Plastic Materials for Industrial Machinery

Webinar Presented by Curbell Plastics

Agenda

- Advantages of Plastic Materials for Industrial Machinery
- Design Considerations
- Plastic Materials Technology
- Plastic Part Geometry

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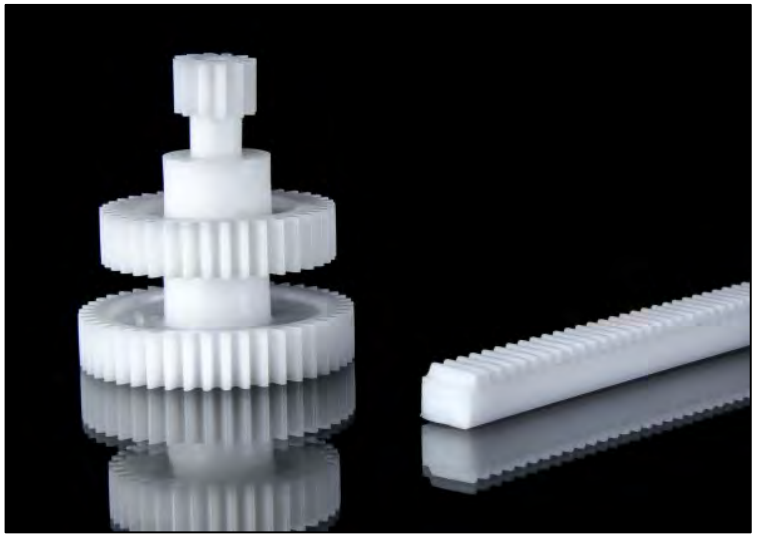
Advantages of Plastics for Industrial Machinery

- Lightweight
- Reduce noise / vibration
- Easy to fabricate
- Grades available with excellent chemical resistance including resistance to cleaners and disinfectants
- Grades available that have low friction without external lubrication
- FDA complaint grades available



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Considerations for Plastic Part Design

- Immediate failure
  - Mechanical loads
  - Impact
- Failure over time
  - Fatigue
    - Flexural fatigue
    - Impact fatigue
    - Rolling contact fatigue
    - Thermal cycling
  - Creep / stress relaxation
  - Wear

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Poll Question #1

Which of these modes of plastic part failure have you seen? Please check all of the ones that you have experienced.

- Failure due to excessively high mechanical loads
- Failure due to impact
- Failure due to fatigue
- Failure due to creep or stress relaxation
- Failure due to excessive wear
- Failure from chemical attack

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Creep

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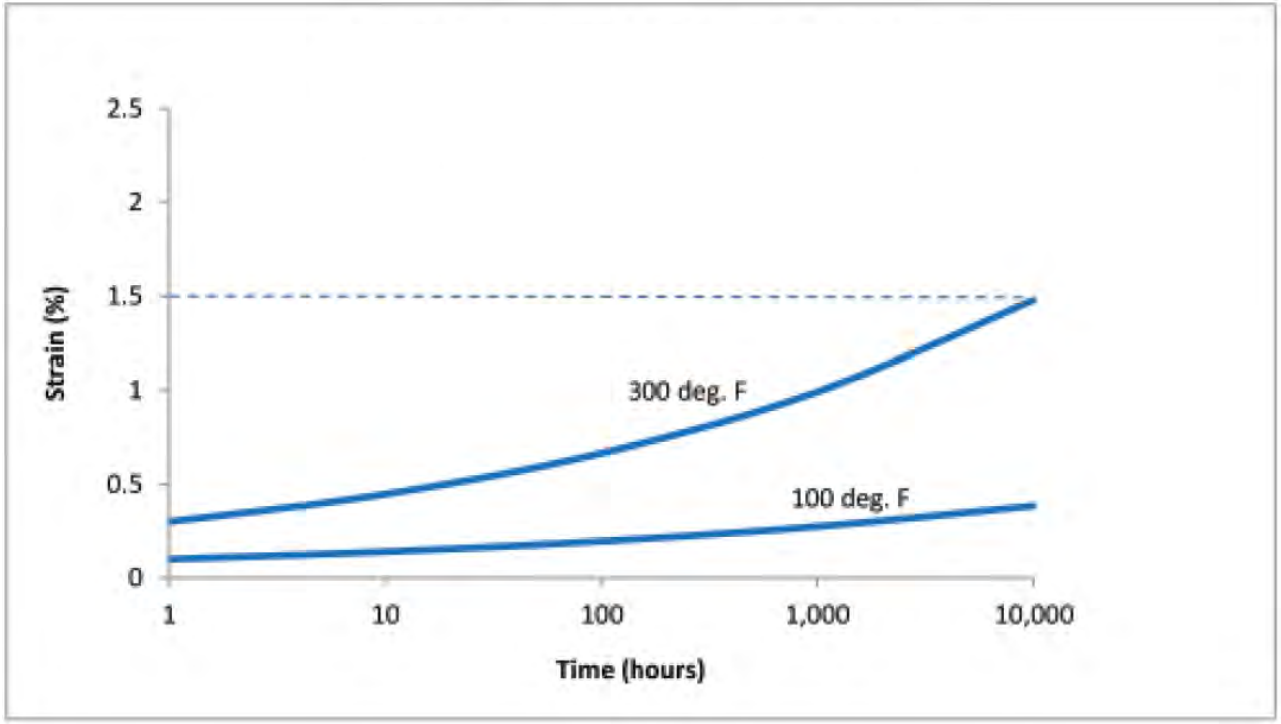
Creep

Thermoplastic Creep Behavior
1000 psi load at various operating temperatures



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Considerations for Plastic Part Design

- Electrical properties
  - Dielectric Strength
  - ESD Properties
  - Dielectric Constant
- Water / humidity
  - Softening
  - Swelling
- Vacuum
  - Outgassing
  - Wear
- Aesthetics

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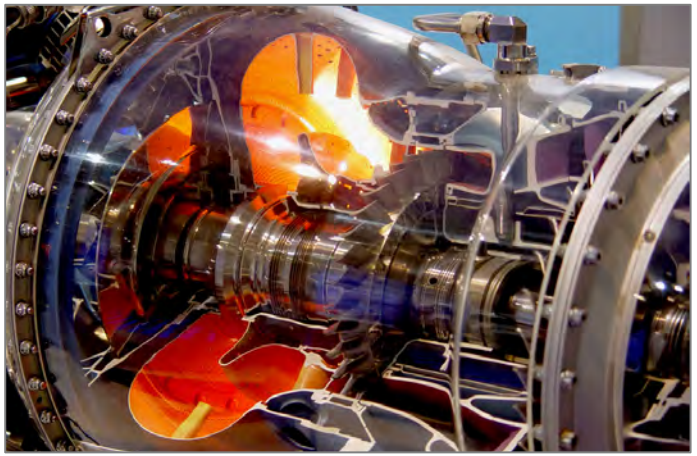
Operating Temperature

