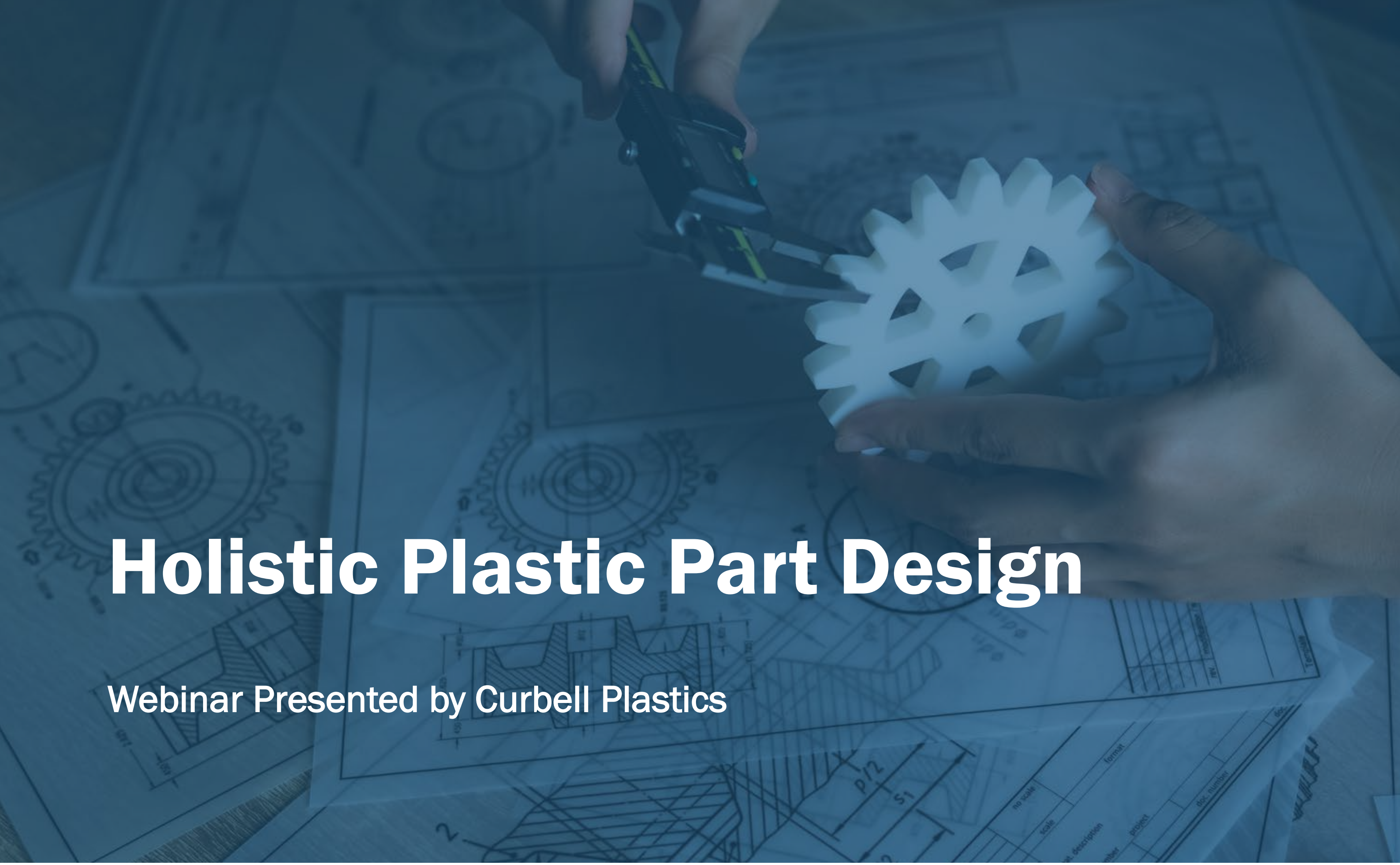

Holistic Plastic Part Design

Webinar Presented by Curbell Plastics

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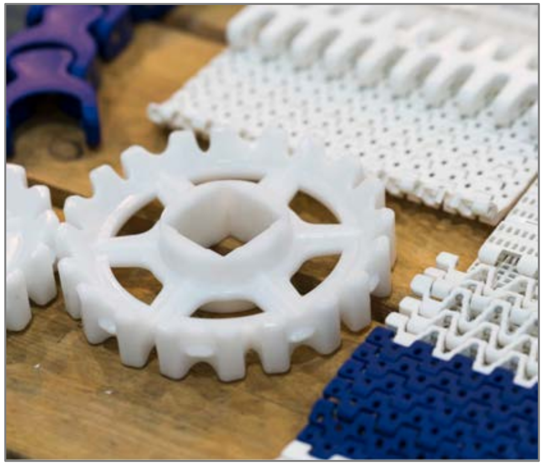
The Benefits of Plastic Materials

- Corrosion resistant
- Complex geometries
- Inexpensive



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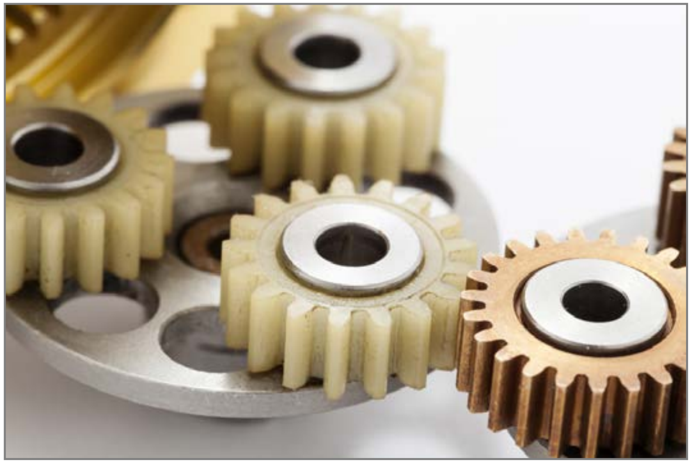
The Benefits of Plastic Materials

- Lightweight
- Durable
- Aesthetic properties
- Optical properties

The Benefits of Plastic Materials

- Sealing characteristics
- Friction and wear
- Good insulators
  - Electrical
  - Acoustical
  - Thermal



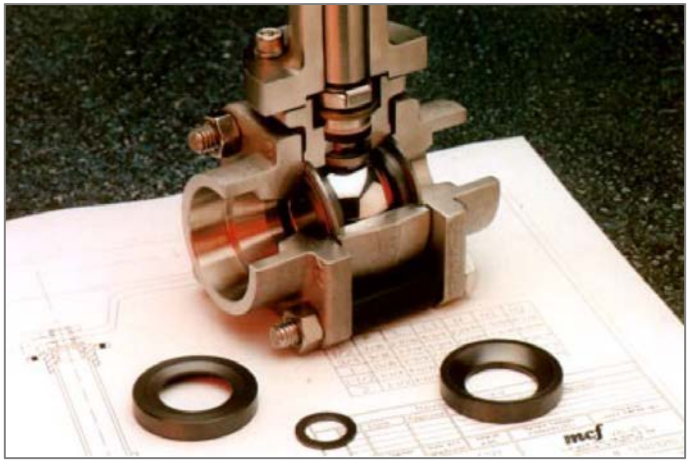


Photo courtesy of DuPont™

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Common Plastic Part Challenges

- Don't perform as expected
- Quality problems
- Lots of "no-quotes"
- Parts are out of tolerance
- Changing materials doesn't always solve the problem

Question for Our Webinar Participants

Have you experienced any of the following unexpected plastic part failures?

