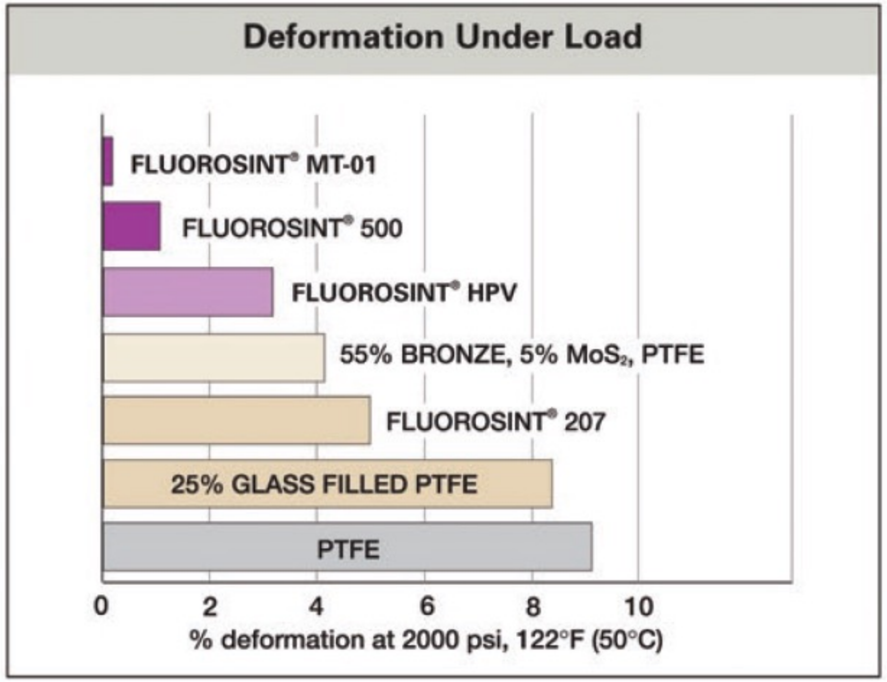


Limitations

- Somewhat brittle
- Limited resistance to steam

Fluorosint®

- Family of filled PTFE materials manufactured by Mitsubishi Chemical Advanced Materials
- Stronger and stiffer than PTFE
- Better dimensional stability and creep resistance than PTFE
- FDA compliant grades available



Source: MCAM (Mitsubishi Chemicals Advanced Materials)

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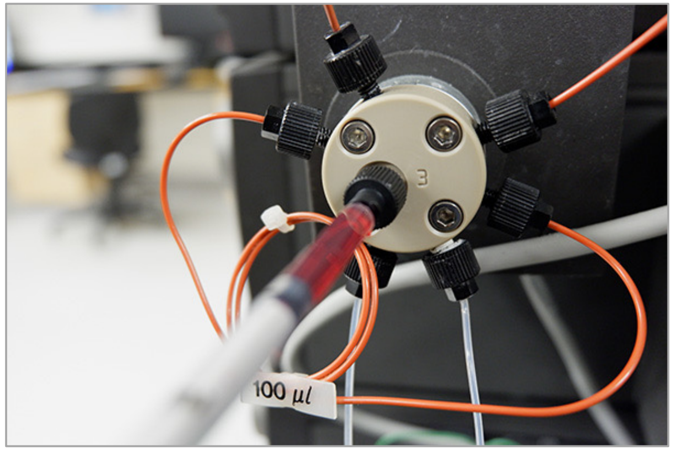
PEEK

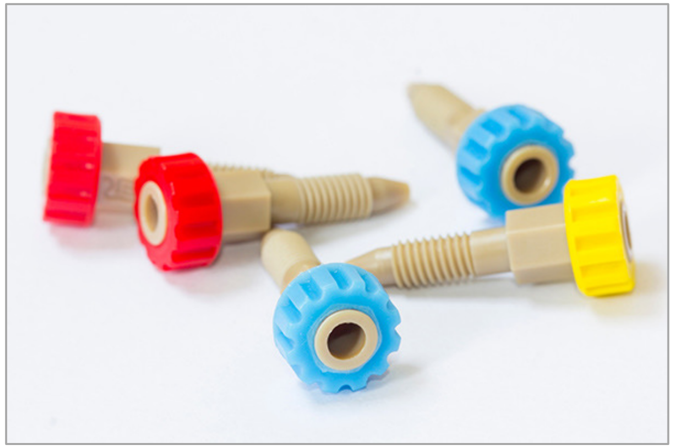
Advantages

- Suitable for high temperature applications
- Steam resistant
- Outstanding chemical resistance
- Strong and stiff
- Friction and wear grades available
- FDA compliant grades available