- Change in modulus
- Change in elongation
- Creep behavior
- Thermal expansion
- Degradation



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Chemical Attack and ESC

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Considerations for Plastic Part Design

- Friction and Wear
  - A system property - not a material property
  - Counterface chemistry, roughness, and hardness
  - Loads and speeds
  - Mechanism of wear (sliding, abrasion, rolling contact, etc.)
- Additives
  - PTFE
  - Graphite
  - Oil
  - MoS_2

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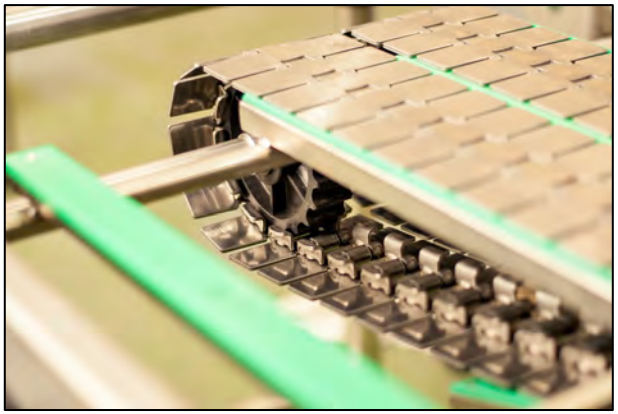
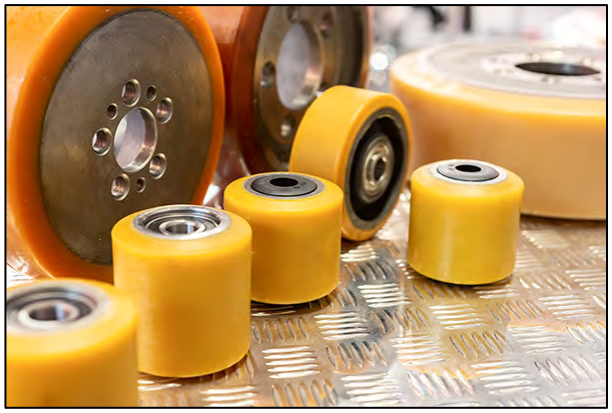
Mechanisms of Polymer Wear

Sliding Wear



Rolling Contact Fatigue



Impact Fatigue Followed by Rolling Contact Fatigue and Sliding Wear

Abrasive Wear

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Effect of PTFE Additives on Sliding Wear Against Hardened Steel

Material:	Specific Wear Rate ($x10^{-15} m^3 N^{-1} m^{-1}$)	Coefficient of Friction
Nylon 6/6	15.9	0.57
Nylon 6/6 with 15% PTFE	0.6	0.14
Acetal	2.1	0.45
Acetal with 15% PTFE	0.4	0.22

Source: Adapted from Friction and wear behavior of 18 polymers in contact with steel in environments of air and water by J. Mens. Wear, 149 (1991) pages 255 to 268.

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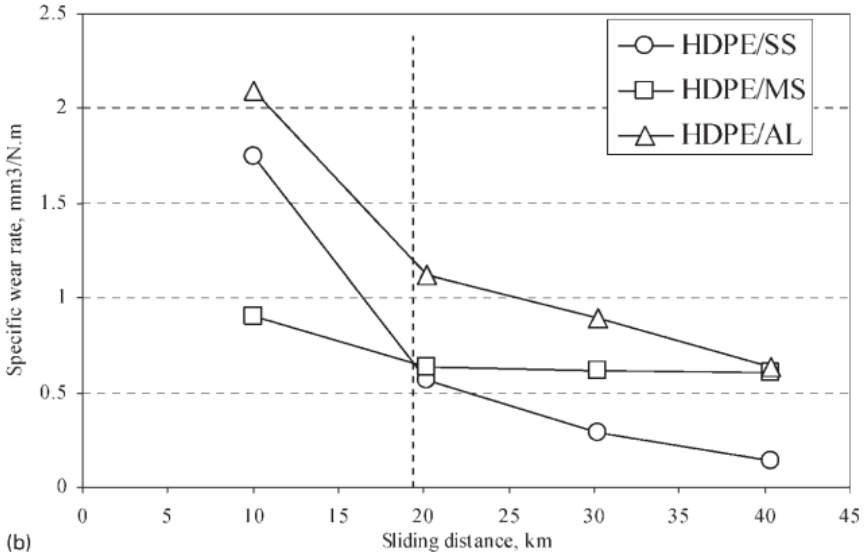
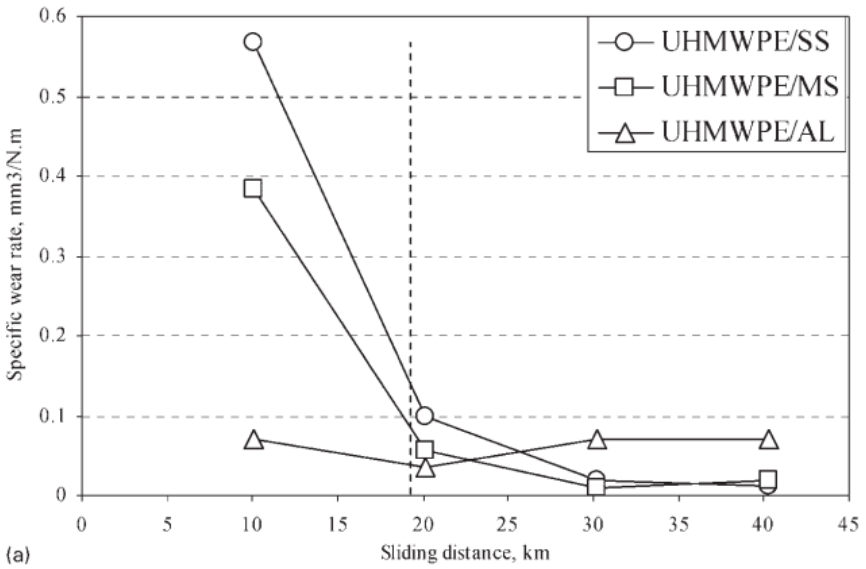
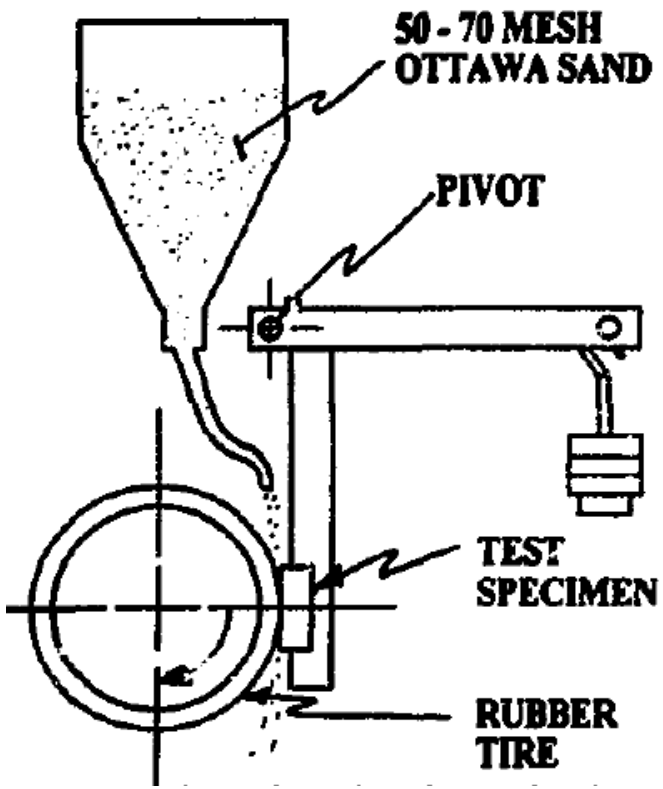
Sliding Wear of HDPE and UHMW-PE Against Stainless Steel, Mild Steel, and Aluminum

