Dimensional Tolerance Challenges with Plastic Parts: Strategies for Success

Webinar Presented by Curbell Plastics

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Dimensional stability frustrations for:

- Engineers
- Fabricators
- Quality teams
- Supply chain professionals

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Agenda

- Thermal Expansion
- Water Absorption
- Creep Strain
- Post Molding Shrinkage
- Residual Stress
- Best Practices for Machining
- Questions / Discussion

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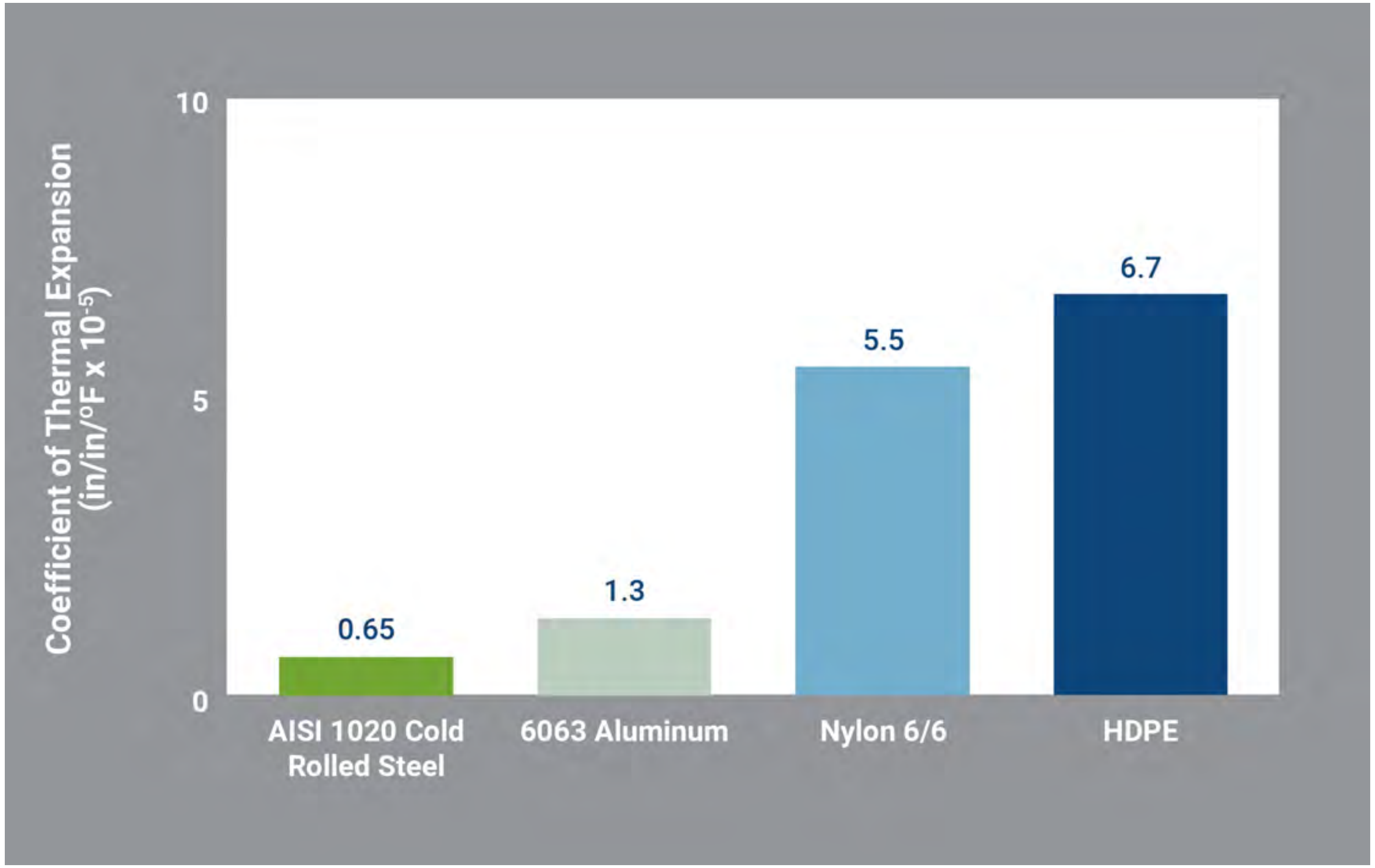
Thermal Expansion

Coefficients of Thermal Expansion for Various Metals and Plastics



Thermal Expansion

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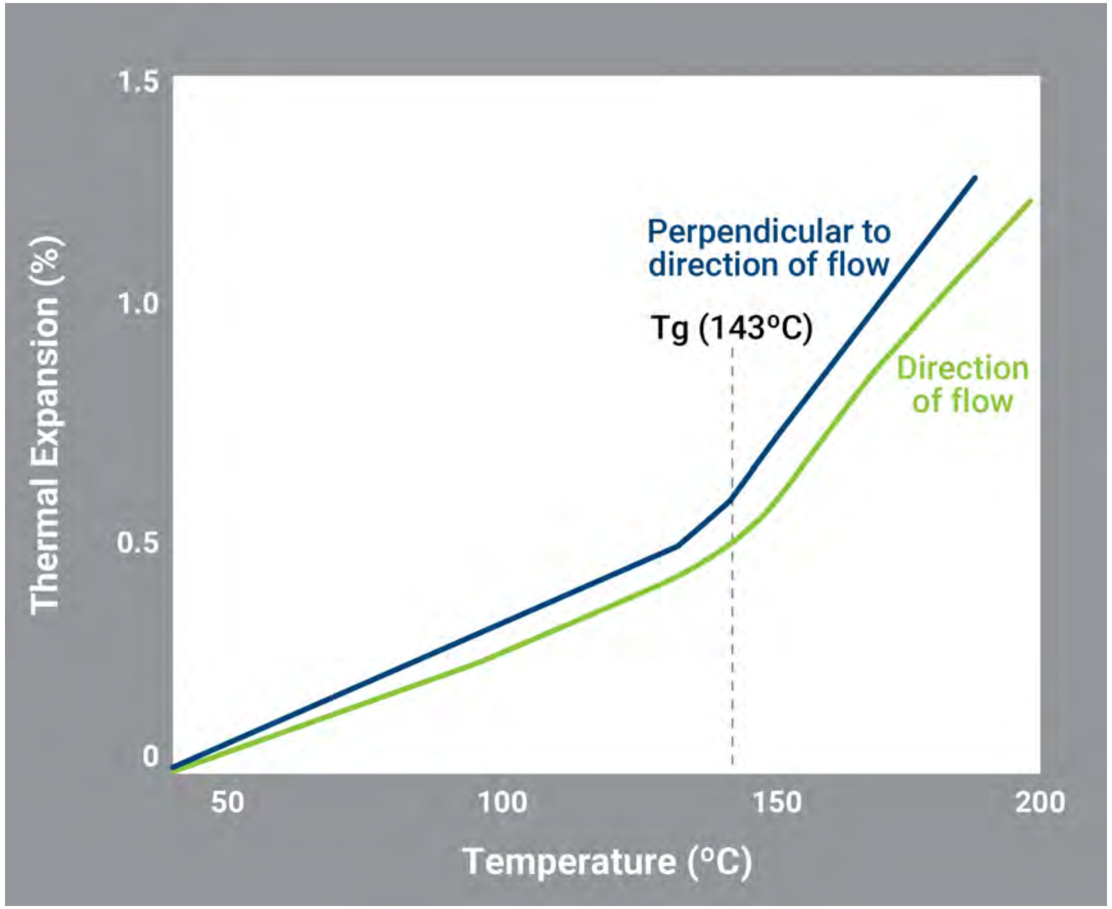
Thermal Expansion

Thermal Expansion Curves for PEEK in the Direction of Flow and Perpendicular to the Direction of Flow, Both Above and Below the Material's Glass Transition Temperature