- Cracking
- Premature wear
- Degradation from the operating environment
- All of the above
- Not sure

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Holistic View of Plastic Part Design

- Material
- Part geometry
- Manufacturing method
- Required performance
- Operating environment

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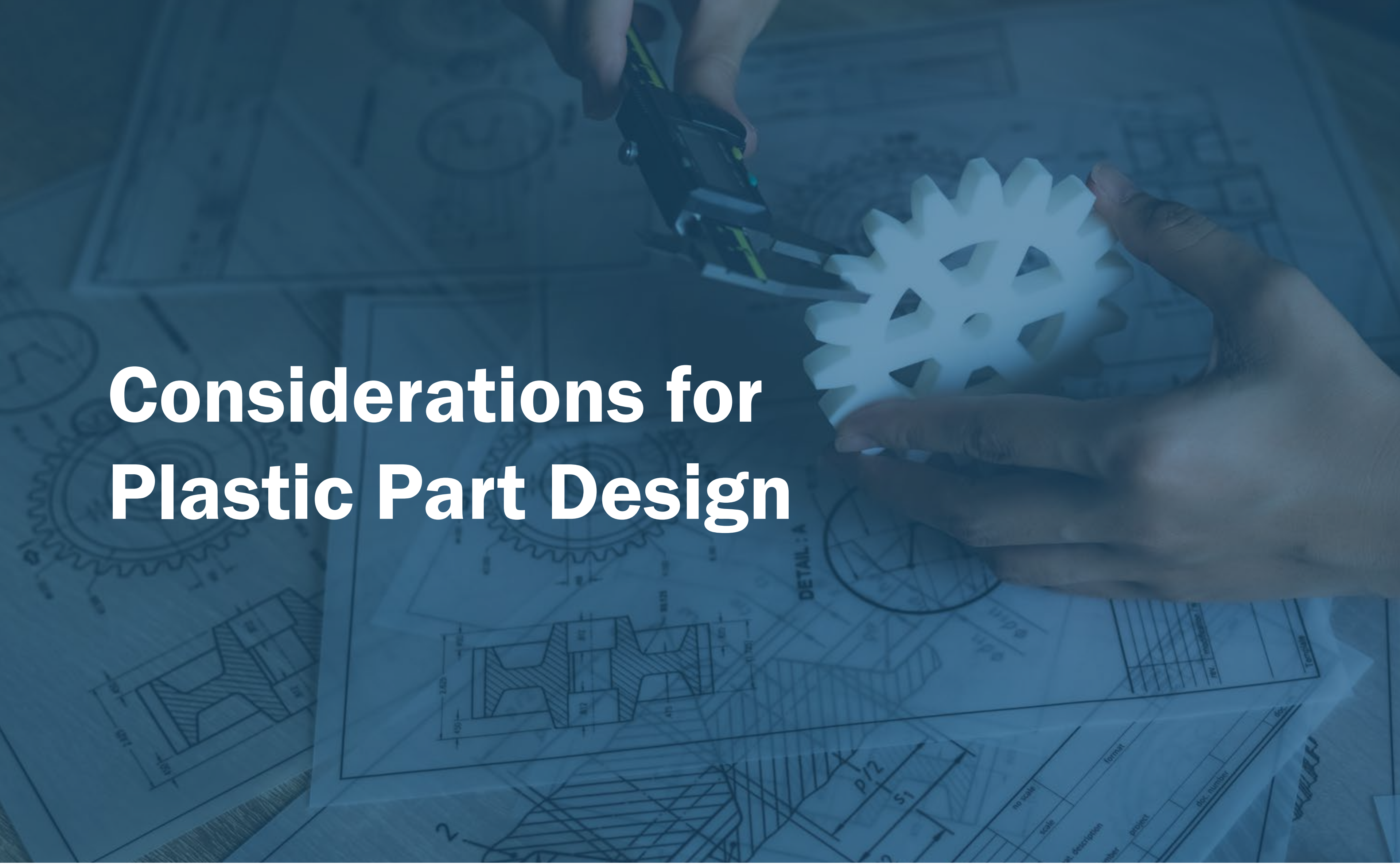

Considerations for Plastic Part Design

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Considerations for Plastic Part Design

- Immediate Failure
  - Mechanical loads
  - Impact

- Failure over time
  - Fatigue
  - Wear
  - Creep / Stress Relaxation

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Question for Our Webinar Participants

Have you had plastic parts exhibit inconsistent performance – sometimes performing well and sometimes failing unexpectedly?

