Chemical compatibility of high performance engineering thermoplastics within compressor environments

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PRESENTATION OUTLINE

• Motivation
• Experimental data
  – Compatibility with refrigerants
  – Compatibility with lubricants and mixtures
  – Dimensional stability
• Processing Guidelines
• Summary
Where can high performance thermoplastics play a role in compressors?
HIGH PERFORMANCE POLYMER SELECTION

Polyetherimides
Amorphous, transparent, amber resins
- Long-term high heat capability
  (continuous use temperatures of 170°C)
- Dimensional stability / Tight tolerances
- Strength & modulus at high temperatures
- Inherent flame resistance
- Hydrolytic and chemical stability

Polyamides
Semi-crystalline transparent resins
- Superior heat resistance
  (continuous use temperatures of 180°C)
- High strength & stiffness
- Good flow and processability
- Wear and friction resistance
- Hydrolytic and chemical stability

Polyamide 4,6 – aliphatic nature
Polyphthalamide – semi-aromatic nature
Polyetherimide 1 (PEI1) - enhanced flow grade with balance of mechanical properties & processability

Polyetherimide 2 (PEI2) - enhanced chemical resistance grade

Polyetherimide 3 (PEI3) - proprietary blend with improved ductility and enhanced hydro-stability

Polyetherimide 4 (PEI4) - proprietary experimental high heat blend with semi-crystalline nature

Nylon 4,6 (PA4,6) - Semi-crystalline resin with superior heat resistance, design stiffness, wear resistance

Polyphthalamide (PPA) - Aromatic semi-crystalline resin with excellent mechanicals, chemical resistance
**EXPERIMENTAL PROTOCOL - CONDITIONS**

<table>
<thead>
<tr>
<th>Test</th>
<th>Duration</th>
<th>Chemicals used</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen immersion</td>
<td>30 days</td>
<td>--</td>
<td>60°C, 127°C</td>
</tr>
<tr>
<td>Refrigerant immersion</td>
<td>30 days</td>
<td>R-134A, R-410A</td>
<td>60°C</td>
</tr>
<tr>
<td>Lubricant immersion</td>
<td>30 days</td>
<td>10cSt, 32cSt POE oils</td>
<td>127°C</td>
</tr>
<tr>
<td>Refrigerant + lubricant</td>
<td>30 days</td>
<td>32cSt + R-134A</td>
<td>127°C</td>
</tr>
<tr>
<td>immersion</td>
<td>300psi</td>
<td>10cSt + R-410A</td>
<td></td>
</tr>
</tbody>
</table>

**Specimen:**
Type V, ASTM tensile bars

**Measurements:**
- Tensile properties (ASTM D638 standard protocol)
- Dimensional changes in tensile bars
- Visual changes in tensile bars
**EFFECT OF EXPOSURE TO NITROGEN**

PEI4, PA4,6 and PPA with semi-crystalline nature show marked drop in tensile strength.

Amorphous resins show increase in tensile strength after annealing.

Tensile elongation does not change significantly.
EFFECT OF EXPOSURE TO NITROGEN

Visual changes in line with tensile data
Semi-crystalline nylons incompatible with polyolester oils
Polyetherimides 1 and 2 and 4 show good resistance to 32cSt lubricant
10cSt oil slightly more aggressive than 32cSt
EFFECT OF EXPOSURE TO POLYOLESTER OILS, 127°C

Visual changes in line with tensile data
Polyetherimides 1, 2 and 3 and PPA show good chemical resistance.
EFFECT OF EXPOSURE TO REFRIGERANTS

Visual changes in line with tensile data
PEI1, 2, 3 and PPA withstand the influence of the chemical mixture well. PA4,6 and PEI4 still show significant loss of tensile strength.
EFFECT OF EXPOSURE TO MIXTURES

Visual changes in line with tensile data
SUPPORTING DATA

Change in weight of tensile bars after exposure (%)

<table>
<thead>
<tr>
<th></th>
<th>PEI1</th>
<th>PEI2</th>
<th>PEI3</th>
<th>PEI4</th>
<th>PA4,6</th>
<th>PPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (127 degC)</td>
<td>-0.1</td>
<td>-0.2</td>
<td>-0.2</td>
<td>-0.1</td>
<td>0.2</td>
<td>-0.2</td>
</tr>
<tr>
<td>POE oils (127 degC)</td>
<td>-0.2</td>
<td>-0.2</td>
<td>-0.2</td>
<td>-0.1</td>
<td>0.1</td>
<td>-0.1</td>
</tr>
<tr>
<td>R-134A (127 degC)</td>
<td>-0.5</td>
<td>-0.4</td>
<td>-0.4</td>
<td>-0.1</td>
<td>-0.4</td>
<td>-1.0</td>
</tr>
<tr>
<td>R-410A+10cSt (127 degC)</td>
<td>2.8</td>
<td>-0.1</td>
<td>3.2</td>
<td>1.6</td>
<td>0.2</td>
<td>-0.6</td>
</tr>
</tbody>
</table>

Tests for leaching of substances from the polymers
- Gas chromatographic and mass spectrometry techniques used for analysis of chemicals
- No low molecular weight species (stabilizers, monomers) were observed at the detection limit of 10ppm.

Polymers are dimensionally and chemically stable
PERFORMANCE SUMMARY

<table>
<thead>
<tr>
<th>Effect of temperature under N2, 60°C and 127°C</th>
<th>PEI1 resin</th>
<th>PEI2 resin</th>
<th>PEI3 resin</th>
<th>PEI4 resin</th>
<th>PA4,6 resin</th>
<th>PPA resin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect of 10cSt POE oil, 127°C</td>
<td></td>
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<tr>
<td>Effect of 32cSt POE oil, 127°C</td>
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<tr>
<td>Effect of R-410A and R-134A, 127°C</td>
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</tr>
<tr>
<td>Effect of compressor environment (ref + lub), 127°C</td>
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</tbody>
</table>

Amorphous resins perform better than crystalline resins
Polyetherimide resins show best resistance against refrigerants & lubricants
Polyetherimides exhibit shear thinning behavior facilitating processing
Processed using standard injection molding equipment

PEI Resins Processing Conditions

- Melt Temperature: 350 – 400°C
- Mold Temperature: 135 – 165°C
- Back Pressure: 0.3 – 0.7 MPa
- Screw Speed: 0.25 m/s
- Drying Temperature: 140 – 150°C
- Drying Time: 4 – 6 hrs
- Max Moisture content: 0.02 %
SUMMARY

Amorphous resins show better chemical compatibility against R-134A, R-410A and polyolester oils compared to semi-crystalline resins

Polyetherimides show the best performance against refrigerants and lubricants at elevated temperatures

Alteration of polyetherimides (blends, copolymers or monomer composition) can alter chemical resistance results

NEXT STEPS

Chemical testing of reinforced grades of PEI and polyphenylene sulfide

Include additional refrigerants (R1234yf, R32, R600A) and lubricants (polyvinyl ether and alkyl benzene) in challenge chemical list
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