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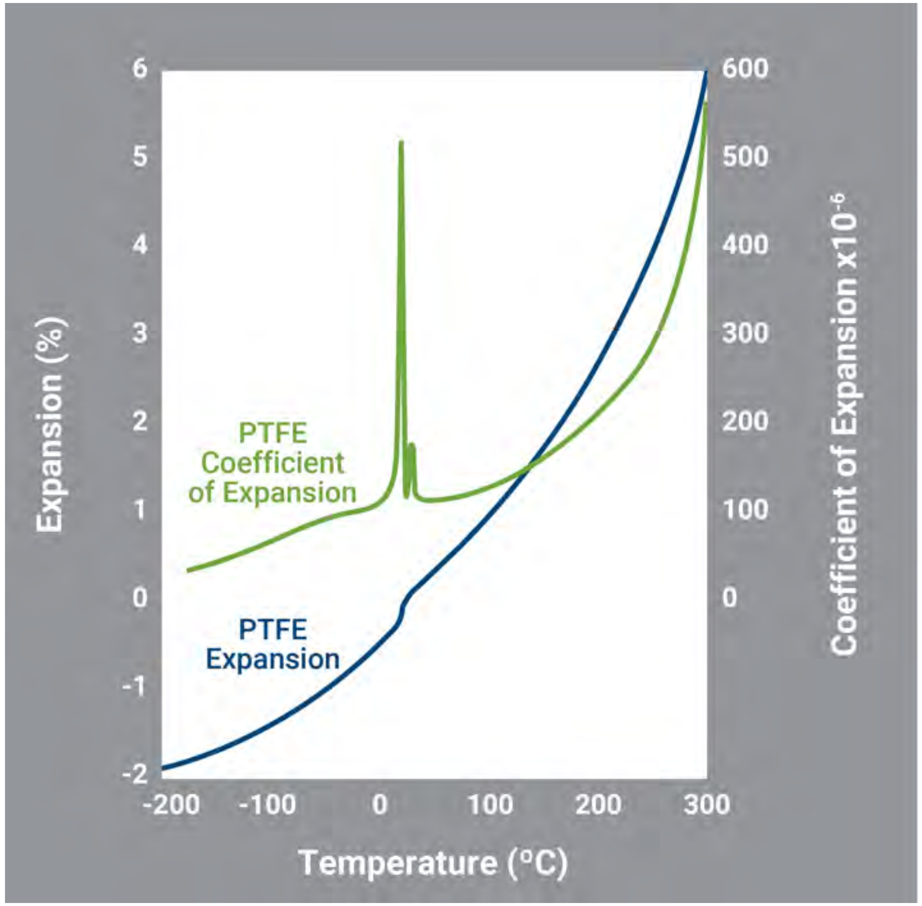
Thermal Expansion

Linear Thermal Expansion and Coefficient of Linear Thermal Expansion of Annealed Teflon®



Source: Kirby, 1956

Water Absorption

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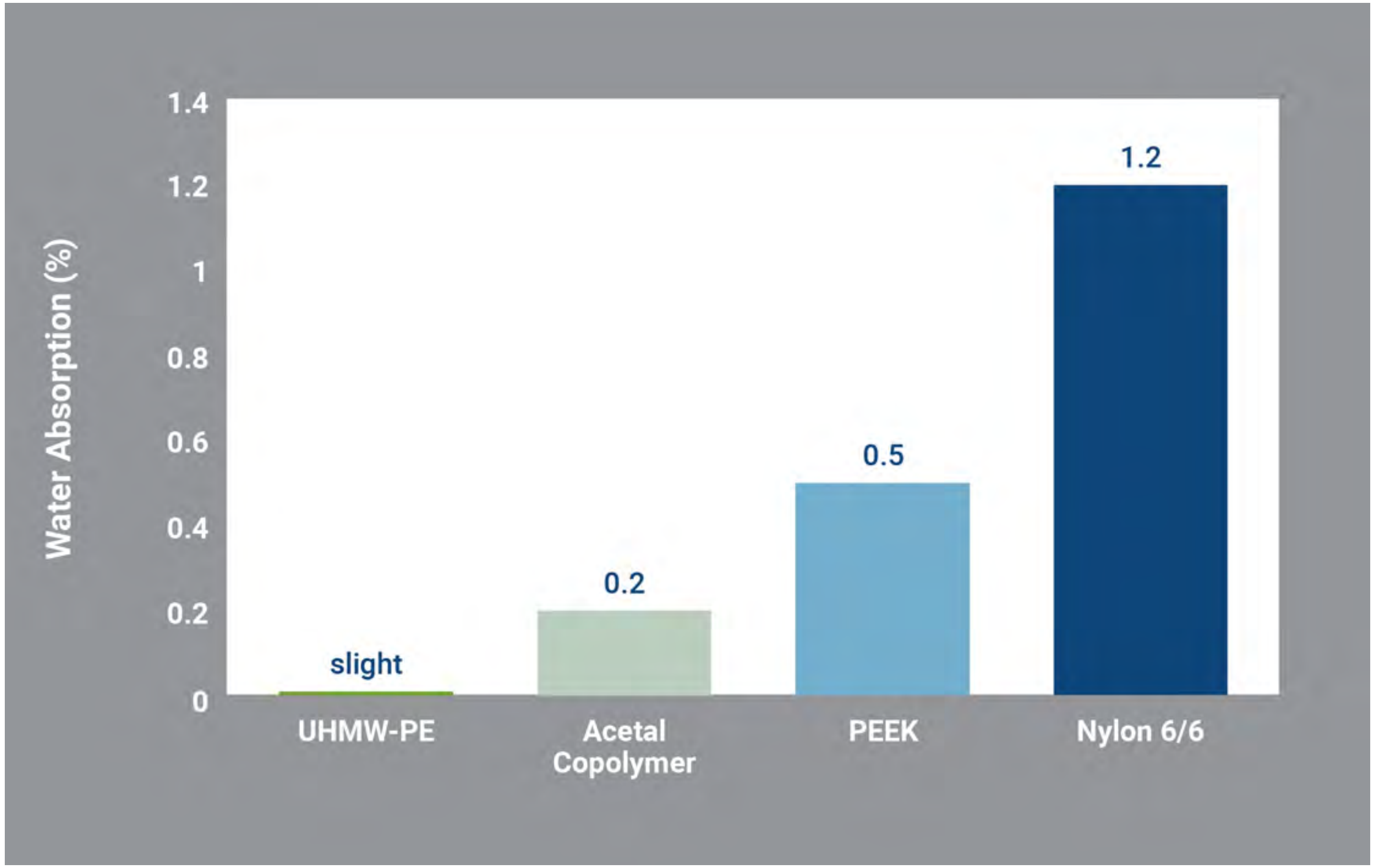
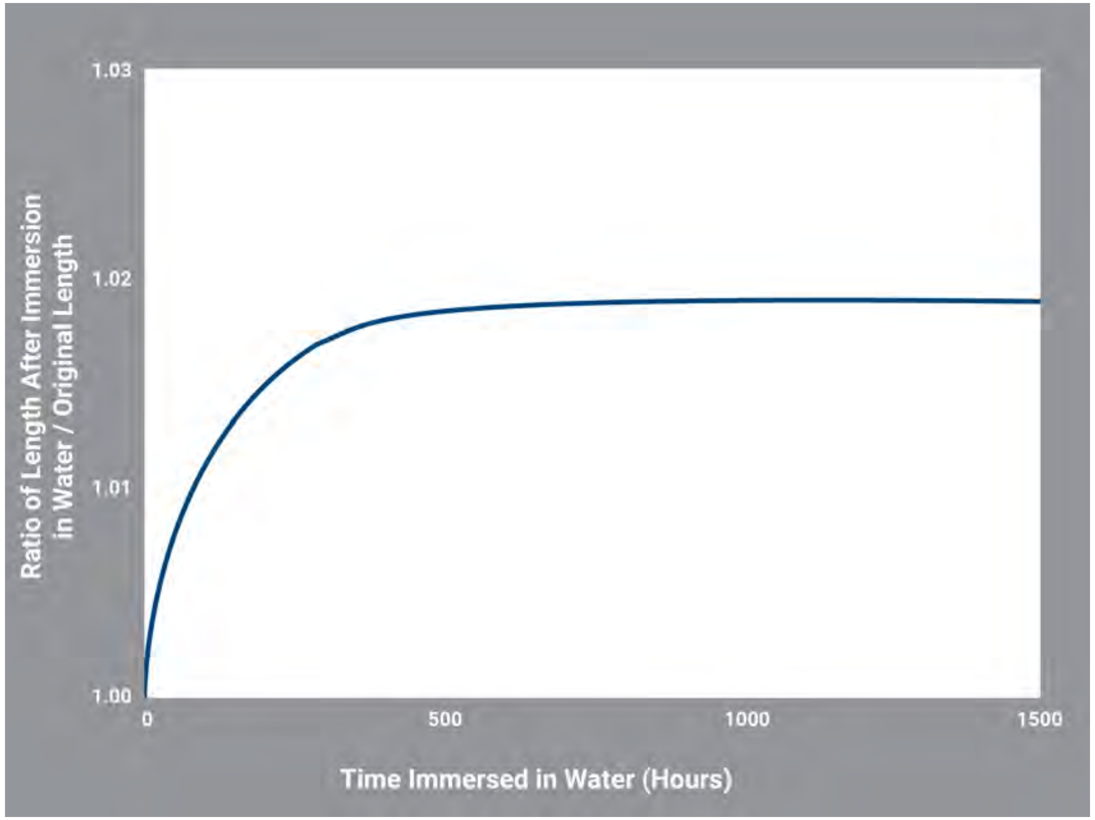
Water Absorption