- Yes
- No
- Not sure

Creep

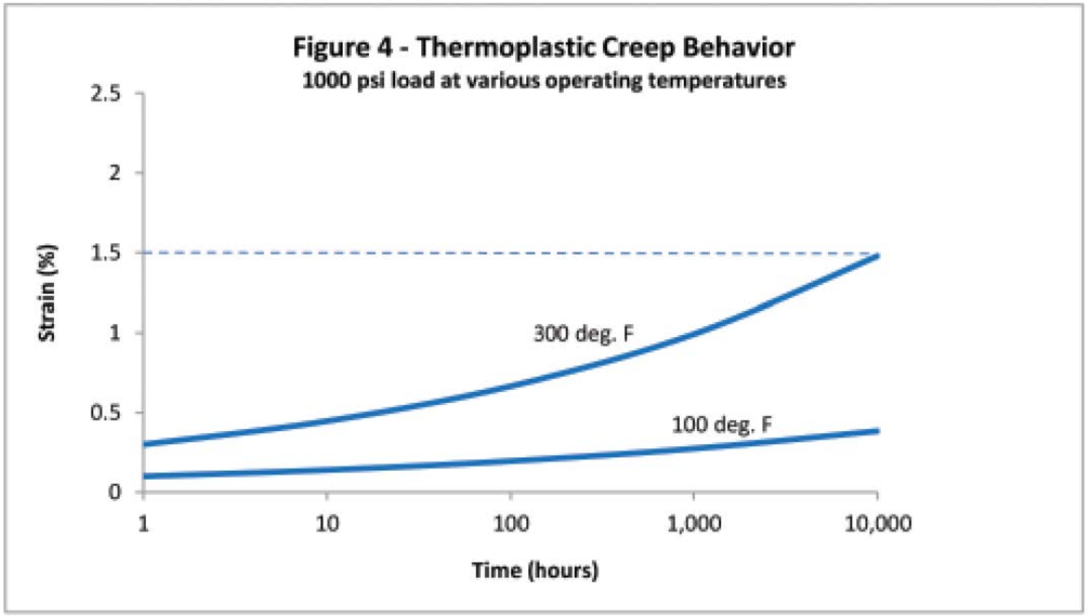
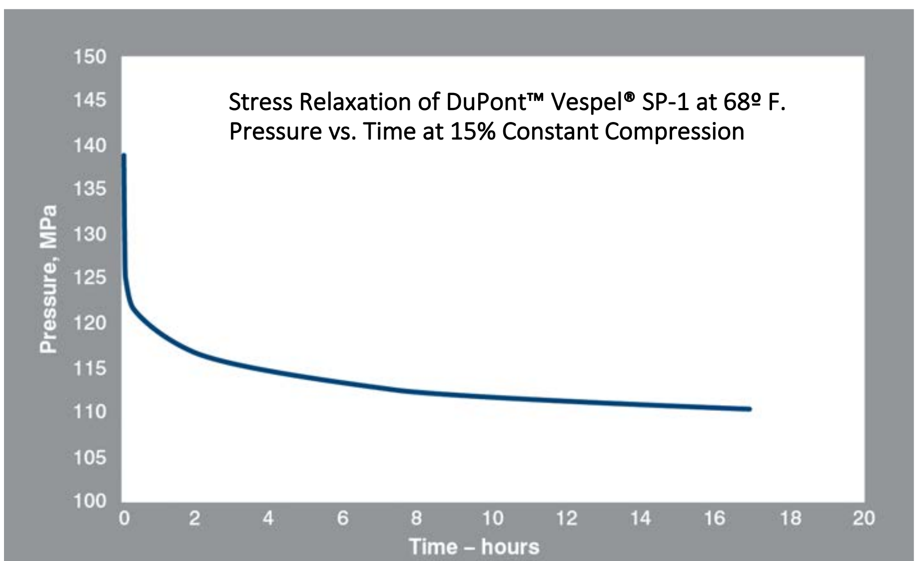


Figure 4 - Thermoplastic Creep Behavior
1000 psi load at various operating temperatures
Strain (%)
2.5
2
1.5
1
0.5
0
300 deg. F
100 deg. F
1
10
100
1,000
10,000
Time (hours)

Stress Relaxation



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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
  - Speeds
  - Mechanism of wear (sliding, abrasion, rolling contact, etc.)
- Additives
  - PTFE
  - Graphite
  - Oil
  - MoS_2

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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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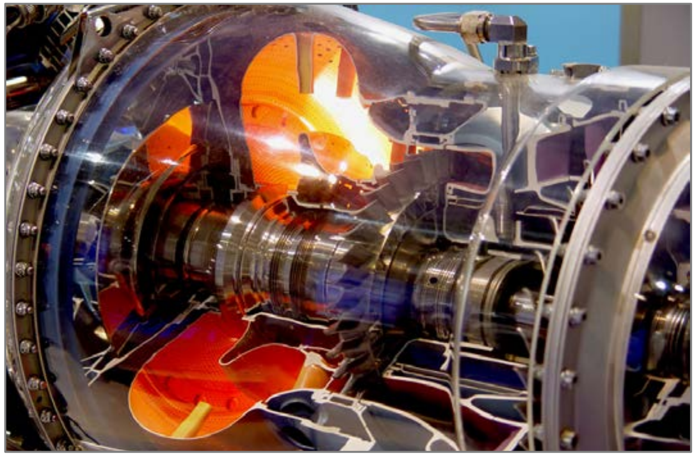
Operating Temperature

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



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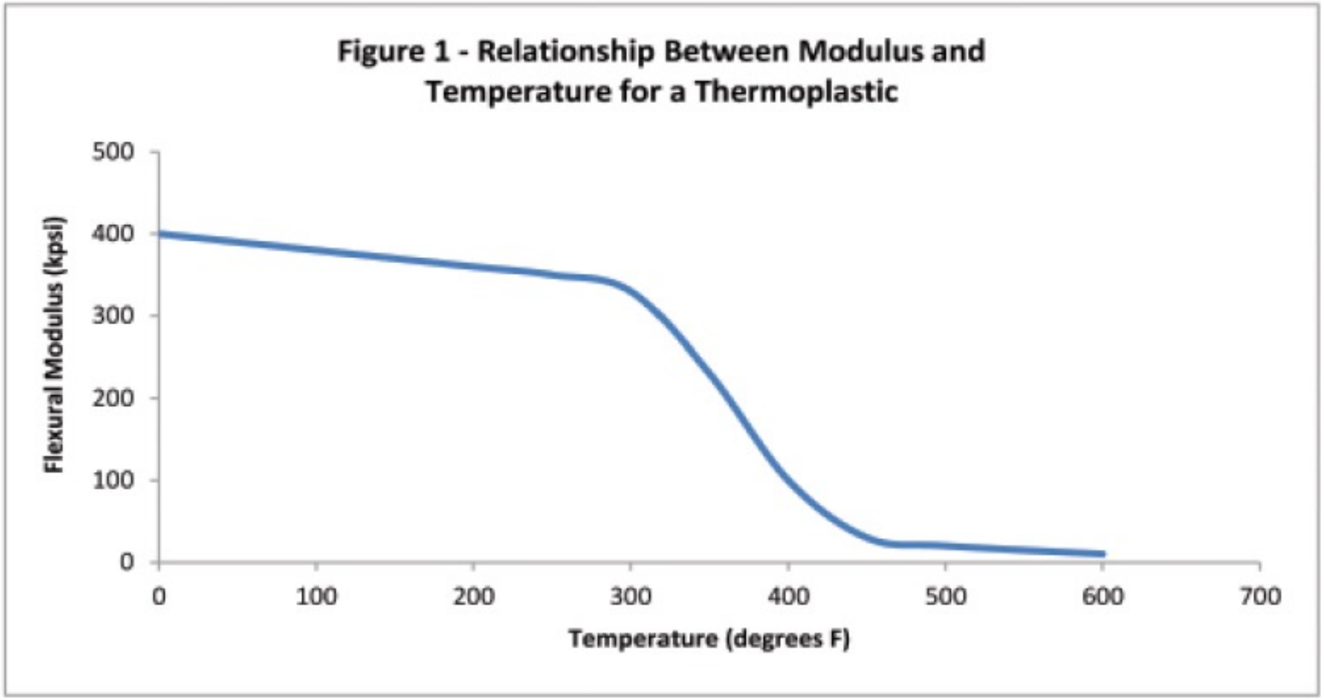
High Temperature Performance