Limitations

- Relatively expensive

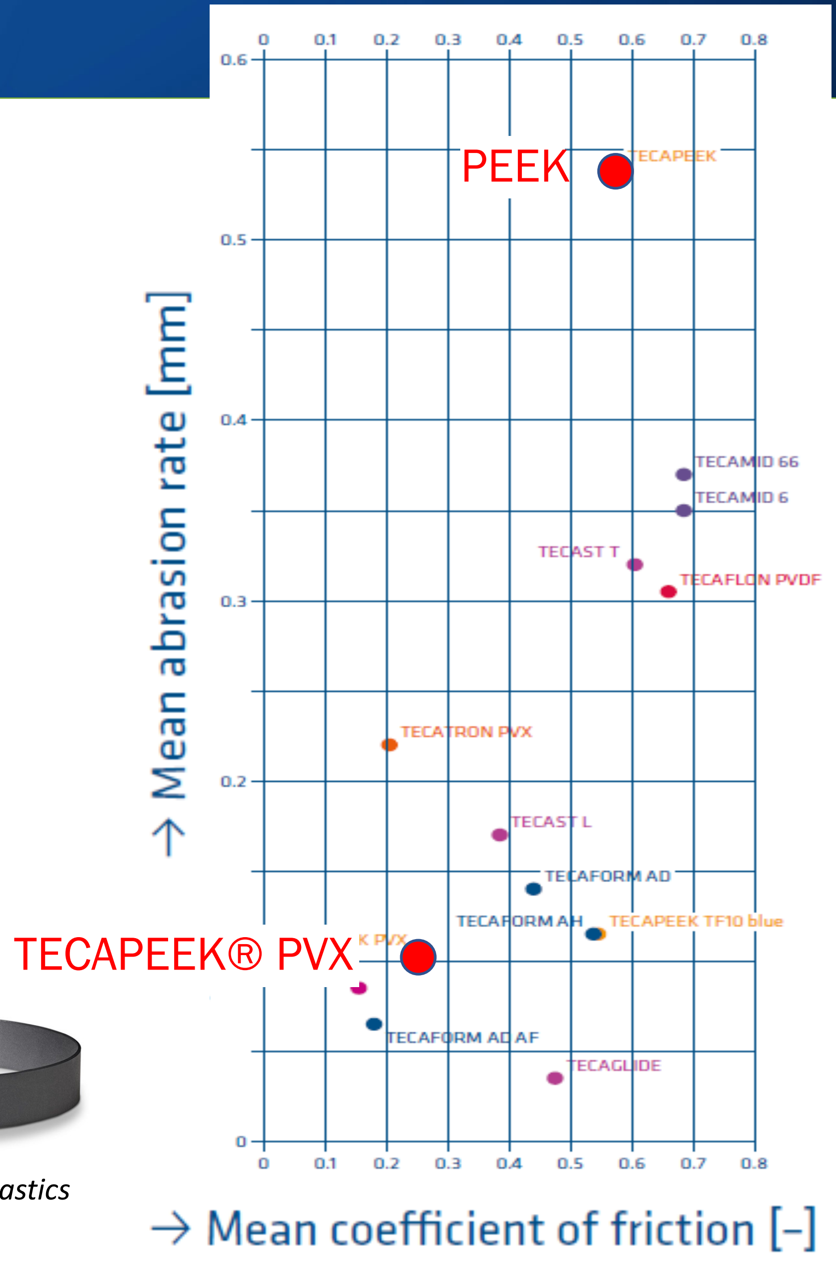




TECAPEEK® PVX

- High performance friction and wear grade of PEEK manufactured by Ensinger Inc.
- Formulation includes PTFE, graphite, and carbon fiber
- Low friction and low wear rate
- High and low operating temperatures
- Chemical resistance
- Radiation resistance