Water Absorption per ASTM D570, 24 Hours Immersion (%)



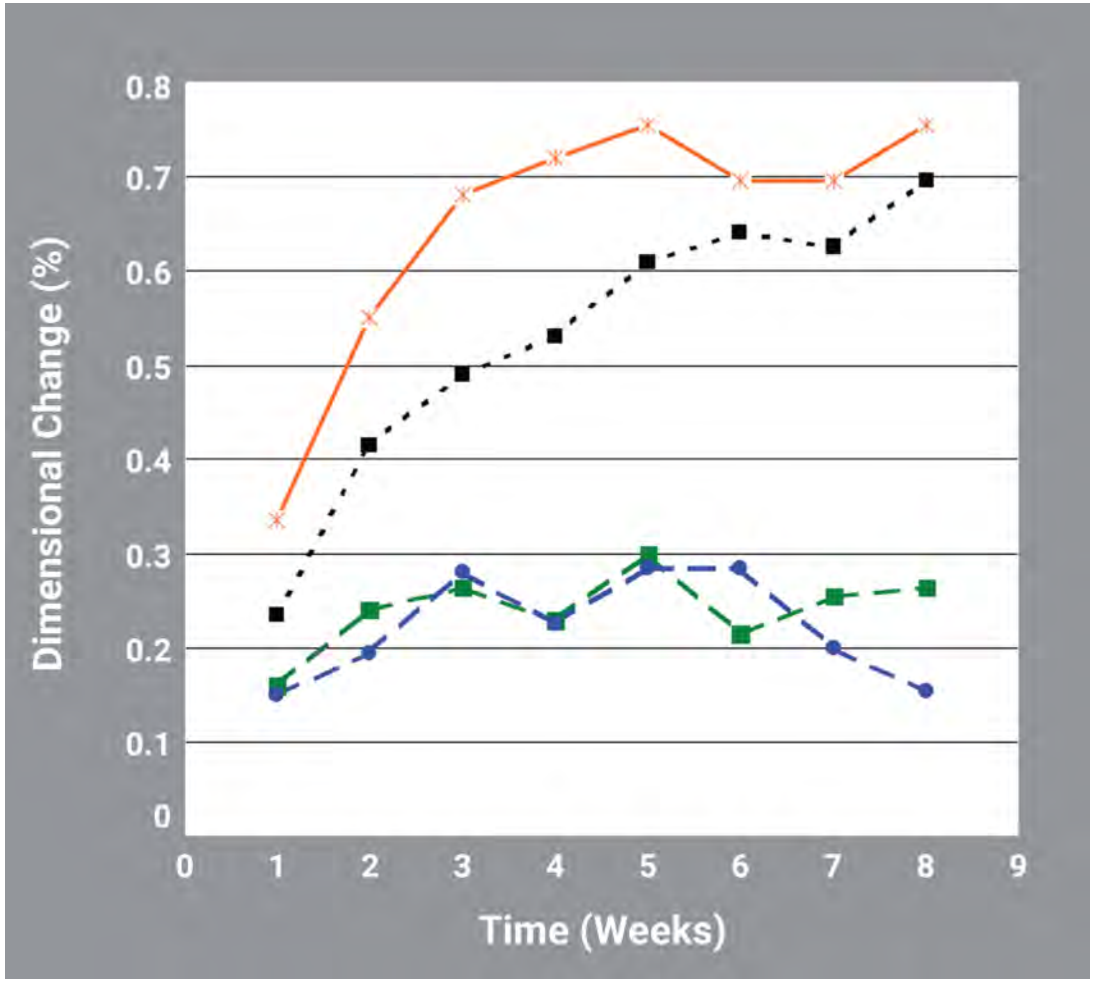
Water Absorption of Nylon 6

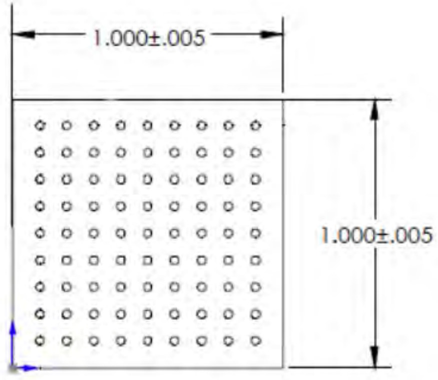
Changes in Length
for a 10 cm Long x 5 cm Wide x 1.6 mm Thick Plaque of
Nylon 6 Immersed in Water at Room Temperature



Source: Adapted from Monson, 2007

Water Absorption of Torlon® PAI and DuPont™ Vespel®





Source: Adapted from Kane, 2004

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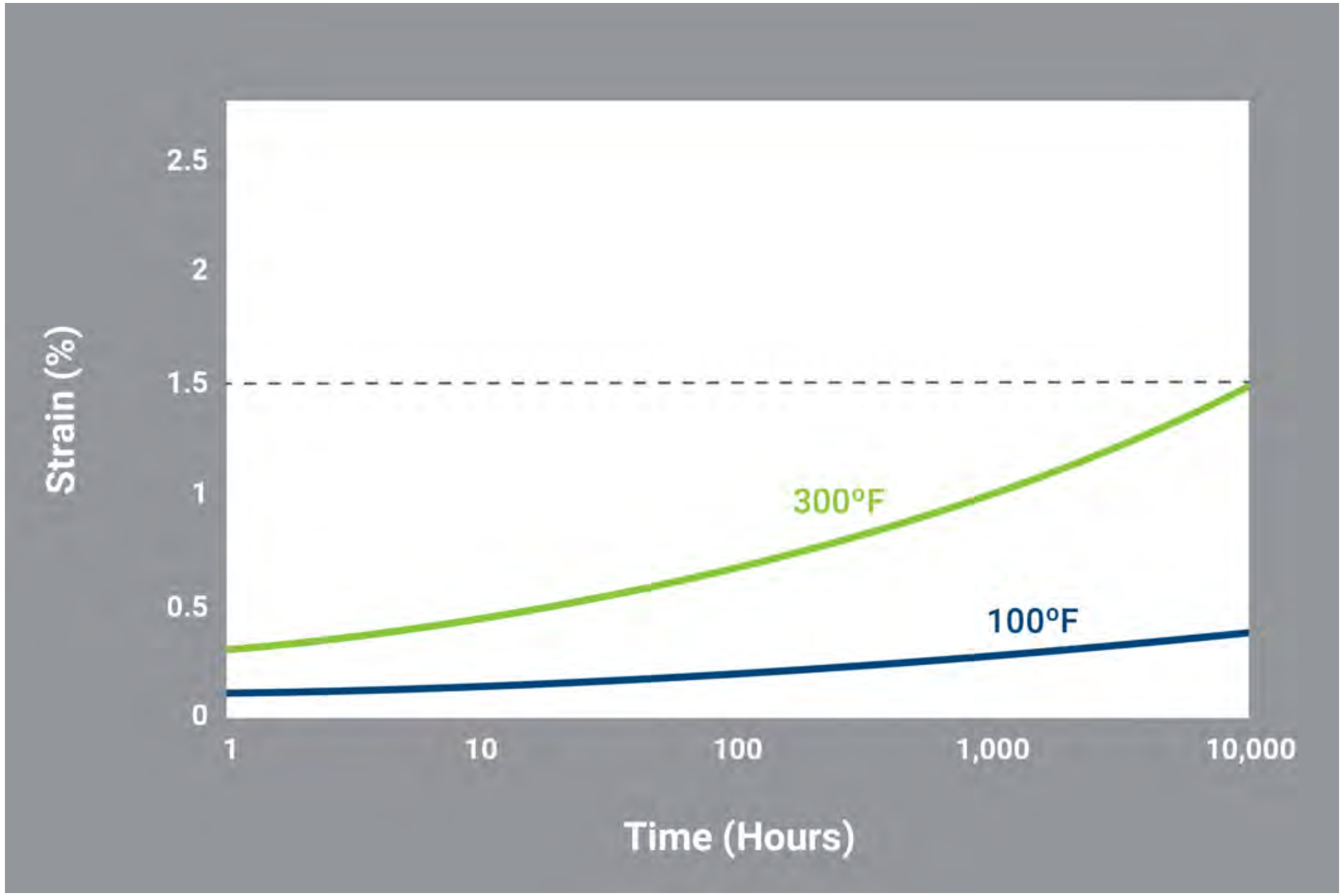
Creep Strain