Lower Modulus

Relationship Between Modulus and Temperature for a Thermoplastic



Source: Hechtel, Turning up the heat

Thermal Degradation

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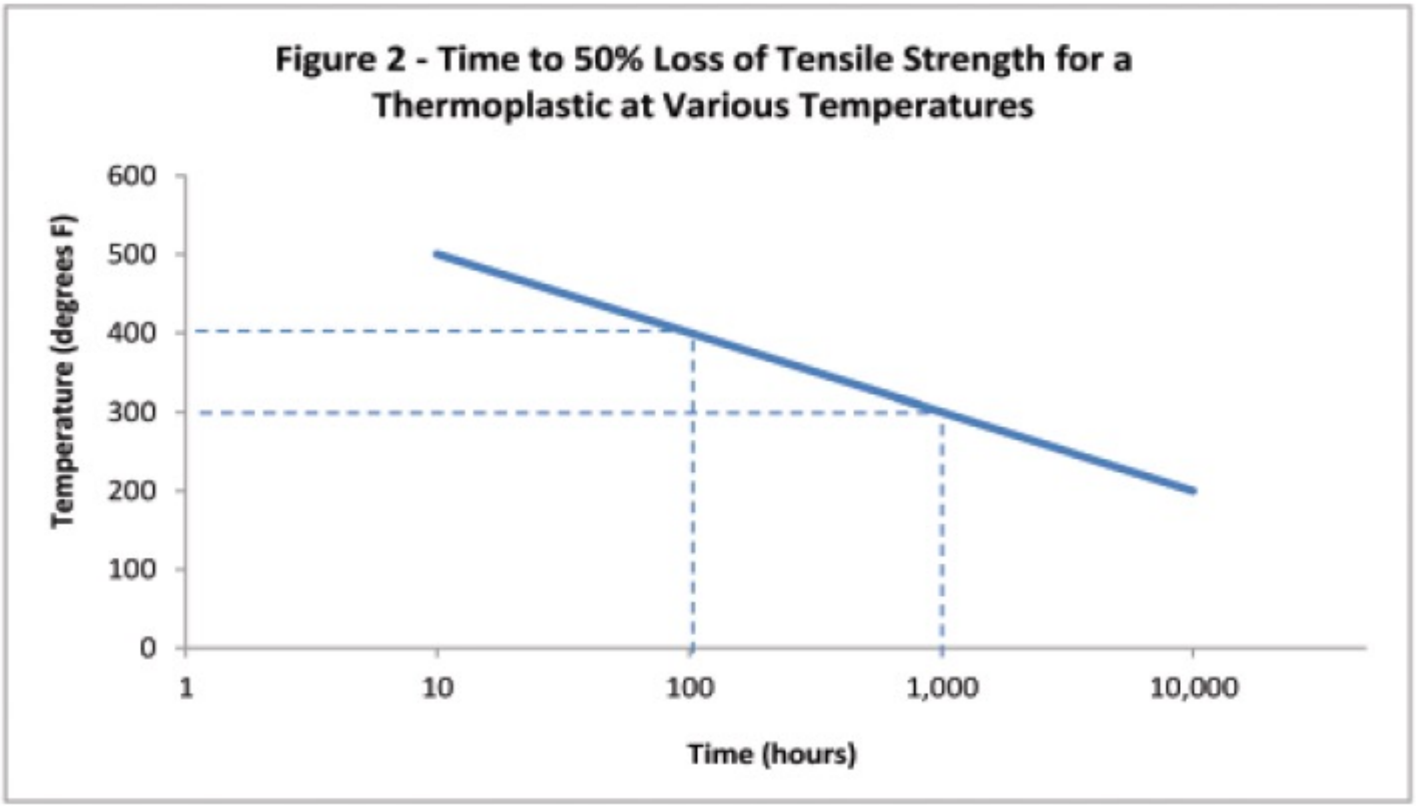
Time to 50% Loss of Tensile Strength for a Thermoplastic at Various Temperatures



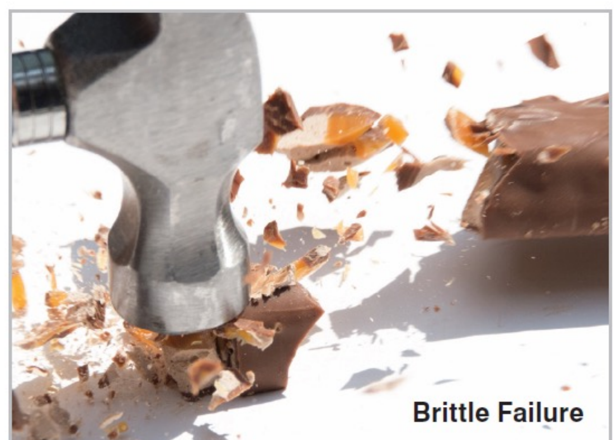
Source: Hechtel, Turning up the heat

CTE Mismatch

Cold Temperatures

- Hardness, strength, and modulus increase
- Reduced toughness below Tg
- Decreased friction
- CTE mismatch