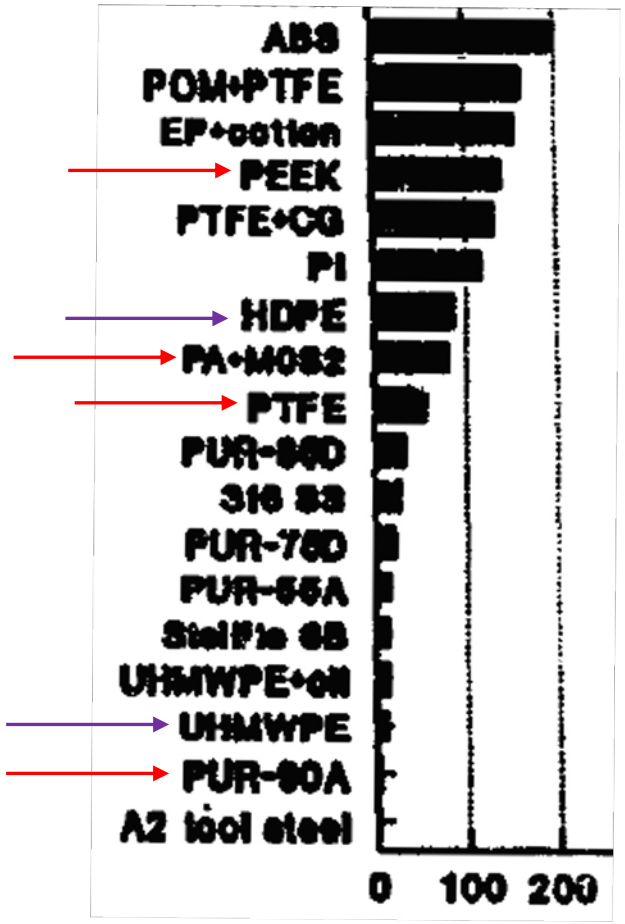




Source: Adhesive wear and frictional characteristics of UHMWPE and HDPE sliding against different surfaces by Belal Yousif. Tribology – Materials Surfaces & Interfaces, June, 2010.

Abrasive Wear





Wear Volume (mm^3)

Source: Resistance to particle abrasion of selected plastics by Kenneth Budinski. Wear 203-204 (1997) 302-309.

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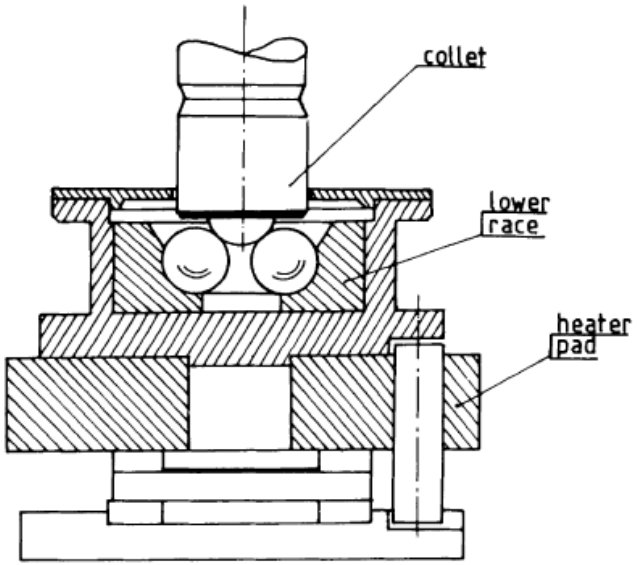
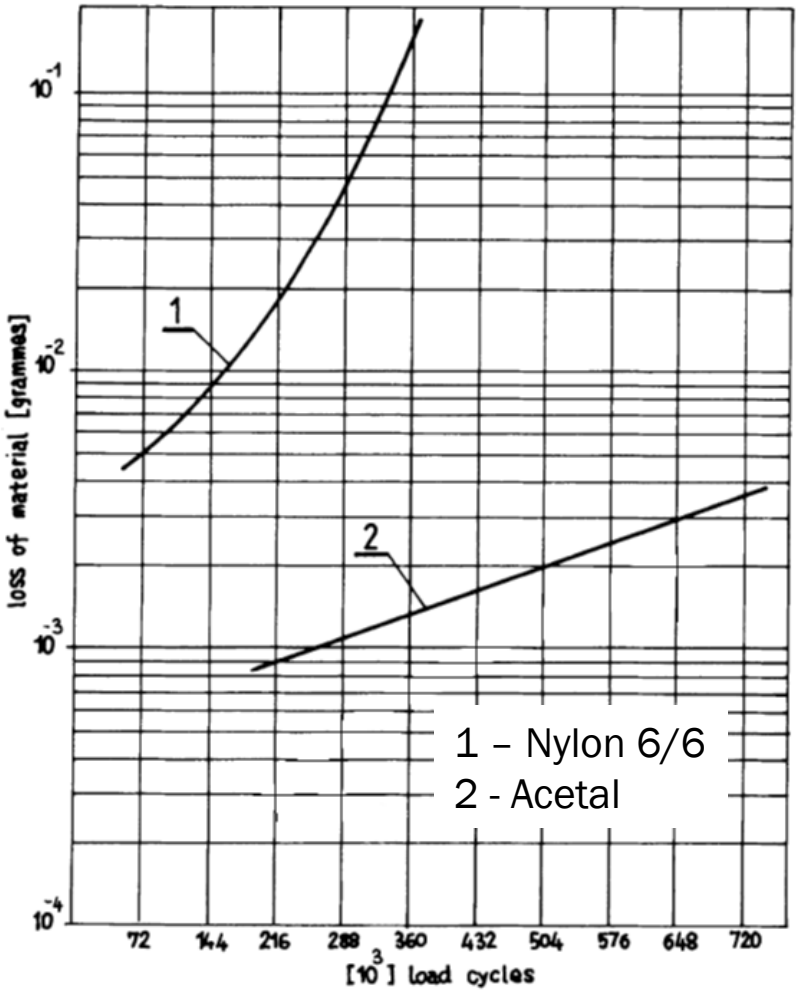
Rolling Contact Fatigue