Thermoplastic Creep Behavior:
1,000 psi Load at Various Operating Temperatures



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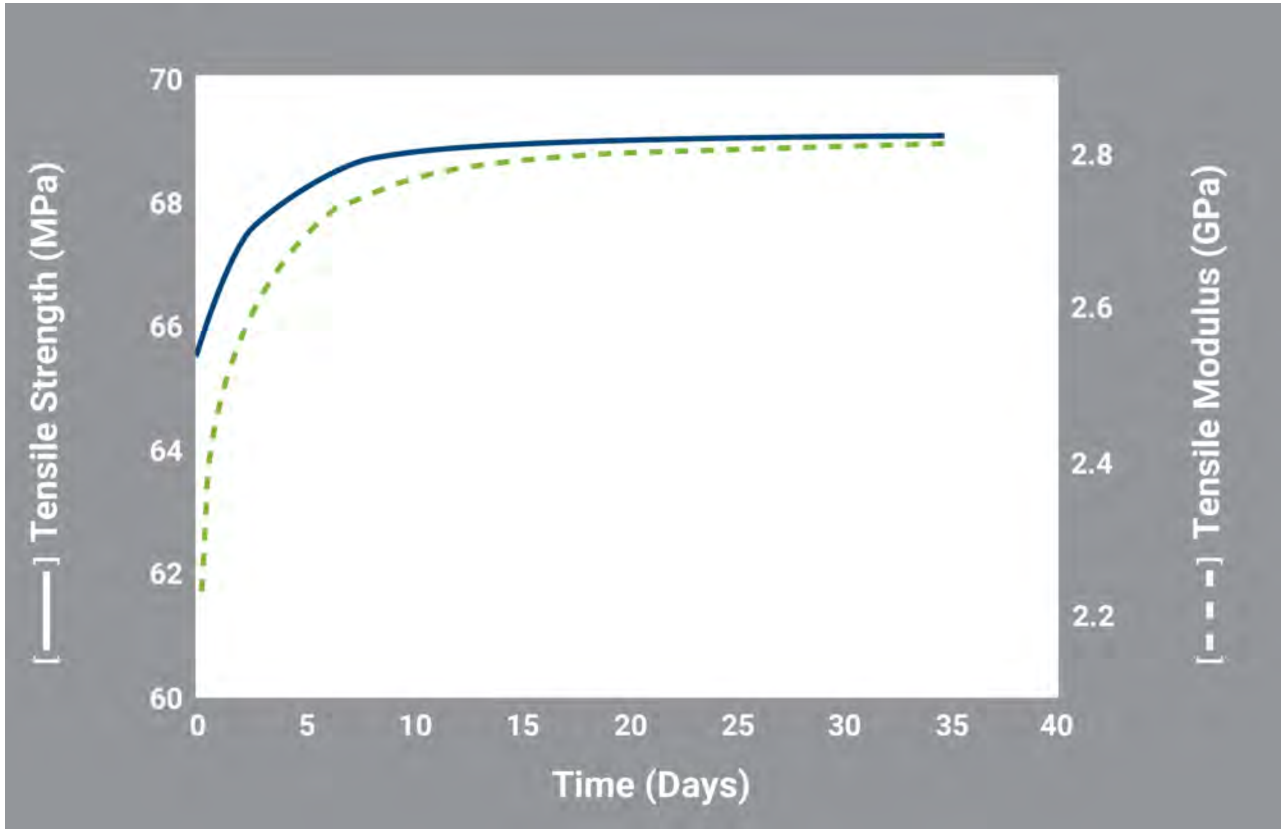
Post Molding Shrinkage - Acetal

- Semicrystalline plastics where room temperature is above the Tg and below the melting point (acetal, PP, PE)
- *"A properly packed out acetal part produced at the correct mold temperature will exhibit continued shrinkage of about 0.001 in./in. between the time the part reaches room temperature and the time that it is truly stable." - Mike Sepe*
- Can accelerate crystallization and shrinkage through annealing

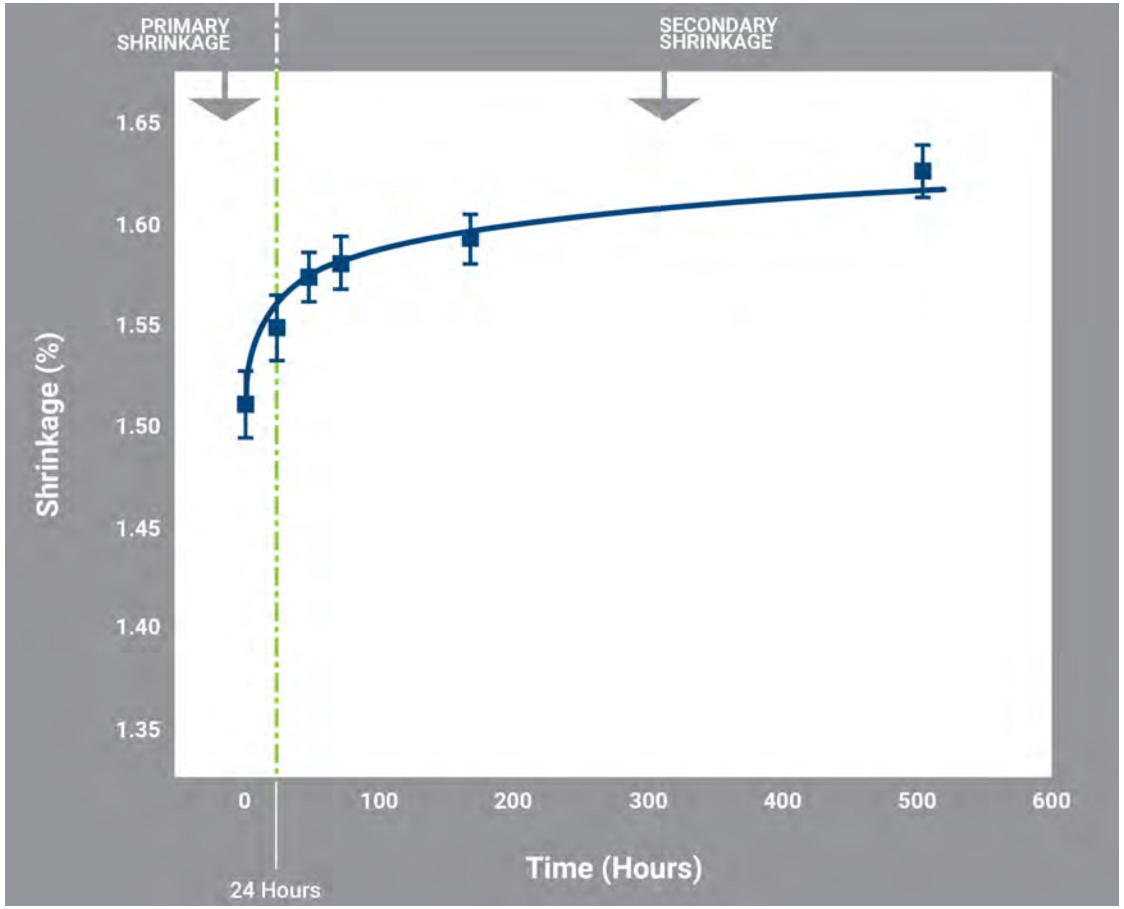
Development of Tensile Strength and Modulus in Homopolymer Acetal Due to Post-Molding Crystallization



Source: Adapted from Sepe, 2013

Post Molding Shrinkage - Polypropylene

Post Molding Shrinkage of a Homopolymer Polypropylene Test Specimen.
80°C Mold Temperature. Conditioned for 504 Hours (21 days) at 23°C.