Ductile Failure


Brittle Failure

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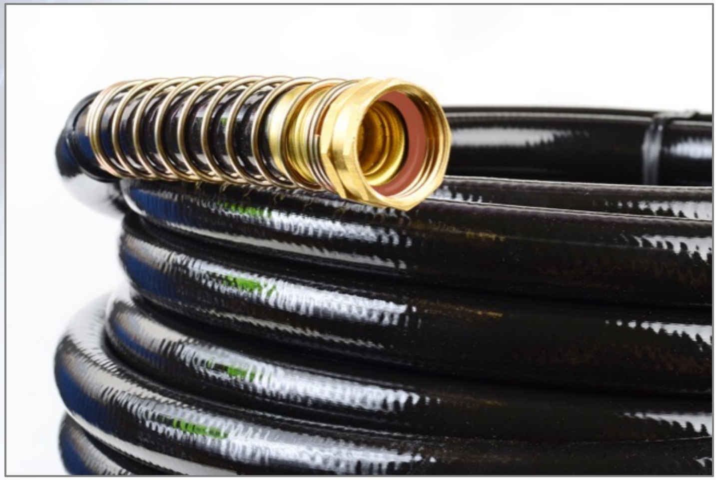
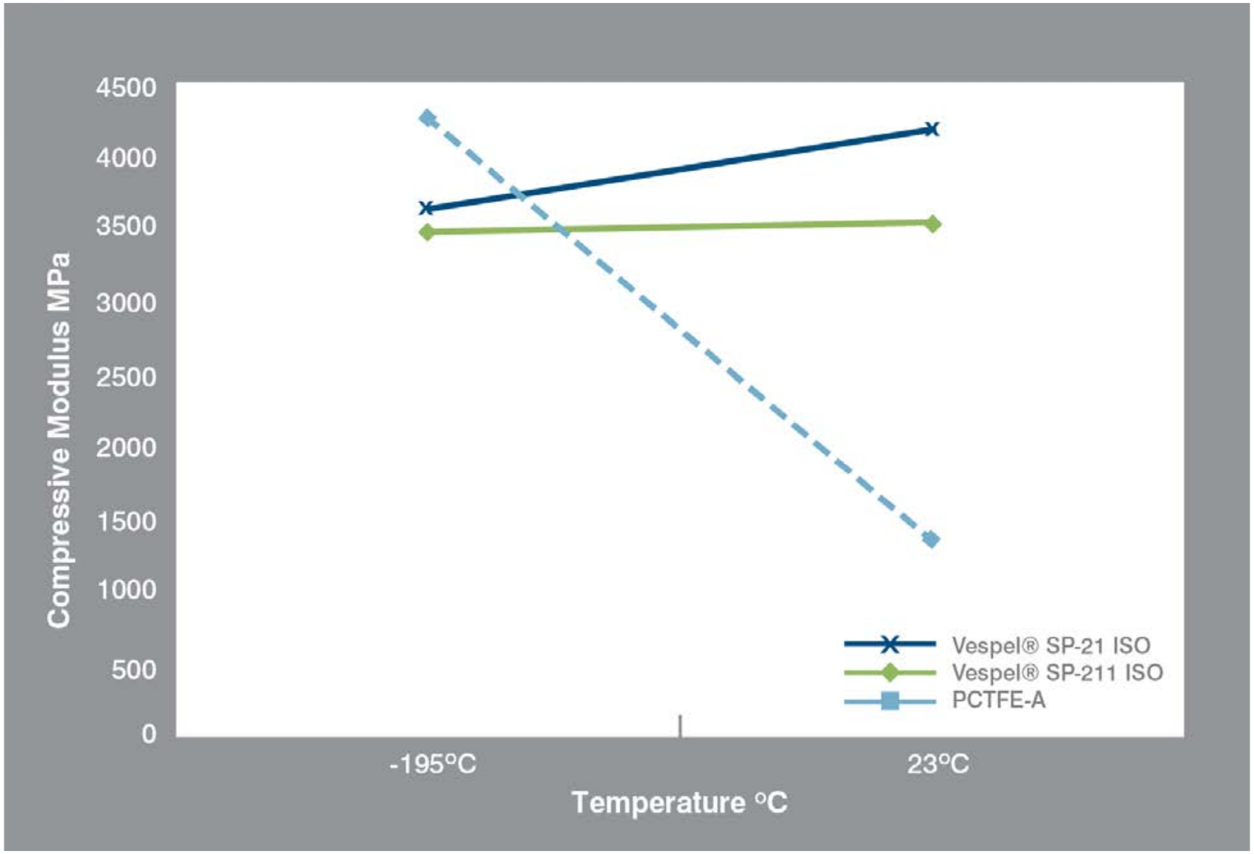
Cold Temperatures



Cold Temperatures

Compressive Modulus (ASTM D695)



Source: Lewis, 2015

Chemical Attack and ESC

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Degradation from UV

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Aesthetics and Light Management

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Plastic Materials Technology

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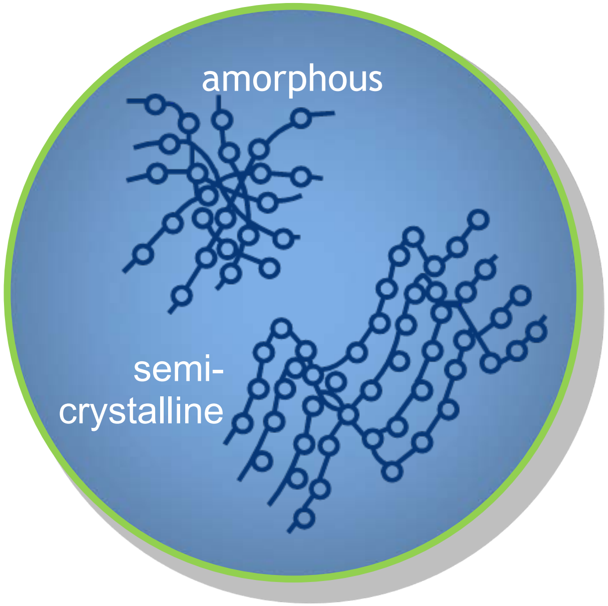
Thermoplastic Material Selection

Amorphous

- Ultem®
- Polycarbonate
- Acrylic
- ABS
- Polystyrene



Semi-Crystalline

- PEEK
- PTFE
- Delrin®
- Nylon
- Polyethylene

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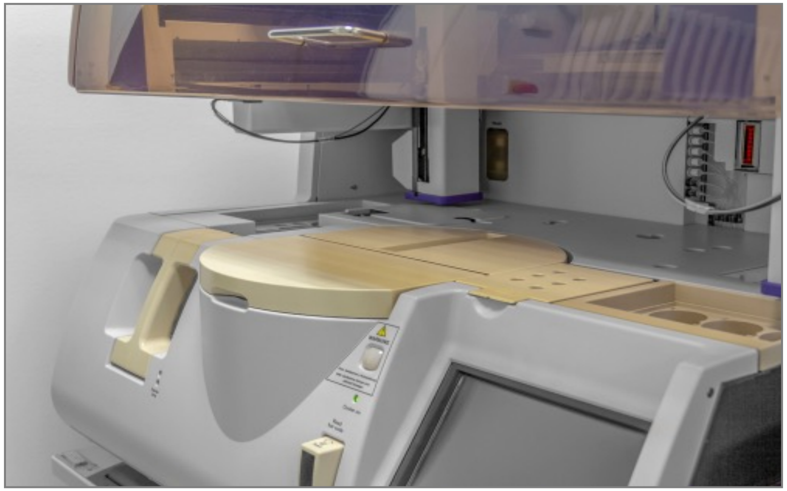
Amorphous Plastics vs. Semi-Crystalline Plastics