400 RPM, 10 N load, Dry Conditions

Source: Adapted from Rolling contact fatigue or polymers and polymer composites by Tadeusz Stolarski. Advances in Composite Tribology edited by K. Friedrich. Pages 629 to 667.

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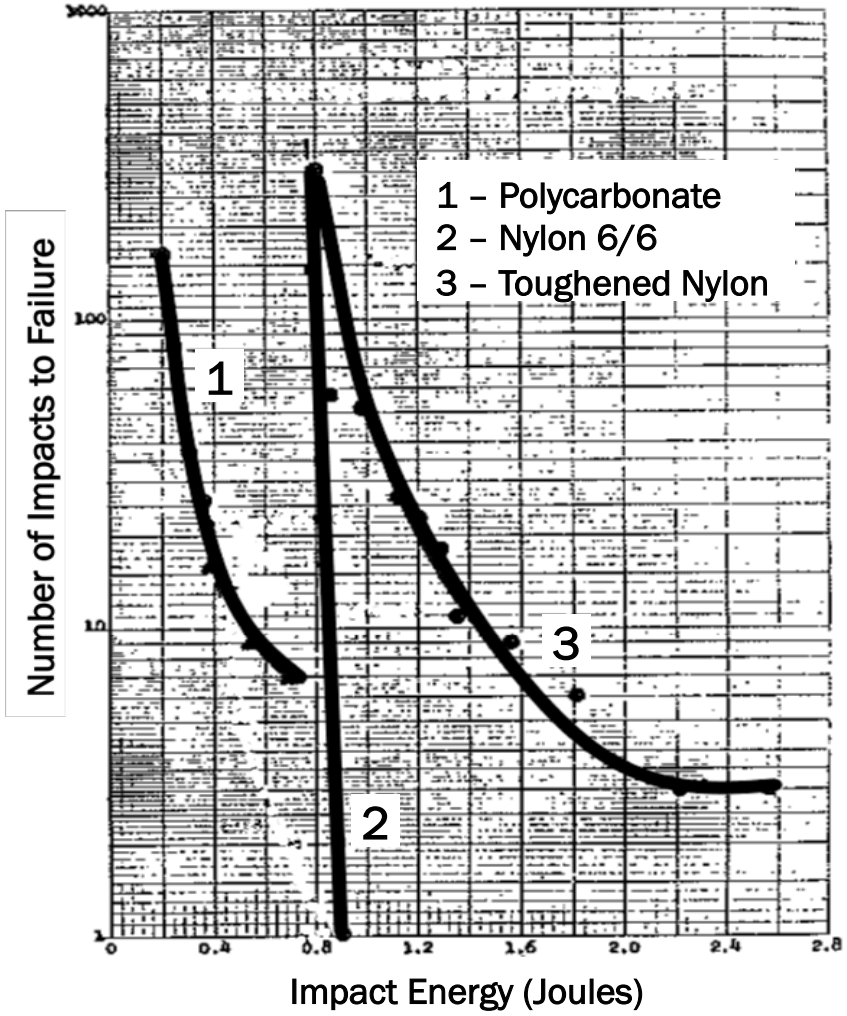
Impact Fatigue



Source: Adapted from Fatigue of Polymers by Instrumented Impact Testing by George Adams.

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Poll Question #2

Which mechanism of wear do you most often encounter with plastic materials?

- Sliding wear
- Rolling contact fatigue
- Impact fatigue
- Abrasive wear

Sliding Wear

Rolling Contact Fatigue

Impact Fatigue Followed by Rolling Contact Fatigue and Sliding Wear

Abrasive Wear

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Plastic Materials for Industrial Machinery

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Acrylic

- Advantages
  - Best optically clarity
  - Stiffer than polycarbonate or PETG
  - Easy to bond with solvent cements
  - Light diffusing grades available

- Limitations:
  - Somewhat brittle

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Acrylic

Applications:

- Machine guards
- Windows
- Sight glasses
- Machine vision system components

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Polycarbonate

- Advantages
  - Optically clear
  - Can operate at higher temperatures than acrylic
  - Can be cold formed into curves or bent in a press brake
  - Light diffusing grades available
  - High notched Izod impact strength
- Limitations:
  - Prone to environmental stress cracking from chemicals

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Polycarbonate

Applications:

- Machine Guards
- Windows

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Properties of Acrylic and Polycarbonate

MATERIALS ▲▼	Tensile Strength 73°F ▲▼	Flexural Modulus of Elasticity 73°F ▲▼	Izod Impact (notched) 73°F ▲▼	Heat Deflection Temperature °F 66psi / 264psi ▲▼	Light Transmittance Transparency / Clarity ▲▼
SEE ALL Units	psi	psi	ft-lbs/in	°F	%
ASTM Test	D638	D790	D256	D648	D1003
☑ Acrylic	10,000	480,000	0.4	- 195	92
☑ Polycarbonate	9,500	345,000	12.0 - 16.0	280 270	86

https://www.curbellplastics.com/Research-Solutions/Plastic-Properties

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KYDEX® Thermoplastics

- Advantages
  - Extremely tough and durable
  - Outstanding aesthetics
    - Wide range of colors with low minimum orders
  - Superior thermoforming characteristics
  - Good Flammability properties
  - Good resistance to cleaning chemicals
- Limitations:
  - Not intended for elevated temperature applications