Source: Adapted from Kosciuszko, 2021

Residual Stress

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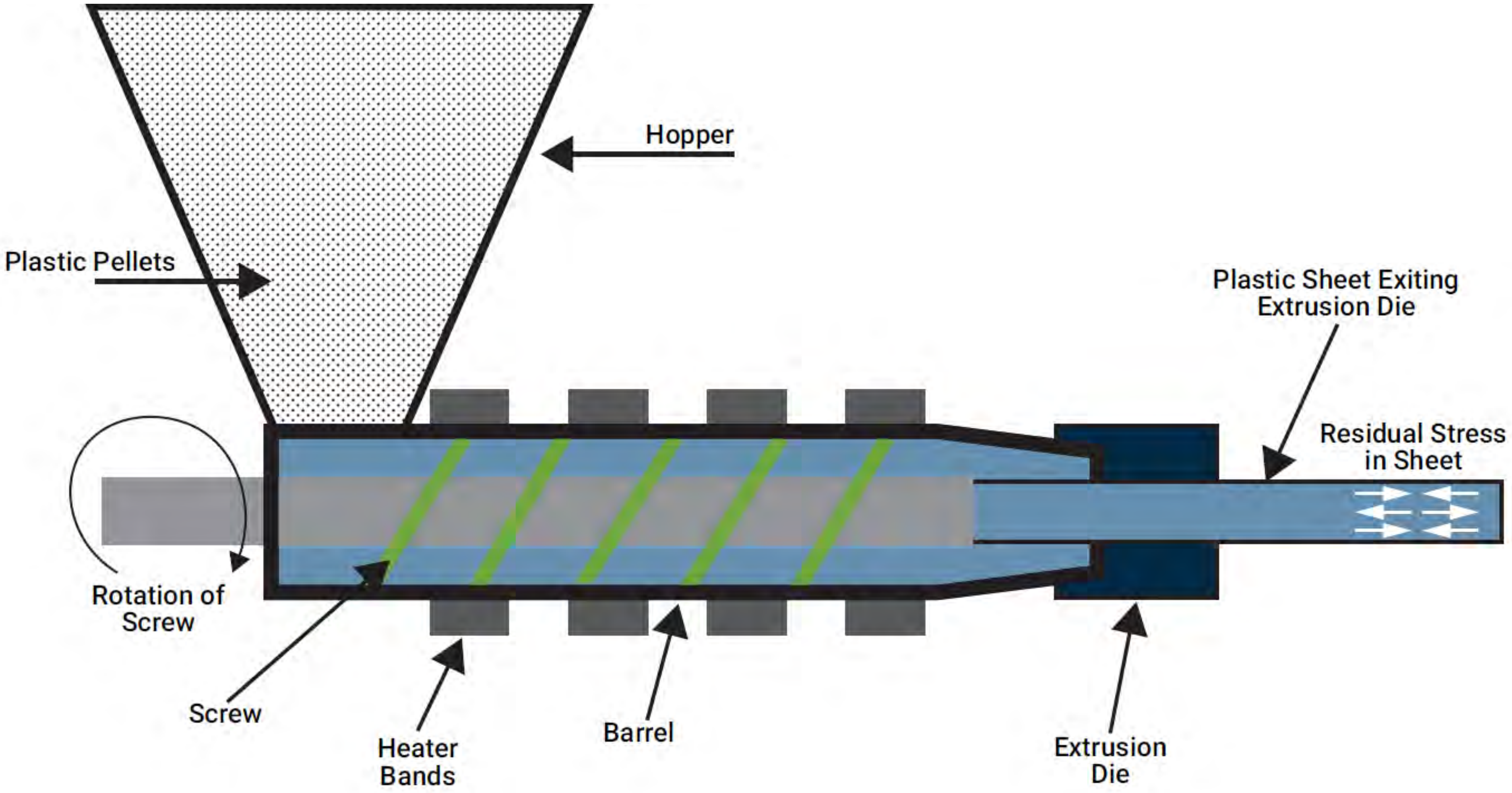
Residual Stress from the Extrusion Process



Induced Stress from Machining

- Frictional heat from the cutting tool
- Deformation of the plastic by the cutting tool
- Stress introduced by clamping/fixturing

Stress Relieving via Annealing

- Heat the part at a rate of 50°F/hr
- Allow the part to stay at that temperature until fully saturated
- Slowly cool material at a rate of 30-50°F/hr

Material	Temperature (°F)	Time
Nylon 6/6	300	15 min per 0.125"
Nylon 6/6, Nylon 6/12	265 - 300	30 min per 0.125"
PEEK	370 - 390	4 hrs per 0.125"
Acetal (Delrin®)	300 - 315	20 min per 0.125"
Polycarbonate	265 - 280	3 hrs per 0.125"
Noryl®	235	1 hr per 0.125"
Polyetherimide (Ultem®)	400	2 hrs per 0.125"

Source: Ensinger

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Machining Techniques to Minimize Stress

- Feeds / Speeds
- Roughing / Finishing
- Proper Fixturing
- Proper Tooling
- Chip Control

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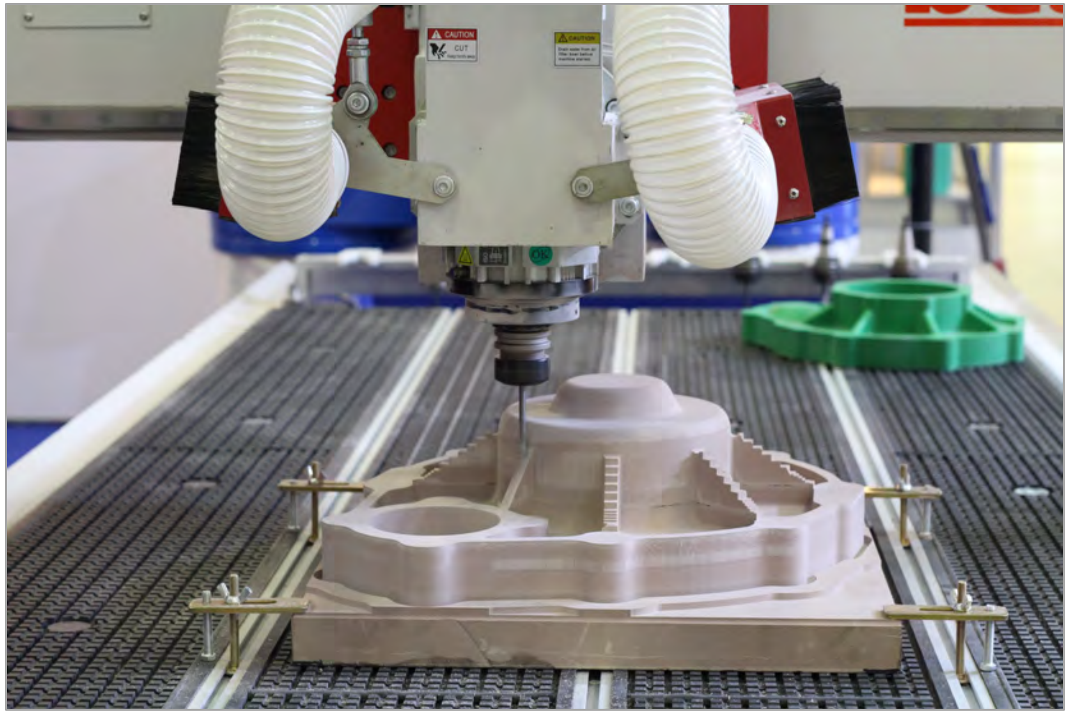
Best Practices - Feeds and Speeds