Source: Ensinger Plastics



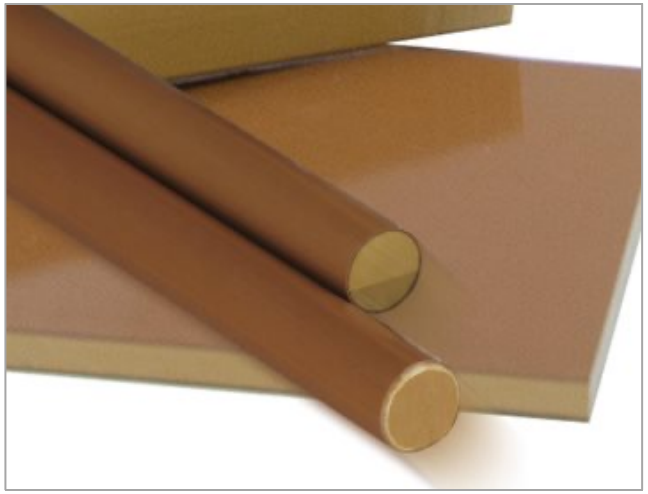
Torlon® PAI

Advantages

- Very high strength and stiffness
- Higher operating temperature than PEEK
- Filled grades available

Limitations

- Expands in humid conditions
- Very expensive
- Limited resistance to steam



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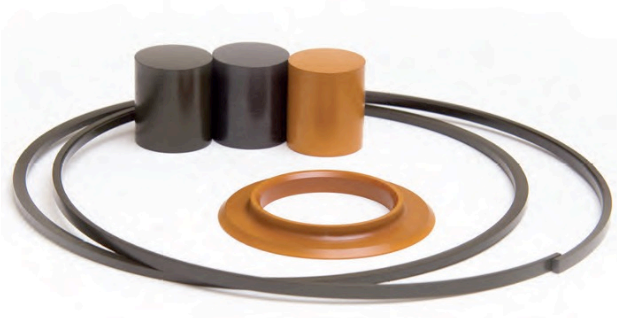
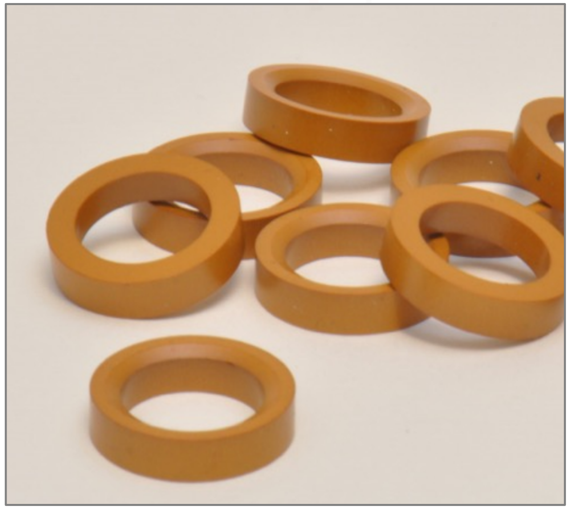
DuPont™ Vespel® Polyimide

Advantages

- Good mechanical properties throughout a broad temperature range
- Higher operating temperature than PEEK or Torlon®
- Ductile at cryogenic temperatures
- Dimensional stability - CTE, creep, stress relaxation
- Outstanding friction and wear properties (certain grades)
- Very high limiting PV