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KYDEX® Thermoplastics

Applications:

- Housings
- Panels

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KYDEX® Thermoplastics Colors

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High Density Polyethylene

- Advantages
  - Gentle on cutting knives
  - Outstanding chemical resistance
  - Easy to weld via thermoplastic welding

- Limitations:
  - Relatively low strength and stiffness
  - Not suitable for elevated temperature applications

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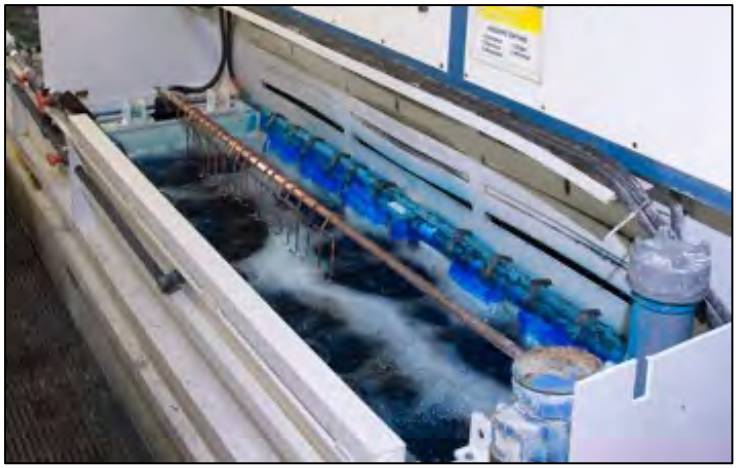
High Density Polyethylene

- Applications:
  - Cutting boards
  - Welded tanks



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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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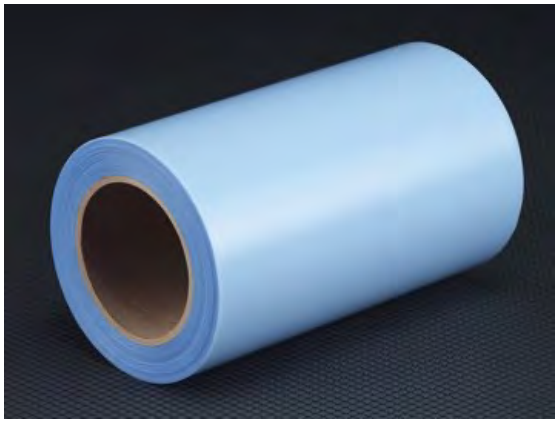
UHMW Polyethylene

Applications:

- Star wheels
- Guide rails
- Wear strips
- Timing screws
- Wheels and rollers



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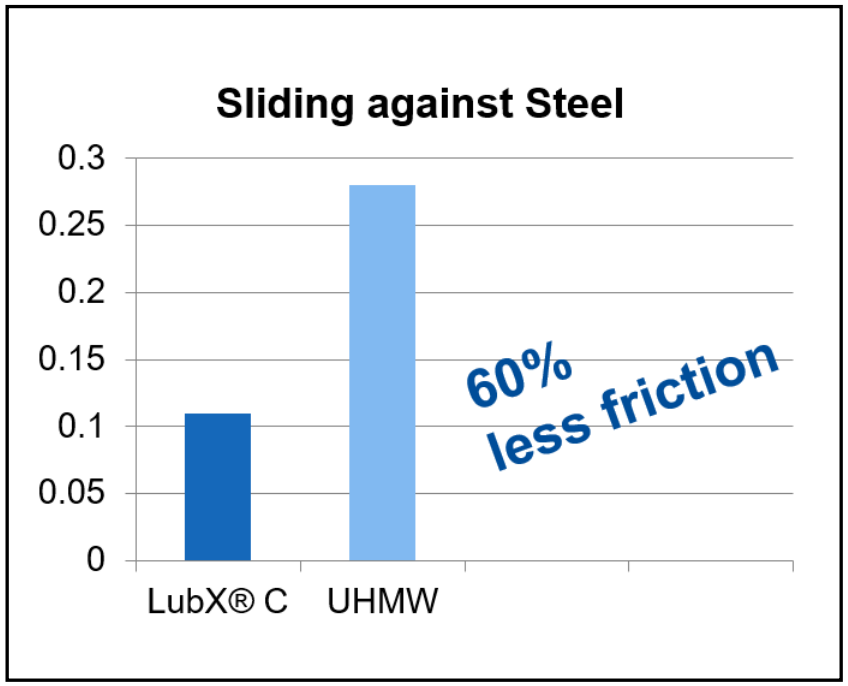
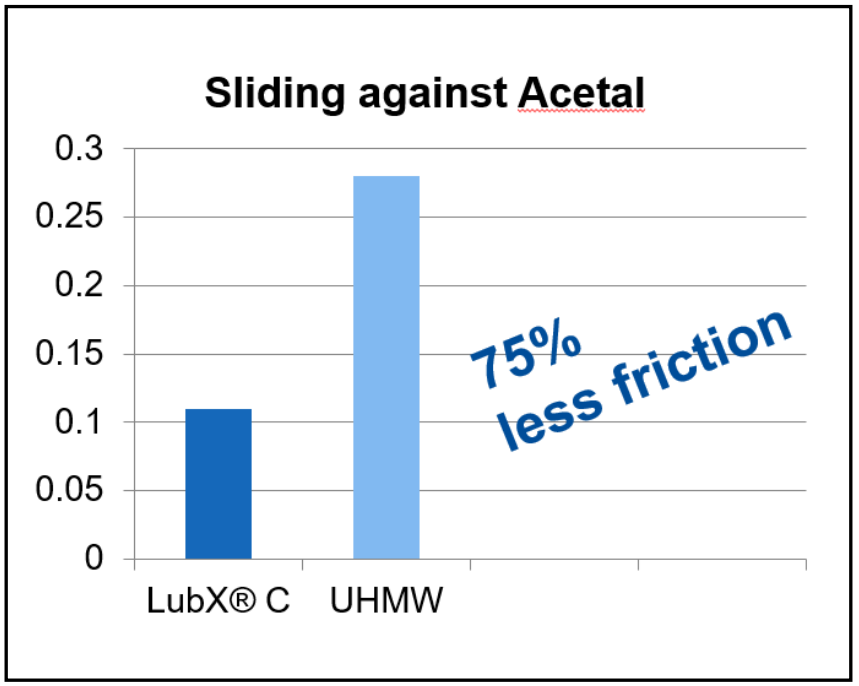
LubX® C