- High RPMs and high feeds must be used for quick material removal
  - Important to move fast enough to minimize heat buildup
  - High RPM and slow feed will result in heat induced stress and melting



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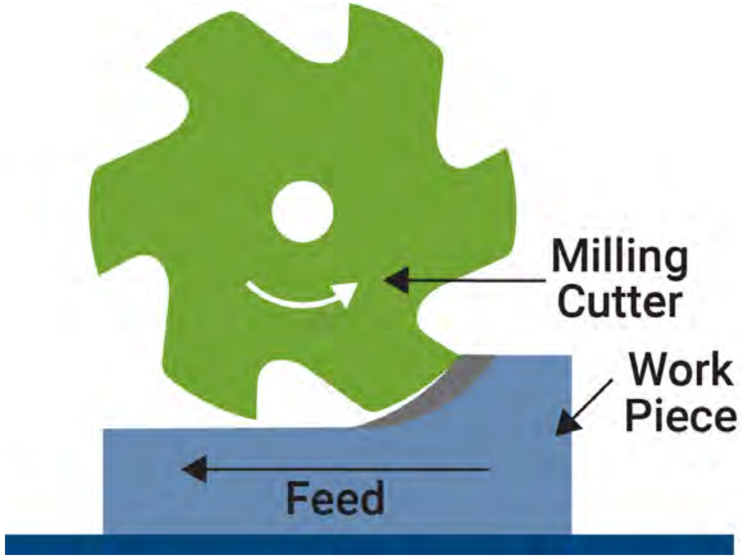
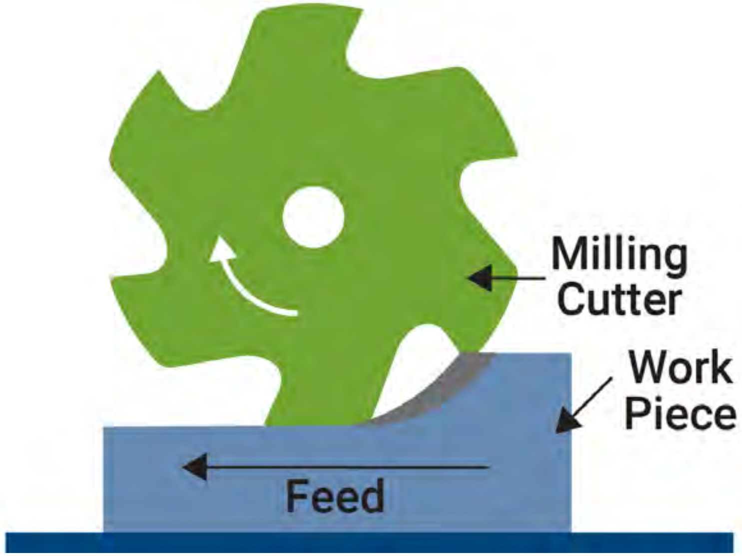
Best Practices - Feeds and Speeds

- Mill softer materials via conventional milling and harder materials via climb milling for the best finish



Conventional Milling



Climb Milling

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Best Practices - Roughing / Finishing

- When large amounts of material are removed
  - Rough the part
  - Let it stabilize and relax. This process can take days.
  - Fixture and finish machine
- A heavier finish cut will give a better finish than a light one. Plastic will push away on light cut.

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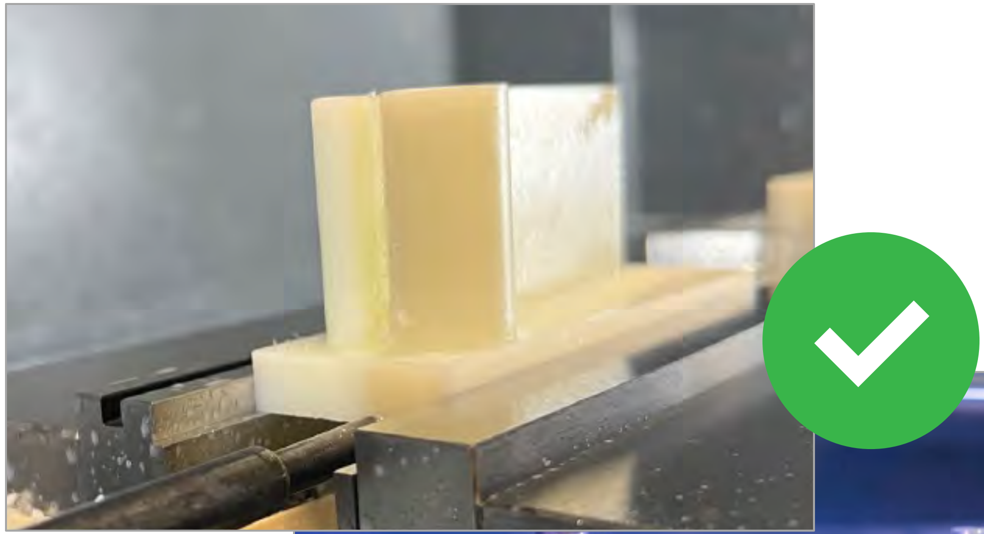
Best Practices - Fixturing to Minimize Stress



Best Practices - Fixturing / Clamping

- Do not overtighten vices or lathe chucks
  - Overtightening can produce movement after the part is released
  - Use an indicator on the floating jaw for the best repeatability
- Apply clamping force to large surfaces to minimize introducing stress into the finished part – use soft jaws to match the contour of the part

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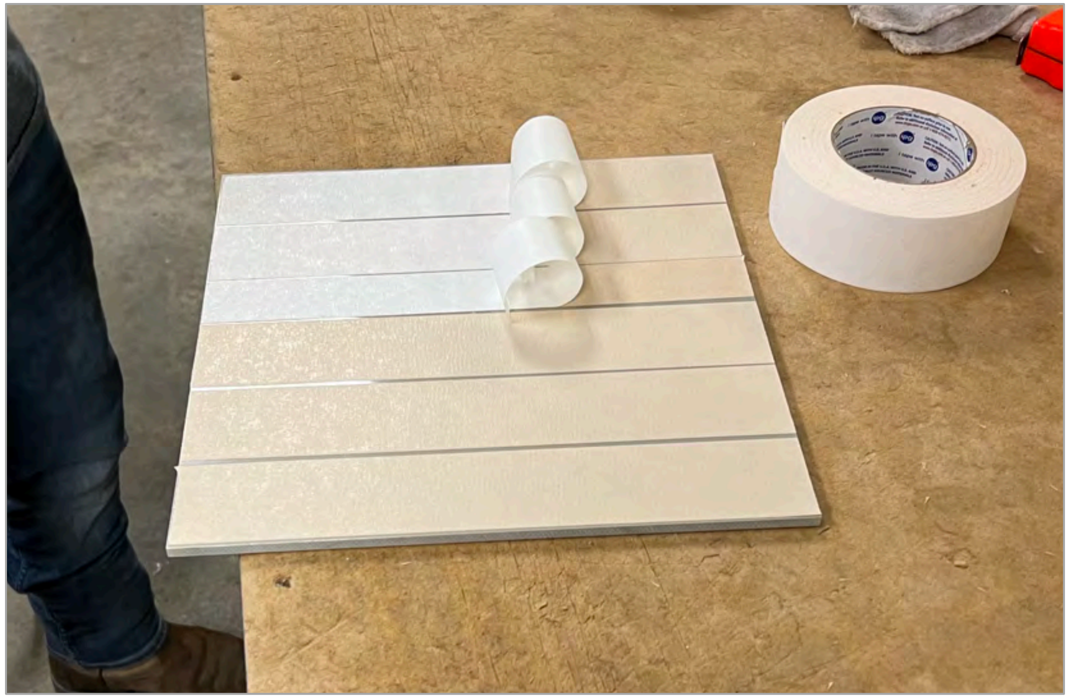
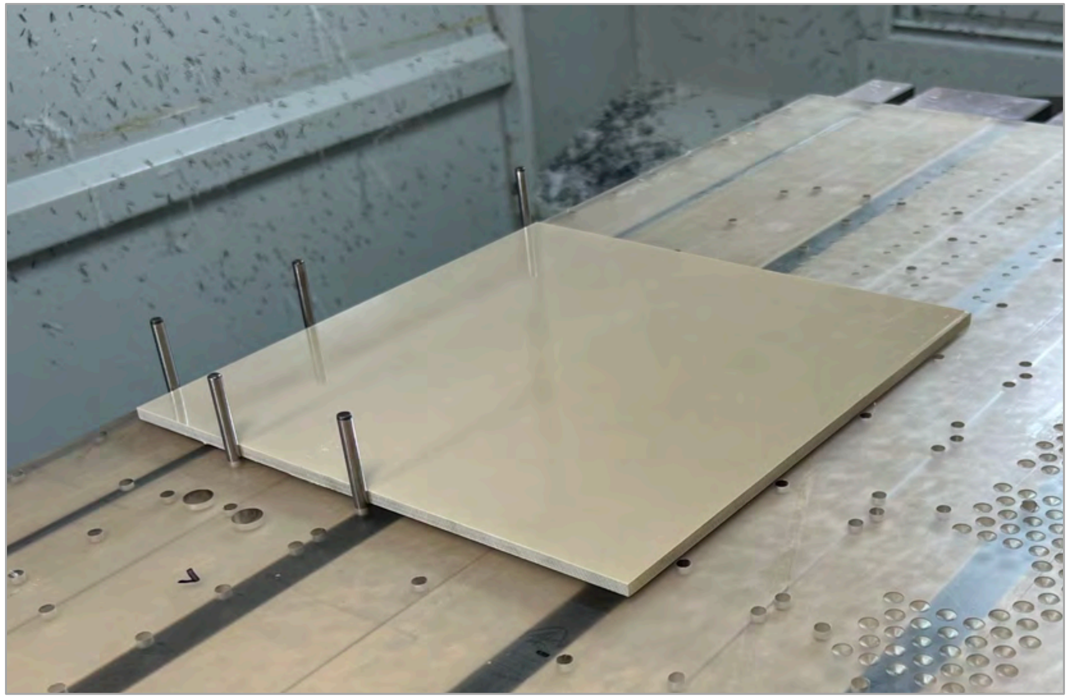
Best Practices - Fixturing to Minimize Stress