Amorphous

- Easy to thermoform

Semi-Crystalline

- Difficult to thermoform



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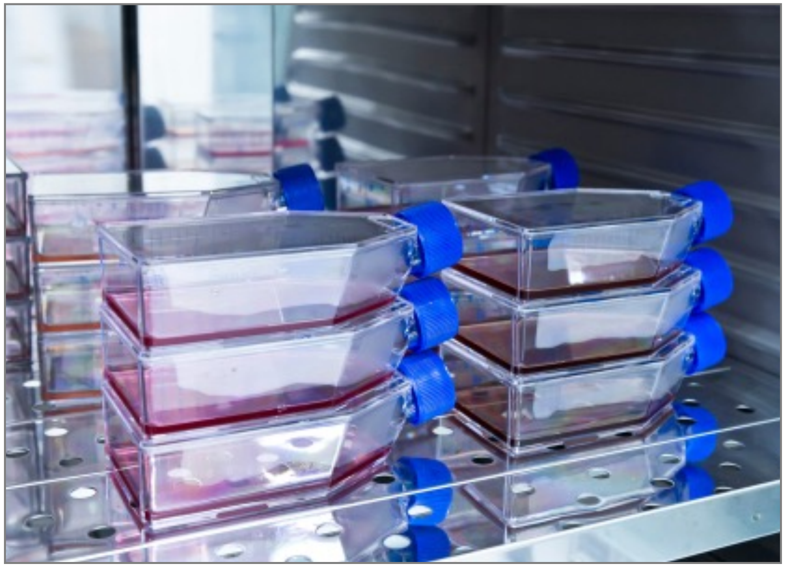
Amorphous Plastics vs. Semi-Crystalline Plastics

Amorphous

- Tend to be transparent

Semi-Crystalline

- Tend to be opaque



Amorphous Plastics vs. Semi-Crystalline Plastics

Amorphous

- Poor chemical and ESC resistance
- Easy to paint/glue

Semi-Crystalline

- Generally good chemical resistance
- Difficult to paint/glue

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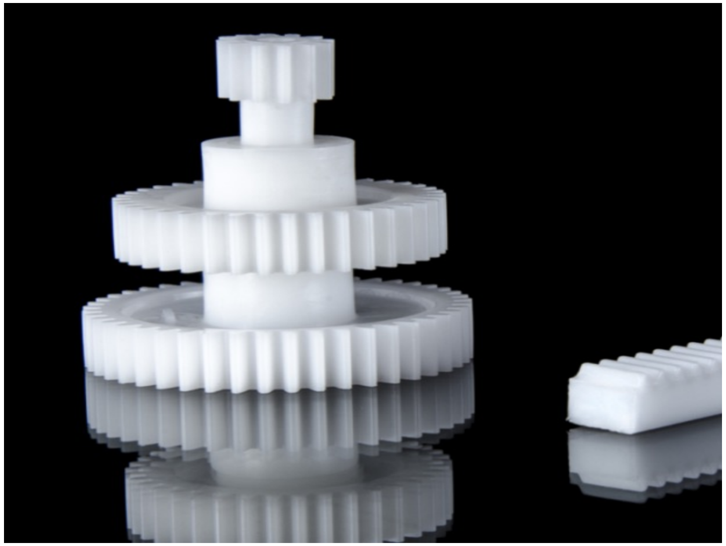
Amorphous Plastics vs. Semi-Crystalline Plastics

Amorphous

- Generally poor friction and wear characteristics



Semi-Crystalline

- Generally good friction and wear characteristics (additives)

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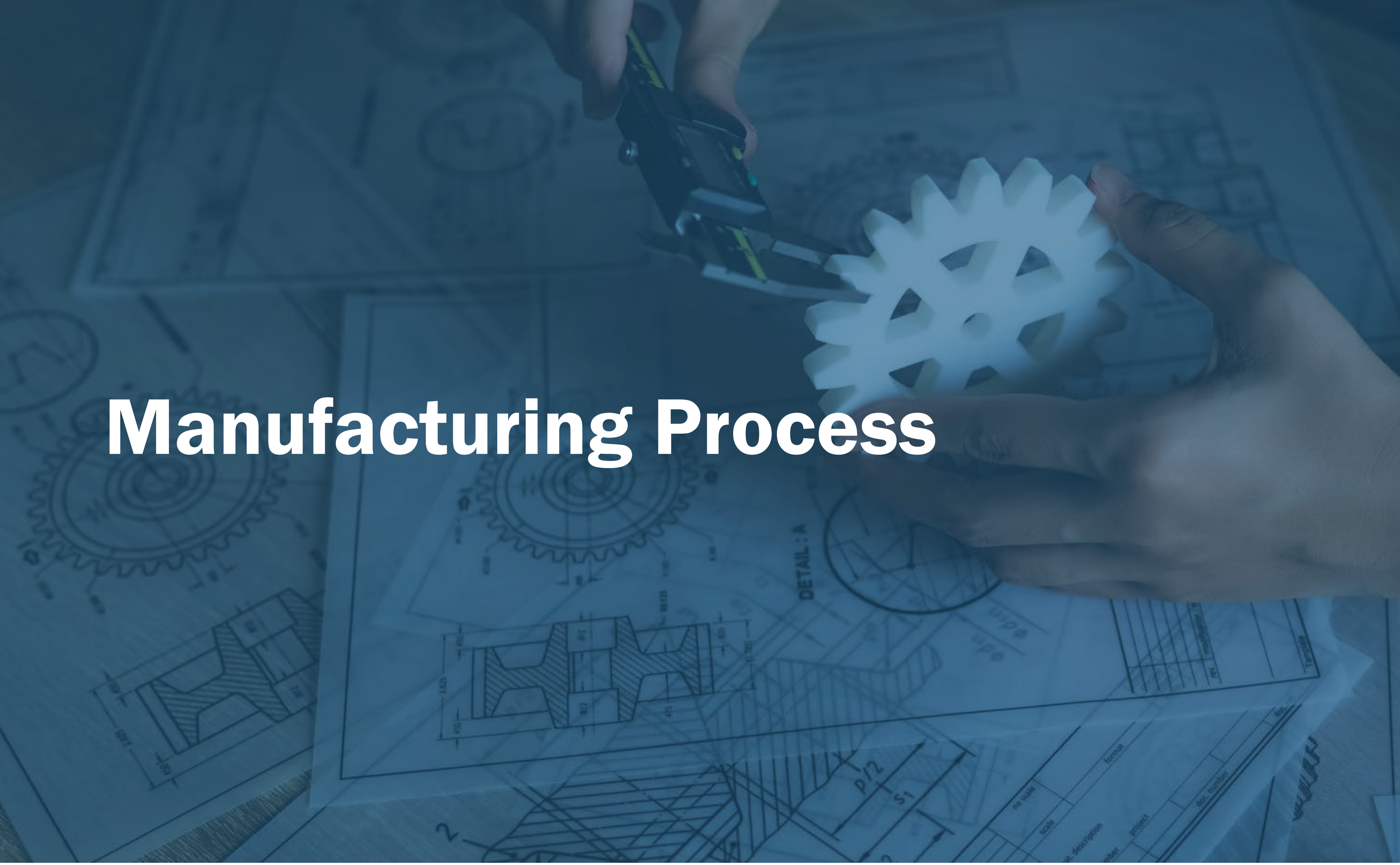
Manufacturing Process