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

LubX® C
Special grade of UHMW-PE with reduced friction

Coefficient of sliding friction under dry conditions





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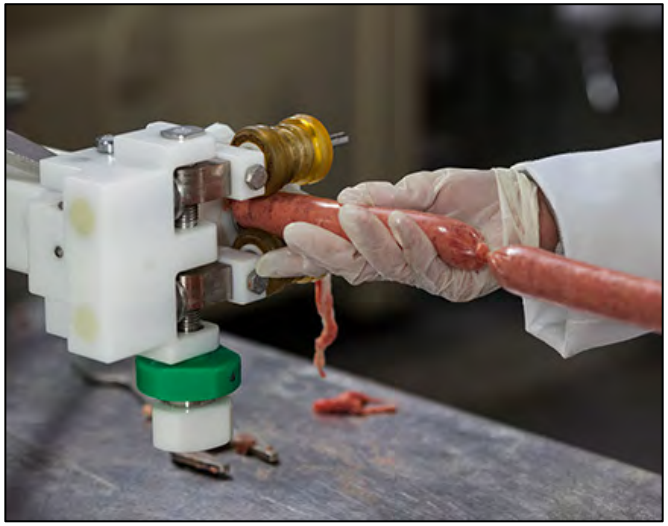
Acetal (including Delrin®)

- Advantages
  - Easy to machine
  - Stronger and stiffer than UHMW-PE
  - Excellent friction and wear characteristics
  - PTFE filled grades available
- Limitations:
  - Moderately high CTE makes it challenging to hold tight tolerances



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Acetal (including Delrin®)

- Applications:
  - Filler tubes
  - Structural supports
  - Bearings and bushings
  - Star wheels and guide rails
  - Wheels
  - Rollers

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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

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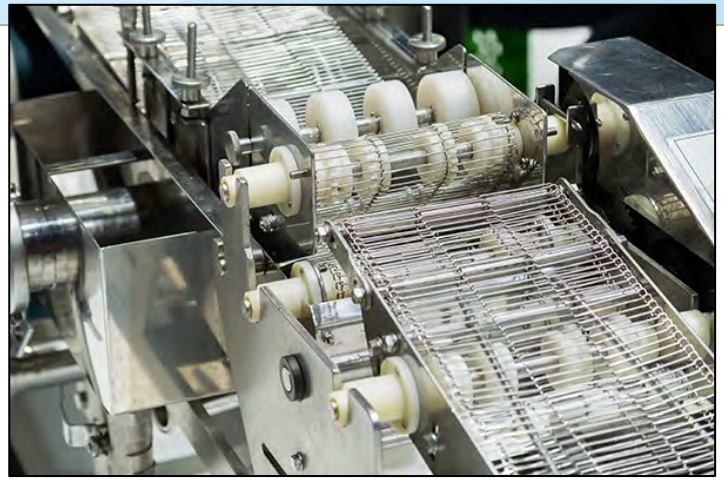
Nylon

Applications:

- Wheels
- Rollers
- Bearing and bushings
- Sheaves and pulleys
- Gears



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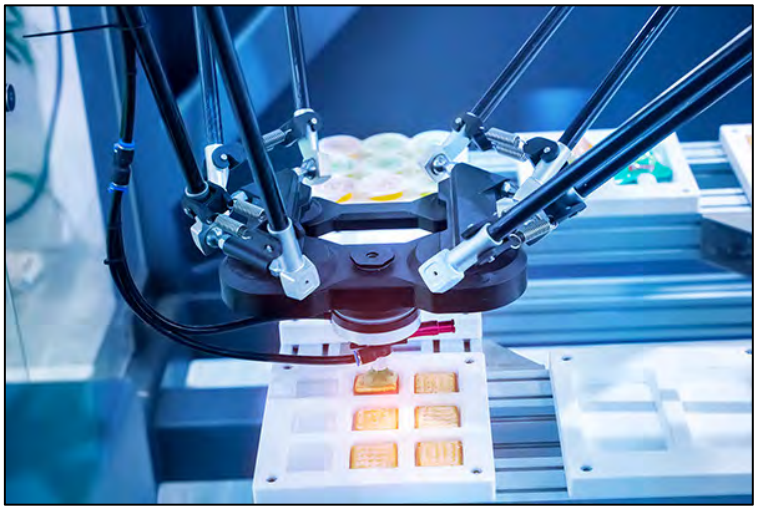
Semicrystalline PET

- Advantages
  - Very low rate of thermal expansion as well as low water absorption allows for tight tolerances
  - Good friction and wear characteristics
  - Available in internally lubricated grades
- Limitations:
  - Somewhat brittle
  - Limited resistance to steam



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Semicrystalline PET

- Applications:
  - Bearings
  - Bushings
  - Wear pads
  - Filler pistons
  - Manifolds

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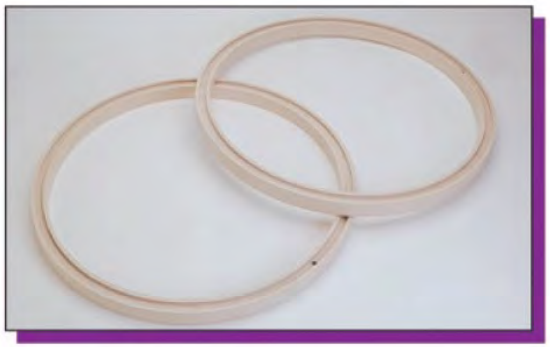
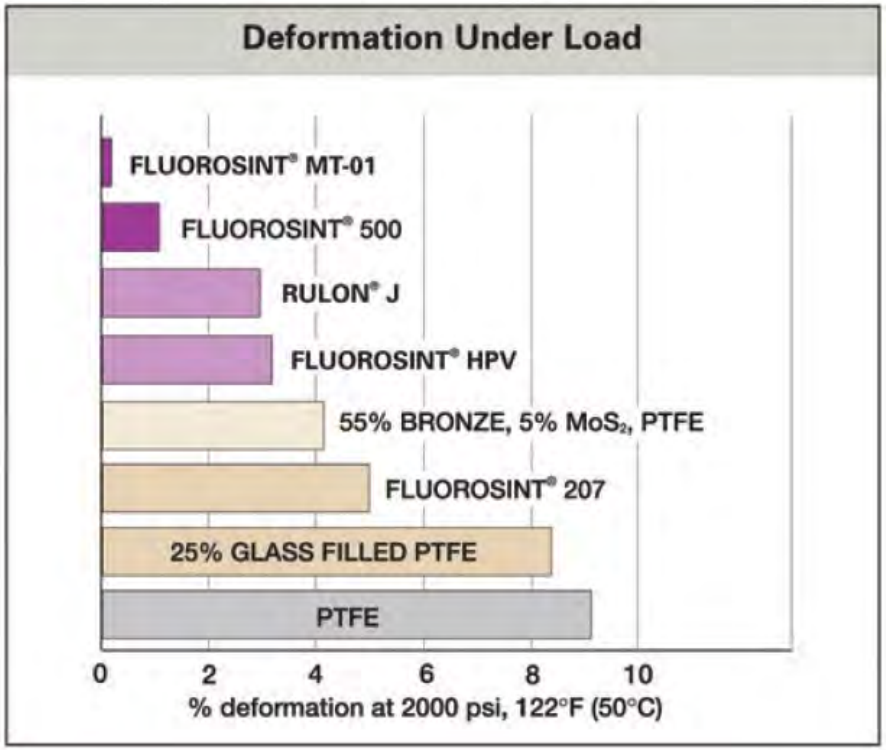
Fluorosint®

