TORLON Polyamide-Imide

Processing and Curing

Solvay Advanced Polymers

TORLON® Polyamide-Imide
TORLON Processing OVERVIEW

- Resin preparation
- Mold design
- Machine settings
- Processing temperatures
- Regrind
- Curing
- Machining
- Post machining curing
General Processing Considerations

Proper processing of TORLON assures:
- Full thermal performance up to 260°C
- Outstanding impact resistance (up to 8%)
- Dimensional stability
- Outstanding flexural fatigue resistance
- Compressive strength
- Outstanding tensile properties
- Creep resistance
- Wear resistance

Torlon is a very high Performance resin. To obtain all of its benefits it must undergo a curing cycle.
Precursors of Torlon

- Depending on what resin we are going to make, R-- can be different.

Crude Torlon

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Structure of Torlon PAI

- A melt processable high $T_g$ (285°C) polymer
  - Ether and amide functional groups
  - Low molecular weight
- Strength and stiffness properties
  - Imide and aromatic groups
  - Curing (heat treatment)
    - Imidization
    - High molecular weight

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Torlon preparation and Processing
Pre-Drying of Torlon

- Product must be dried to a moisture content of 200 ppm (0.02%)
- Dry 24 hours at 121°C
- Dry 8 hours at 149°C
- Dry 4 hours at 177°C
- Use a dessicant equipped dryer!
Injection Molding TORLON

- Mold Materials & Design
- Processing Temperatures
- Machine Settings
- Regrind
Mold Materials

• Pre-hardened Steel (~RC30) for Prototype Tools
• Hardened Steel (H-13 or Similar, ~RC50) for Production Tools
• Plating (Balzer etc) Not Necessary
  - TRLON is Non-Corrosive
Tool Steels*

- Uddeholm: Stavax ESR, Orvar
- Thyssen: W66EFS
- Aubert & Duval: SMV3W, SMV5W

Steel choice guided by strength and wear resistance (not corrosion resistance or grain size)

*This list is not exhaustive
Mold Design

• Sprues/Runners as Short as Possible
  • Hot sprue bushing to reduce resin consumption

• Balanced Runner Systems
  - Equal Velocity in Each Runner

• Generous Vents/Overflow Tabs
  • 0.015 – 0.060mm

• No hot runner systems!

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TORLON Machine Settings

• Injection Speed and Pressure at Maximum
  - Hydraulic Accumulators Greatly Improve Quality

• Back Pressure ~ 3,5 bar (limit shear)

• Shot Size 20% - 80% of Machine Capacity
Processing temperatures

- Mold Temperature 205° C - 218° C
- Barrel Temperatures
  - Rear 305°C
  - Middle 327°C
  - Front 343°C
  - Nozzle 370°C
- 1.0:1 Compression Ratio Screw, No Check Device
Screw design

- Limit shear of material
- Promote “self-cleaning” of injection unit
- Free flowing, no dead spots
- Accuracy of bbl to screw diameter

<table>
<thead>
<tr>
<th>Screw Design</th>
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<tbody>
<tr>
<td>Rudimentary Flights on Screw Tip</td>
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<tr>
<td>Compression Ratio: 1:1 to 1.5:1</td>
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<tr>
<td>Length to Diameter Ratio: 18:1 to 24:1</td>
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<td>Smooth, Constant Taper</td>
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TORLON® Polyamide-Imide
Regrind

- Polyamide-imide is reactive
- Acid number decreases with Temperature
- Molecular weight increases w/ temp
- Viscosity increases dramatically after thermal exposure
- Risk of “seizing” screw & barrel
- Regrind STRONGLY discouraged
Curing of Torlon

- Depending on parts thickness and temperature profile the imidization goes on to the final performance level.
## Torlon Curing Cycles

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Curing Schedule</th>
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<tbody>
<tr>
<td>&lt; 7.62 mm</td>
<td>7 days ramp, 10 days @ 260°C</td>
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<tr>
<td>7.62 -12.7 mm</td>
<td>13 days ramp, 10 days @ 260°C</td>
</tr>
<tr>
<td>&gt;12.7 mm</td>
<td>25 days ramp, 10 days @ 260°C</td>
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</tbody>
</table>
## Curing Conditions

**Thickness ≤ 7.62mm**  
*(Standard cycle)*  
1 day @ 149°C  
1 day @ 191°C  
1 day @ 204°C  
1 day @ 218°C  
1 day @ 232°C  
1 day @ 243°C  
1 day @ 252°C  
10 days @ 260°C  

**Total:** 17 days  
**Temperatures:** +/− 3°C

**Thickness 7.62 – 12.7mm**  
1 day @ 149°C  
1 day @ 176°C  
1 day @ 191°C  
1 day @ 204°C  
1 day @ 218°C  
2 days @ 232°C  
3 days @ 243°C  
2 days @ 249°C  
1 day @ 254°C  
10 days @ 260°C  

**Total:** 23 days  
**Temperatures:** +/ 3°C

**Thickness > 12.7mm**  
1 day @ 149°C  
1 day @ 177°C  
1 day @ 191°C  
2 days @ 204°C  
2 days @ 215°C  
2 days @ 226°C  
3 days @ 232°C  
3 days @ 238°C  
5 days @ 243°C  
3 days @ 249°C  
2 days @ 254°C  
10 days @ 260°C  

**Total:** 35 days  
**Temperatures:** +/ 3°C
Curing Torlon

- Tensile Strength @ RT doubles

![Graph showing the increase in tensile strength with curing temperature and days.](image-url)
Curing Torlon

- Tensile strength @ 177°C almost doubles
Curing Torlon

Tensile elongation @ RT quadruples

Elongation in %

Oven temperature in °C

Days

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Curing TORLON

Tensile elongation @ 177°C increases +six times

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TORLON® Polyamide-Imide
Curing TORLON

- Impact (Izod) @ RT almost triples

![Graph showing impact and temperature over days](image-url)
Machining Torlon

- Use standard machine tools
- Use cutting oils for cooling and ease of cutting
- Remove small layers (several passes, not one single thickness)
Post Machining Re-cure

- Machining may remove some of the cured/oxidized outer layer
- Oxidized layer provides some additional tribological properties
- Re-cure recommended to improve friction and wear resistance
Post-machining Re-curing conditions

- **Day 1**: to 150°C (ramp up over 6 hours)
- **Day 2**: from 150 to 175°C (over 2 hours) then remaining time (22 hrs) at 175°C
- **Day 3**: from 175 to 200°C (over 2 hours) then remaining 22 hours at 200°C
- **Day 4**: from 200 to 225°C (over 2 hours) then remaining 22 hours at 225°C
- **Day 5**: from 225 to 260°C (over two hours) balance of day at 260°C
- **Day 6**: 260°C
- **Day 7**: 260°C Ramp down at ambient heat loss rate to room temp at end of D7.