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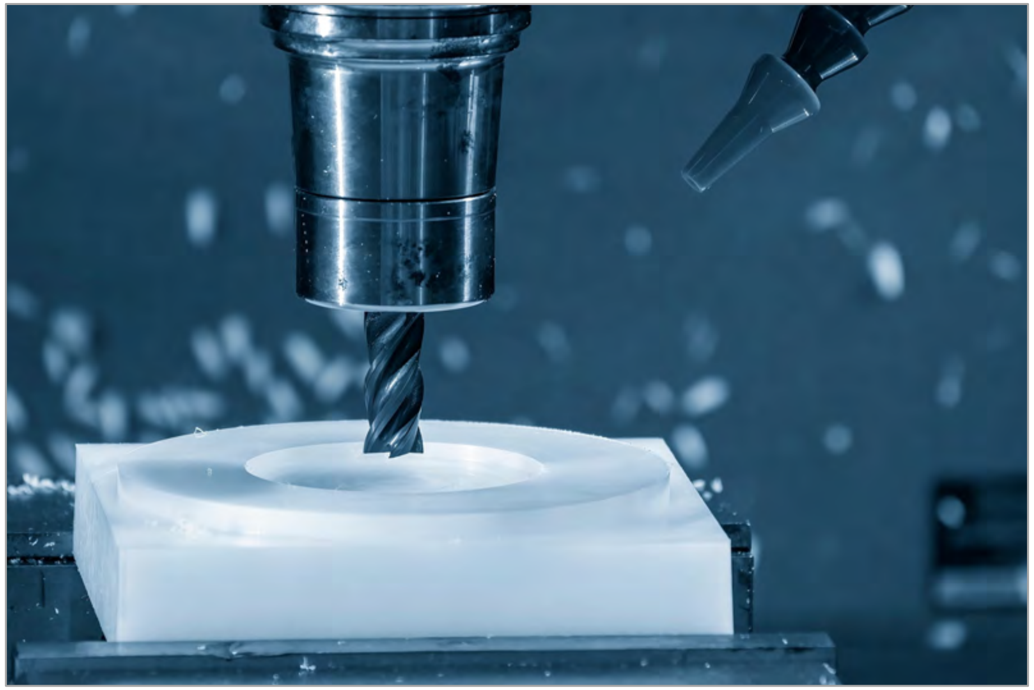
Best Practices – Tooling

- Carbide tooling
- Tool geometry optimized for the polymer



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Best Practices - Tooling

- Lower helix for soft, ductile materials
  - 10-20 degree helix angle for 2-flute router bits
  - Maximum of 30 degree helix angle for 3-flute endmills
- Higher helix angle for harder materials as long as the holding method can sustain the uplift created by the tool

Left: 18° helix angle for soft ductile plastics (UHMW-PE)
Center: 30° helix angle for medium hardness plastics (nylon, acetal)
Right: 40° helix angle for hard plastics (Ultem®, PEEK)

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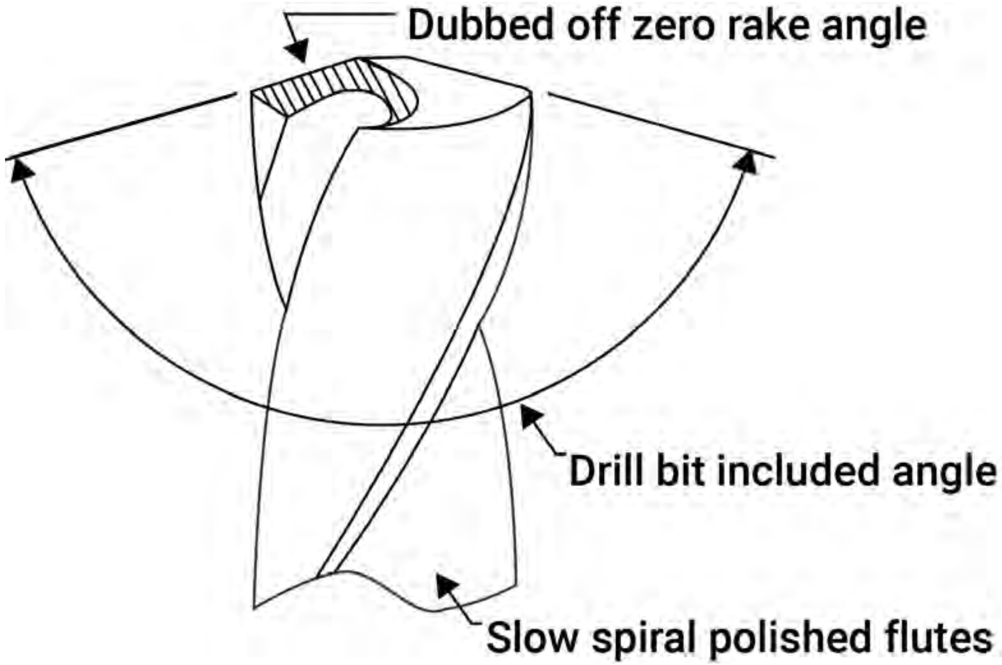
Best Practices - Ductile vs. Brittle Materials

- Hard plastics require different machining techniques than soft plastics
- Machining hard plastics
  - Hard, brittle plastics (acrylic, PET) can exhibit cracking/chipping. Must pay attention and adjust feedrates/rpms as needed to obtain results desired
  - Zero rake drills minimize chipping in brittle materials. Try to back up the part being drilled to eliminate the drill exiting the part unsupported