Limitations

- Very expensive
- Limited resistance to steam

Very important to have authentic material

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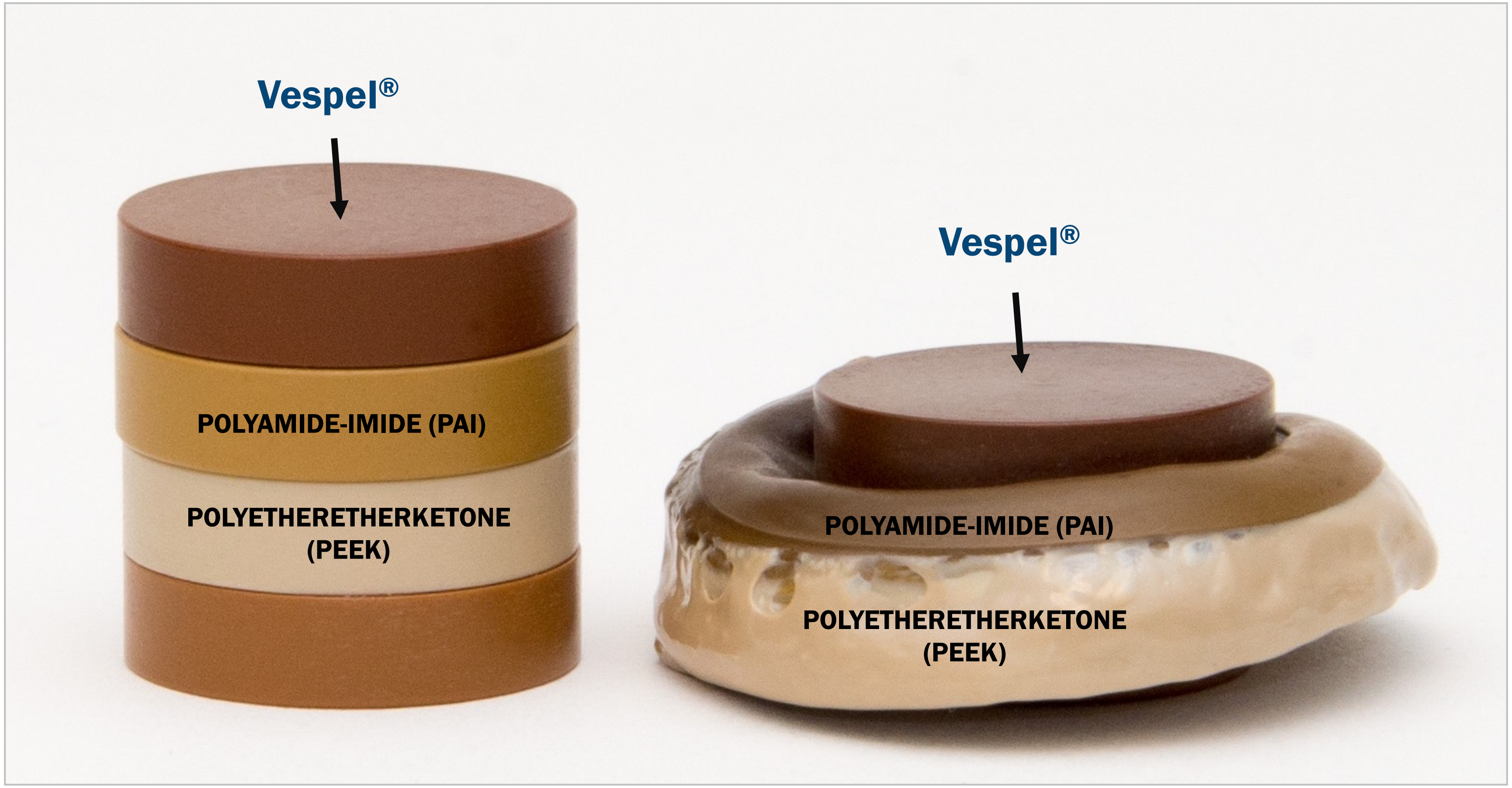
High Temperature Performance of DuPont™ Vespel® Polyimide



BEFORE

AFTER
Compressive Load, 700 °F

Source: DuPont

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High PV Value for Friction and Wear Grades of DuPont™ Vespel® Polyimide

PV Limits of Unlubricated Bearing Materials

Table 1 shows the maximum PV limits for unlubricated VESPEL parts and several other unlubricated bearing materials under conditions of continuous motion. Properly lubricated VESPEL parts can withstand approximately 1 million psi-ft/min.