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





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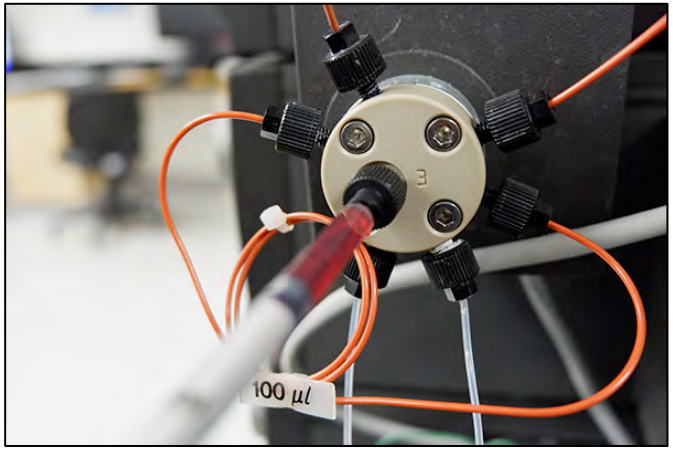
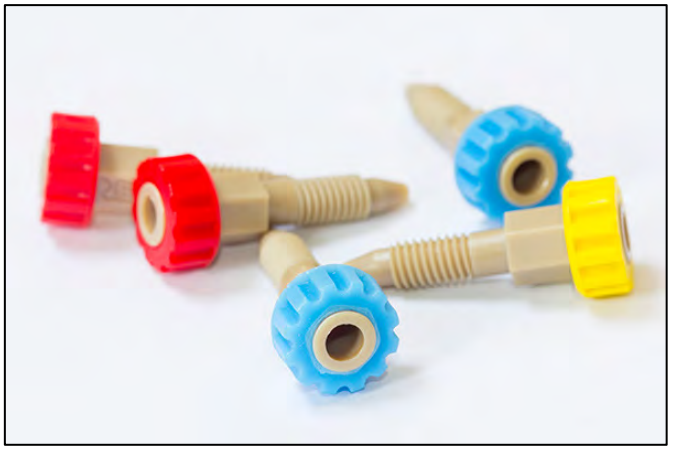
PEEK

- 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





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PEEK

Applications:

- Manifolds
- Valve components
- Seals
- Fillers
- Bearings and bushings (friction and wear grades)

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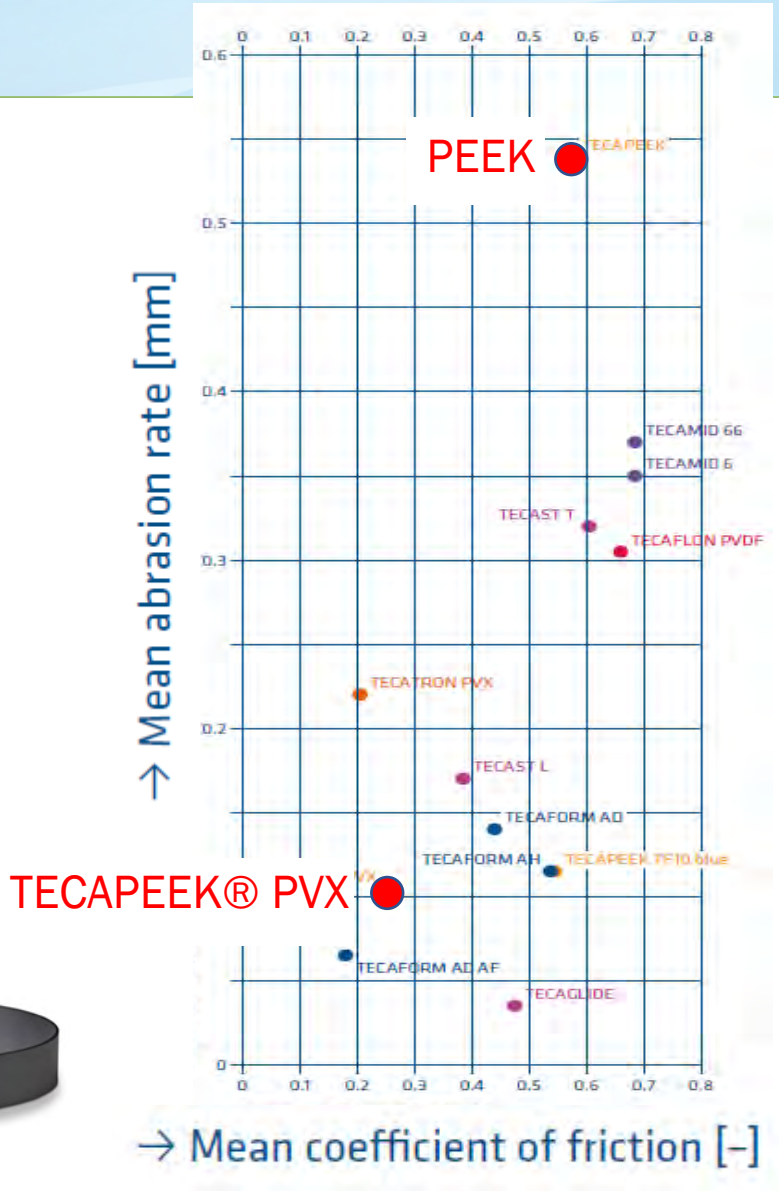
TECAPEEK® PVX

- High performance friction and wear grade of PEEK manufactured by Ensinger Inc.
- Formulation includes 10% PTFE, 10% graphite, and 10% carbon fiber
- Low friction and low wear rate
- High and low operating temperatures
- Chemical resistance
- Radiation resistance