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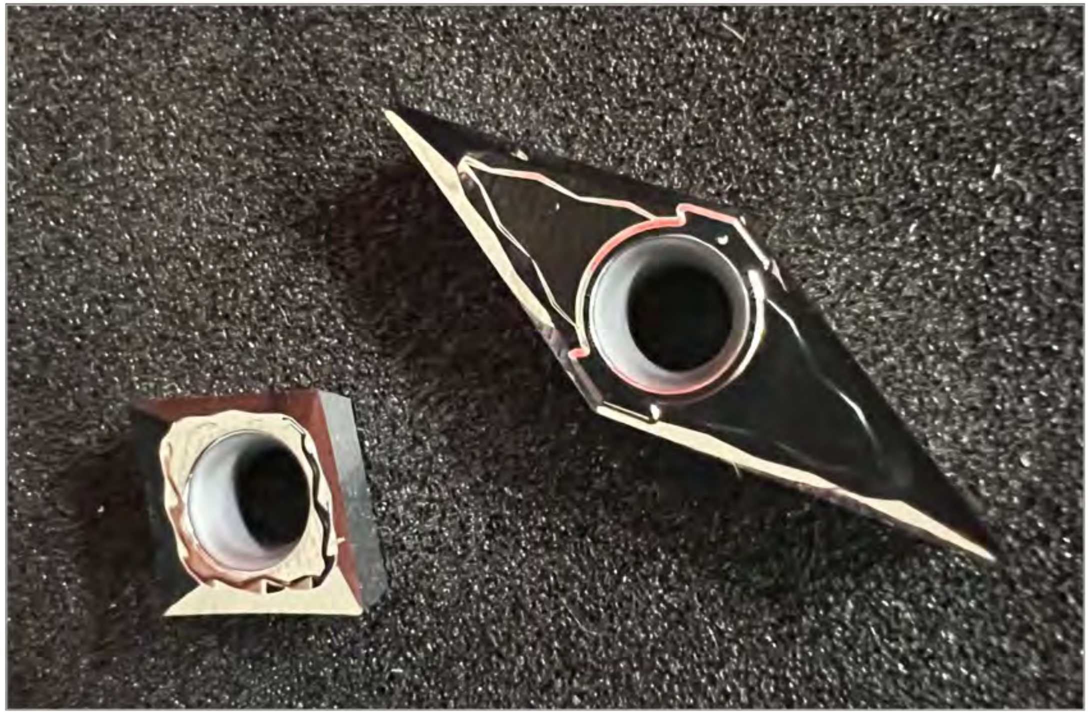
Best Practices - Tooling

- Highly polished inserts for turning or surface milling
- Endmills with a small corner radius and/or a wiper will provide the best bottom finish



Left: 80° polished insert for turning for most materials. Nose radius can vary depending on finish requirements.
Right: 35° polished insert used for profiling and back turning

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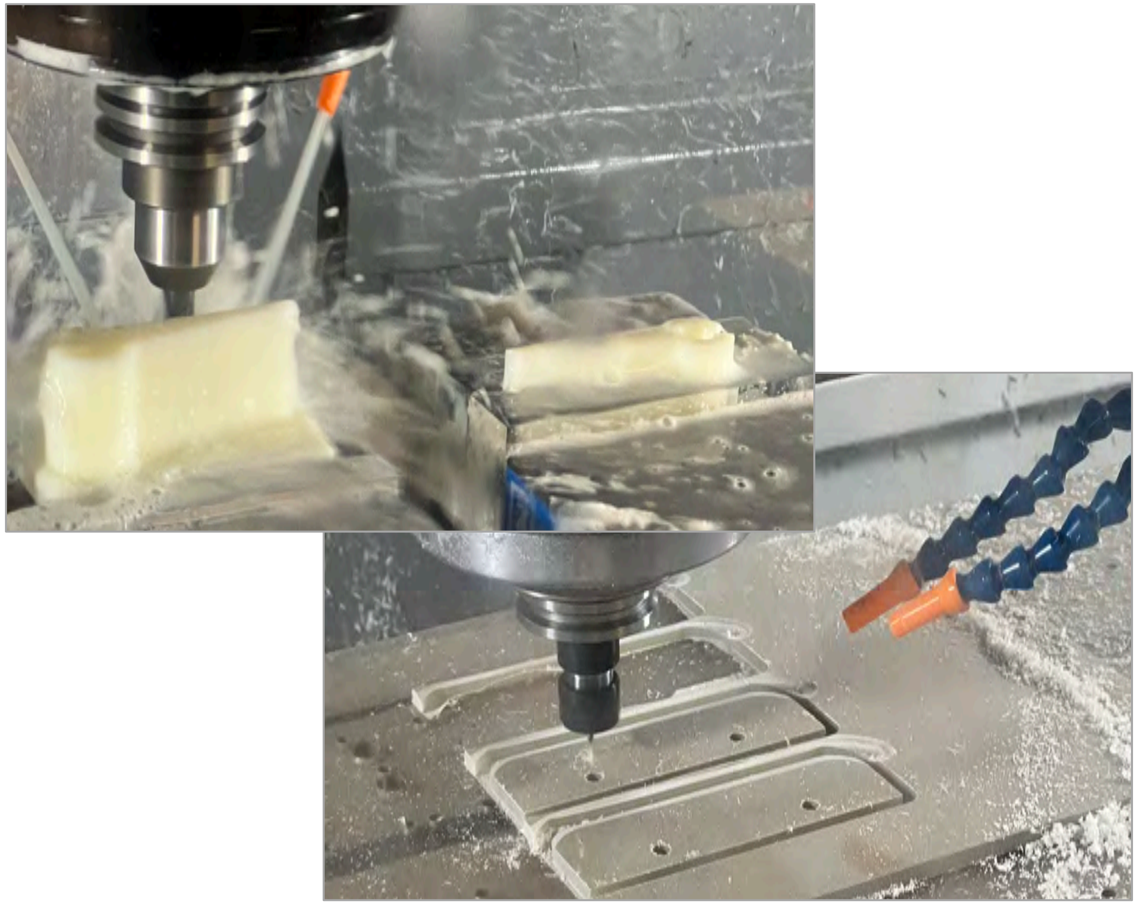
Best Practices - Coolant and Chip Control

- Coolants and air blasts are used to clear chips and take away heat
- Water soluble coolants help minimize the chance for petroleum interaction with some plastics



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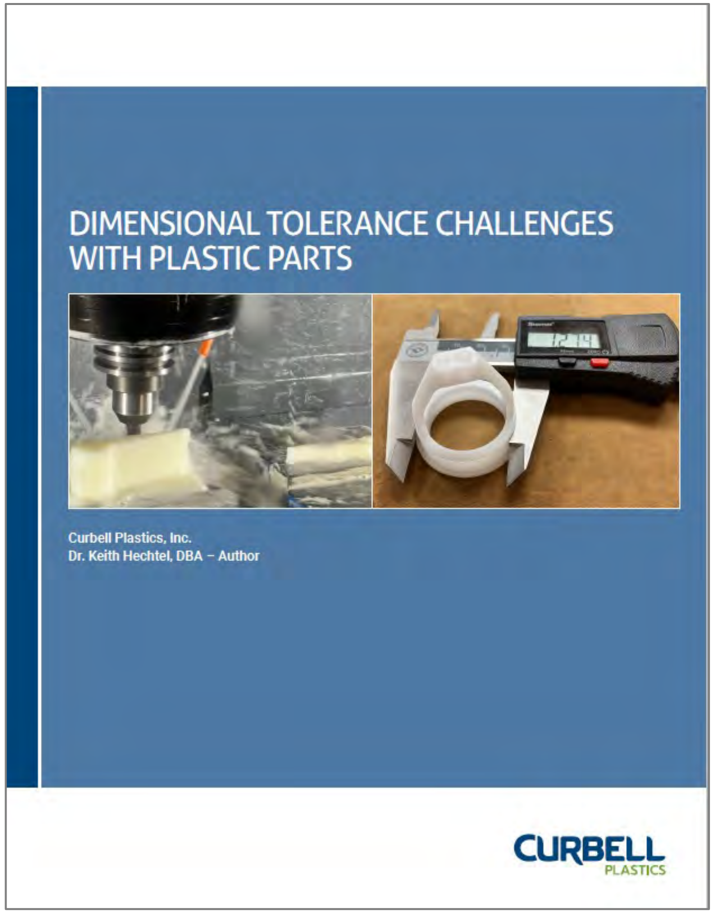
NEW White Paper

For additional information about dimensional stability challenges with plastics, read our new white paper:

Dimensional Tolerance Challenges with Plastic Parts



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Thank you for your time today! Questions?

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References

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