Manufacturing Process Considerations

Material

- Must be compatible with manufacturing process
- Molecular weight/melt flow

Tolerances and surface finish

- Must be compatible with the manufacturing method

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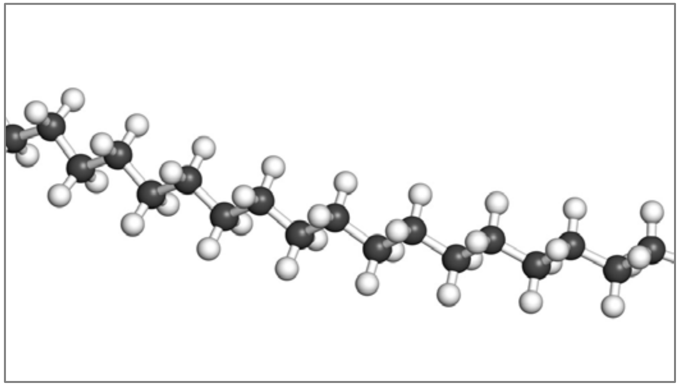
Molecular Weight and Performance

High Molecular Weight Polymers

- High melt viscosity / low melt flow
- Improved cold temperature toughness
- Better chemical resistance / ESC resistance
- Superior wear properties



Manufacturing Process Considerations

Part Geometry

- Must be manufacturable by chosen method

Budget for Tooling

- Annual quantity – tooling cost vs. part cost
- Requirement for design flexibility
- May not be practical with hard tooling

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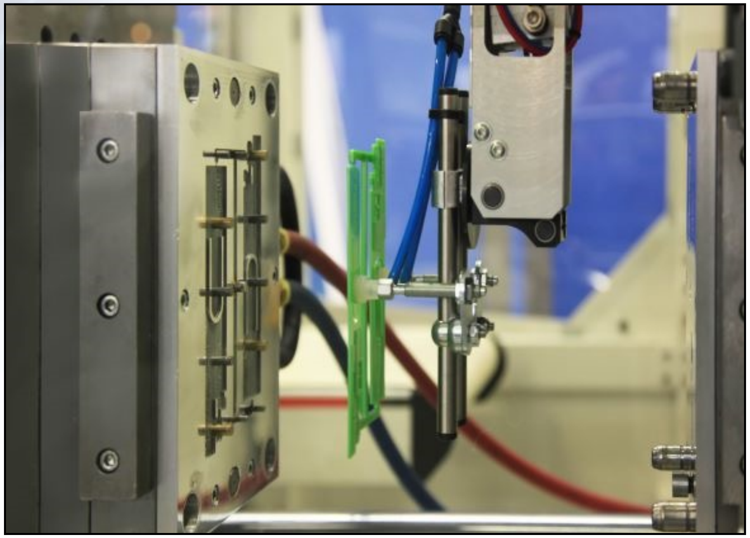
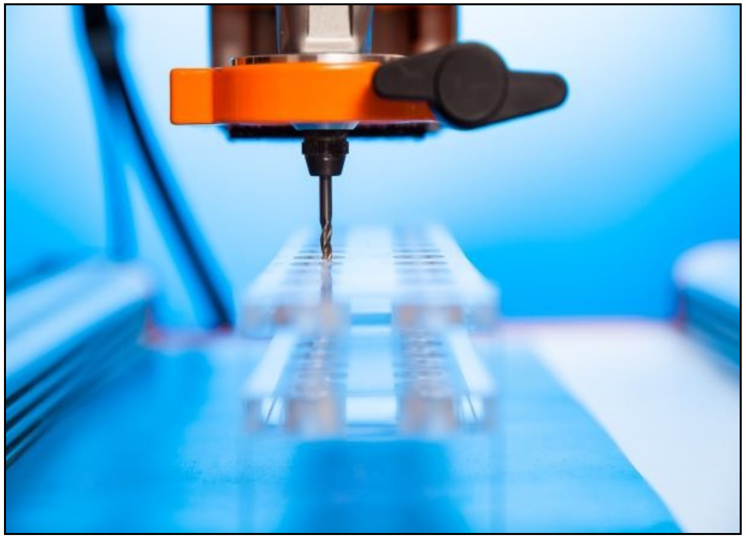
Manufacturing Method



Injection Molding

- High melt flow, low molecular weight
- Thin, even walls
- Polished surfaces
- High tooling cost, low part cost



Machining

- Low melt flow, high molecular weight
- Thick walls OK
- Difficult to achieve polished surfaces
- Low (if any) tooling cost
- Labor intensive