Polyurethane

- Flexible elastomer
- Can be cast into finished shapes
- Impact resistant
- Resists abrasive wear
- Gentle on mating parts

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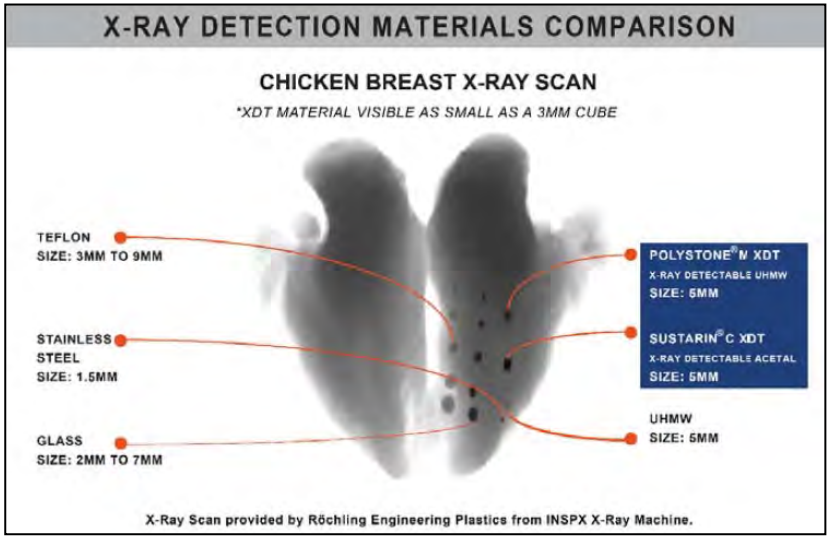
Polyurethane

Applications:

- Roller covers
- Bumpers
- Dunnage for protecting critical surfaces

Detectable Plastics

- Designed for metal detection, and/or X-ray equipment
- Blue for easy detection by optical scanners
- FDA compliant grades available
- Available in Acetal, UHMW, PBT, and PEEK



Plastic Part Geometry

Geometry

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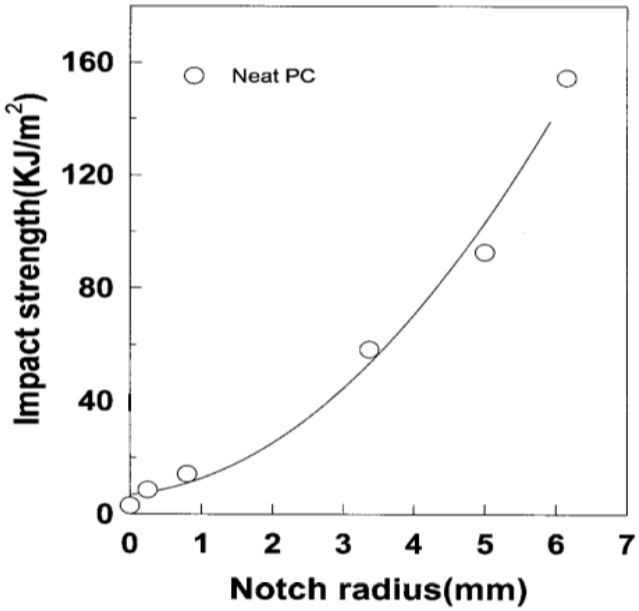
Sharp Corners

- Sharp internal corners reduce the impact resistance of plastic parts.



Source: Adapted from Notch sensitivity of polycarbonate and toughened polycarbonate by Kilwon Cho. Journal of Applied Polymer Science, Vol. 89, pages 3115 -3121 (2003).

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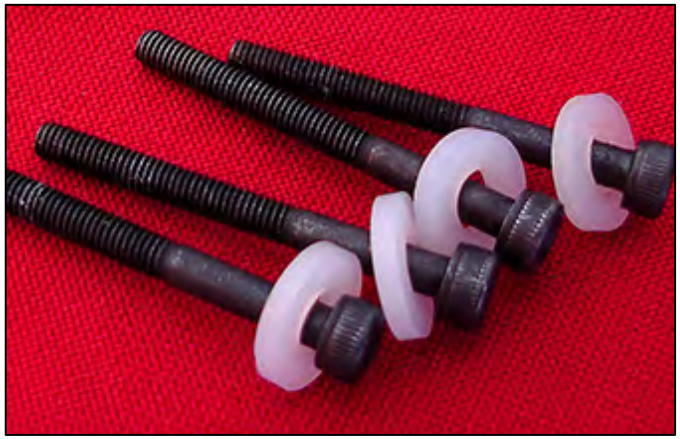
Fasteners

- Avoid countersunk, flat head screws.
- Use round head screws with flat washers to reduce stress concentrations.
- Clean screws to remove any contaminants.
- Be careful of thread lockers.
- Control torque.

Fasteners

- Don’t put holes too close to the edge of a plastic part
- Be careful of elastomer washers that may contain stress crack agents



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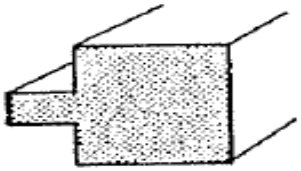
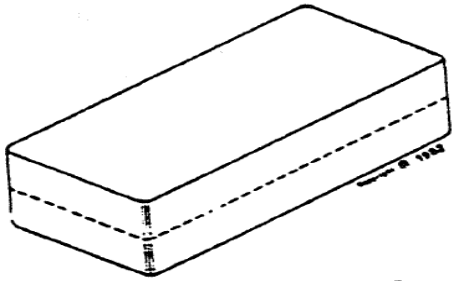
Part Geometry as it Relates to Processing

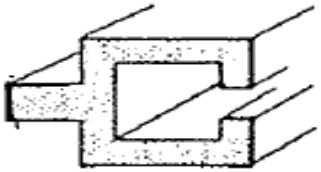


Machining

Machining

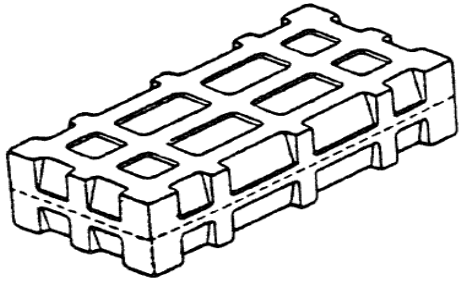


Machining



Extrusion

Extrusion



Injection Molding

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Thank you for your time today! Questions?

- **Ask a Plastics Expert** form for help with your application at CurbellPlastics.com
- Ask about **Customized Presentations**

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