TABLE I—PV LIMIT GUIDELINES**

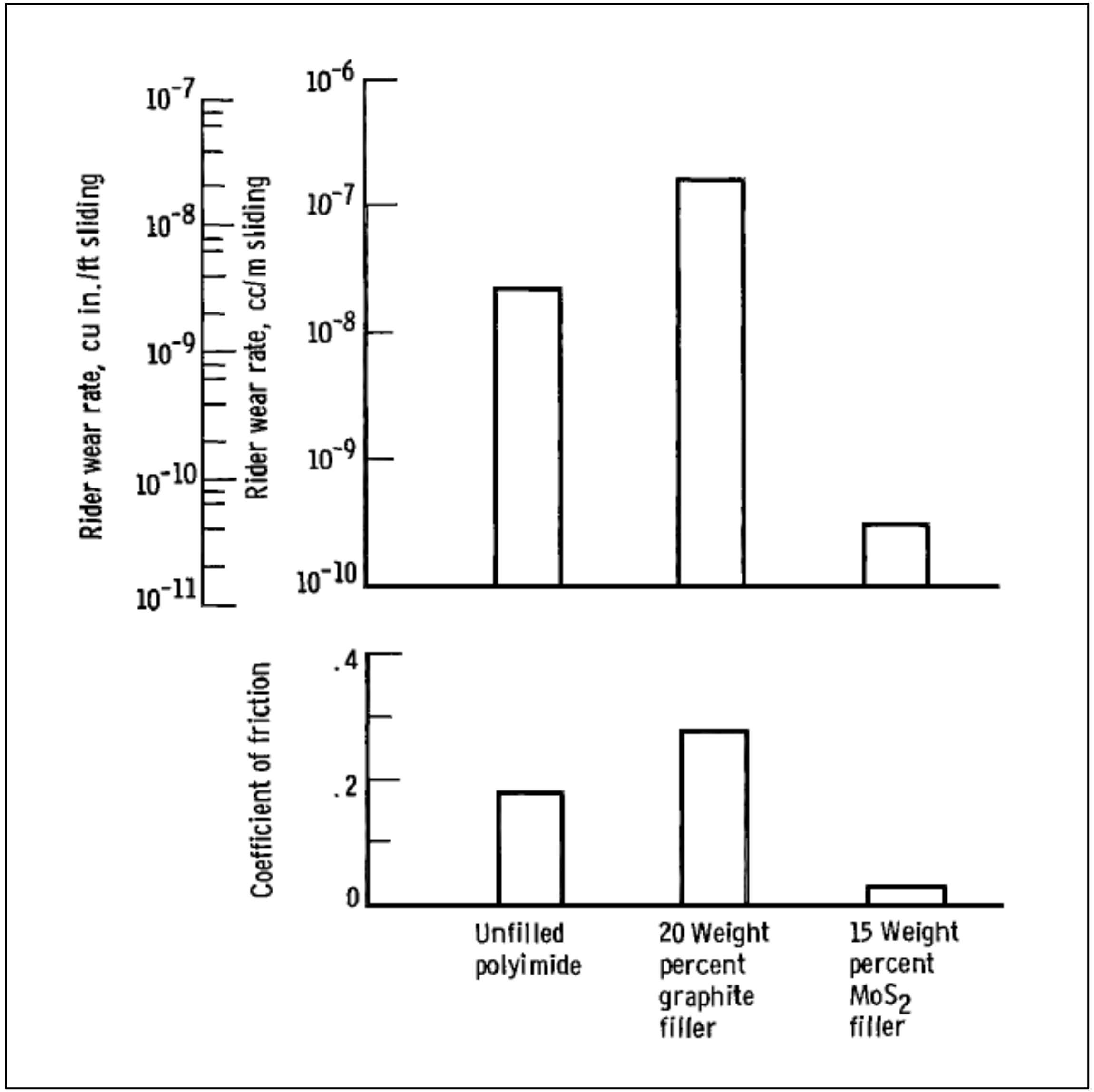
Material	Filler	lb-ft / in²-min	kg-m / cm²-sec	Maximum Contact Temperature °F	Maximum Contact Temperature °C
SP-21	15% Graphite	300,000	107	740	393
SP-22	40% Graphite	300,000	107	740	393
SP-211	15% Graphite 10% PTFE	100,000	36	500	260
PTFE*	Unfilled	1,800	0.64	500	260
PTFE*	15–25% Glass	12,500	4.5	500	260
PTFE*	25% Carbon	20,000	7.1	500	260
PTFE*	60% Bronze	18,500	6.6	500	260
Nylon	Unfilled	4,000	1.4	300	217
Acetal	PTFE Unfilled	7,500 3,500	2.7 1.2	250	201

* At 100 fpm.

** These guideline values are supplied for reference only. PV limits for any material vary with different combinations of pressure and velocity as well as with other test conditions. Consult manufacturer's literature for detailed information.