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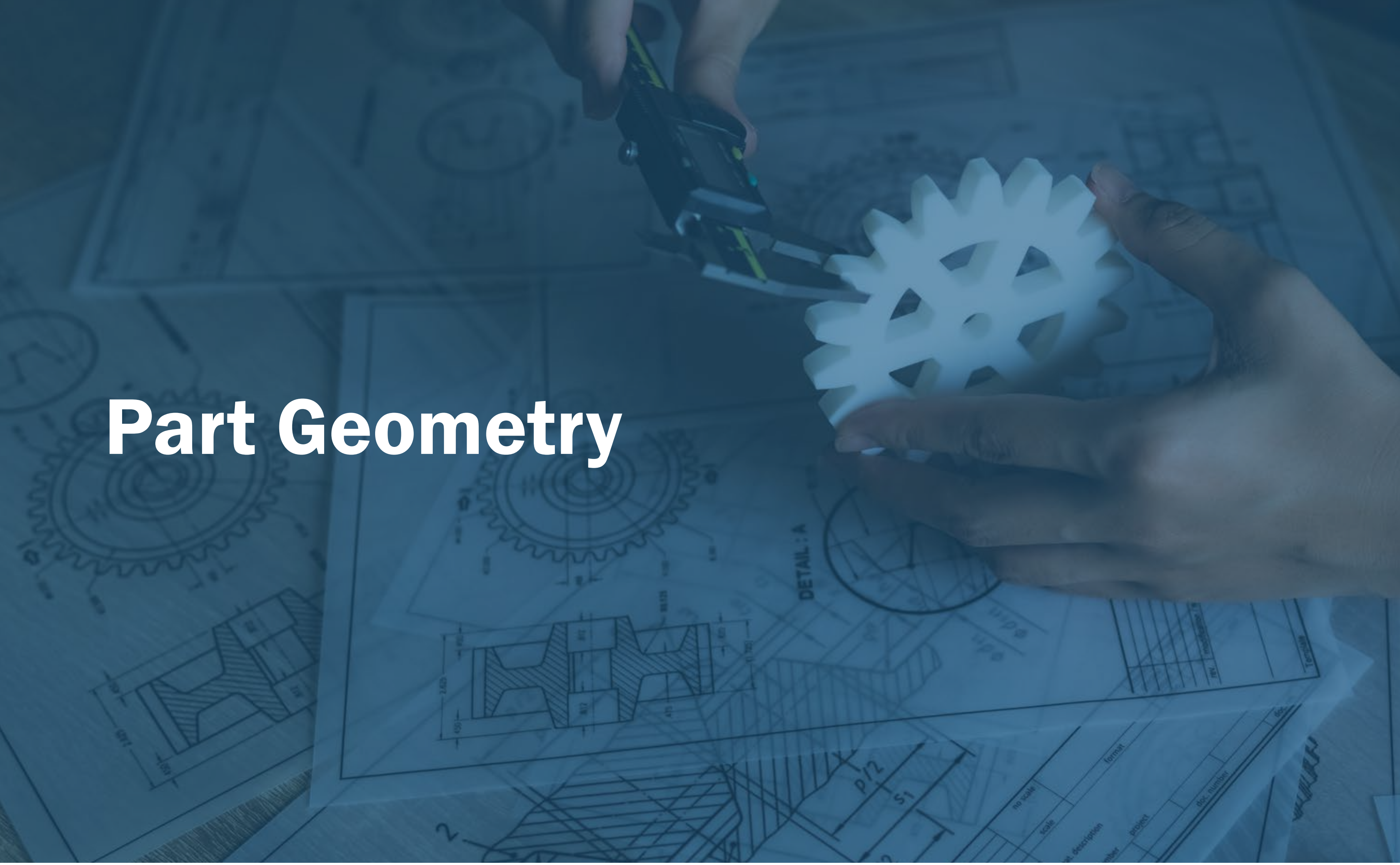
Part Geometry



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Geometry (Function and Processing)

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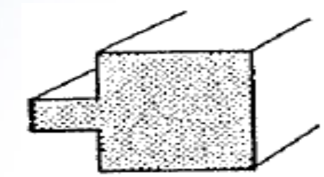
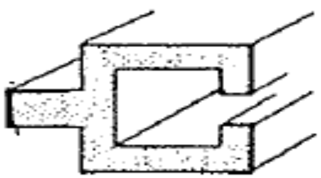
Part Geometry as it Relates to Processing and Molecular Weight



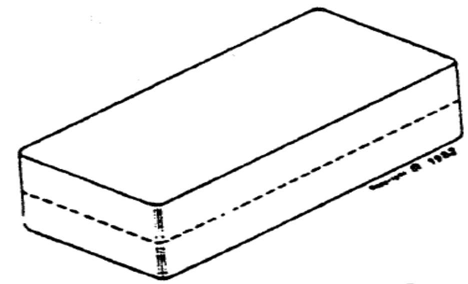
Machining



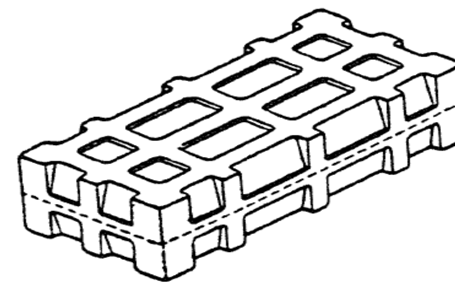
Extrusion

Machining

Extrusion



Machining



Injection Molding

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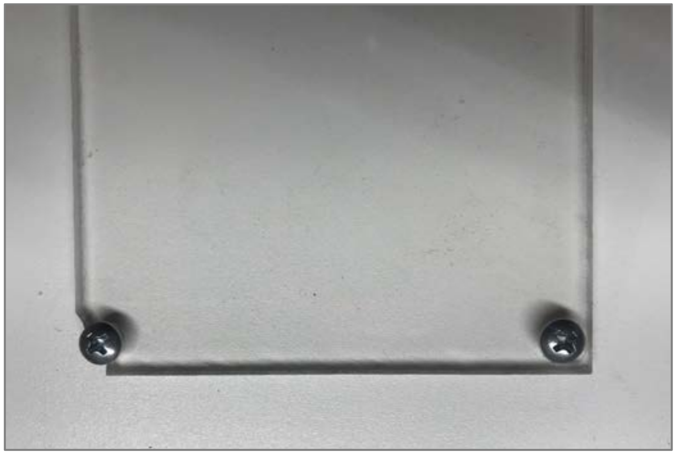
Geometry

Sharp, internal 90 degree corners



Holes close to the edge of the part

Flat head screws

Plastic Part Design Questions

- What base polymer?
- Additives and fillers?
  - Wear additives
  - Glass reinforcements
- Manufacturing method?
  - Is it compatible with molecular weight and part geometry?
- Part geometry problems?
  - Stress concentrations?
  - Compatible with manufacturing methods?

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Thank you for your time today! Questions?

Dr. Keith Hechtel, DBA
Senior Director of Business Development
Curbell Plastics, Inc.
Office: 716-740-9142
Mobile: 563-271-9316
khechtel@curbellplastics.com

Timothy Buchanan
Associate Technical Service Engineer
Curbell Plastics, Inc.
Office: 716-667-3377 Ext. 7412
Mobile: 518-416-1342
tbuchanan@curbellplastics.com

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References

Lewis, G., Merot, P., & Matoux, J. (2015). High performance polyimide parts can help reduce actuation torque and improve sealing in cryogenics ball valves for LNG (Liquid Natural Gas) applications. Presented at the AMI International Conference on Oil & Gas Non-Metallics. London. December 8-10, 2015.

McDonald, P. & Rao, M. (1987). Thermal and mechanical properties of Vespel® at low temperatures. Proceedings from the International Cryogenic Materials Conference, Saint Charles, IL, 14-18 June, 1987.

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