Source: DuPont

Friction and Wear of Molybdenum Disulfide Filled Polyimide in Vacuum



Polyimide compositions sliding on 440-C stainless steel in vacuum (10^{-10} mm Hg).

- Sliding velocity: 197 cm/sec
- Load: 1000 grams
- Duration of run: 1hour

Source: Buckley

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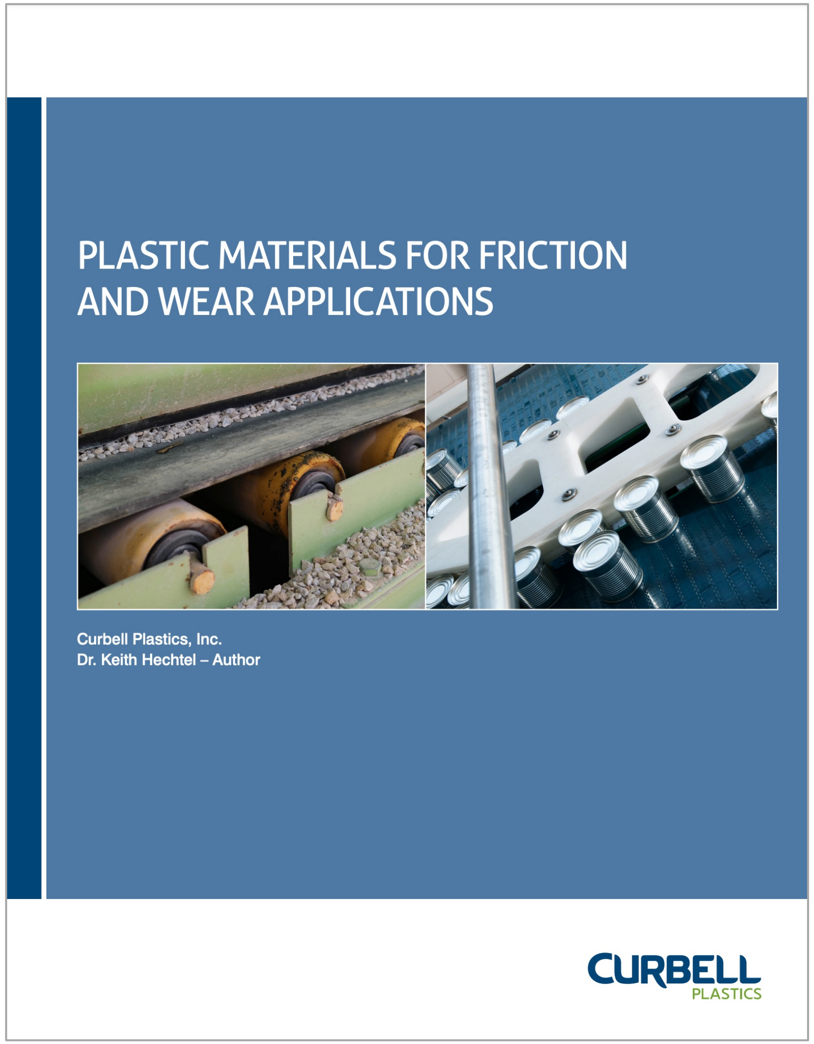
Selecting Plastic Materials for Friction and Wear Applications

1. Determine the mechanism (or mechanisms) of wear
   (sliding wear, abrasive wear, impact fatigue, or rolling contact fatigue)
2. Consider the chemistry of the mating surface (soft metal, hard metal, or plastic)
3. Quantify the relevant tribological variables (loads, velocity, etc.)
4. Consider environmental factors (temperature, humidity, etc.)
5. Identify base polymers that are capable of operating under the mechanical loads and the environmental conditions (example: steam)
6. Consider which of the candidate base polymers has the required friction and wear characteristics
7. Determine which (if any) additives to the polymer formulation would enhance friction and wear performance
8. Conduct empirical testing

Plastic Materials for Friction and Wear Applications White Paper

For additional information about plastics for friction and wear applications [read our new white paper](#).


PLASTIC MATERIALS FOR FRICTION AND WEAR APPLICATIONS

Curbell Plastics, Inc.
Dr. Keith Hechtel – Author

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Thank you for your time today! Questions?

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