Expanding the Temperature Range of Polyolefin Films

Presented by:
Matt Sonnycalb
Tom Schwab
LyondellBasell
Statement of Problem

- PP and PE each offer advantages over the other

- PP
  - Heat resistance
  - Modulus / Optics balance
  - Abrasion / Grease Resistance

- PE
  - Impact resistance, especially at low temperatures
  - Tear resistance

Can we use multilayer films to leverage the advantages of each material to create differential performance?
Experiment

- Combined 3 key types of PP with 3 key types of PE
- Coextrusion: 25 / 50 / 25 ABA layer distribution
  - Allows structure inversion with constant composition
  - No hPP skin / LDPE core sample due to lack of material
- 51 micron films, 2.54 mm die gap, 152.4 mm die, 2.5:1 BUR, 68 kg/hr

<table>
<thead>
<tr>
<th>PP Type</th>
<th>Product Code</th>
<th>MFR (g/10 min)</th>
<th>% Ethylene</th>
<th>Key Additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homopolymer</td>
<td>hPP</td>
<td>1.5</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Random Copolymer</td>
<td>Raco</td>
<td>2.0</td>
<td>3.5</td>
<td>Clarified</td>
</tr>
<tr>
<td>Impact Copolymer</td>
<td>Impact</td>
<td>1.8</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PE Type</th>
<th>Product Code</th>
<th>MI (g/10 min)</th>
<th>Density (g/cc)</th>
<th>Key Additives (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butene-LLDPE</td>
<td>LLDPE</td>
<td>1.0</td>
<td>0.918</td>
<td>900 slip / 5500 AB</td>
</tr>
<tr>
<td>mLLDPE</td>
<td>mLLDPE</td>
<td>1.0</td>
<td>0.918</td>
<td>1000 slip / 5000 AB</td>
</tr>
<tr>
<td>LDPE</td>
<td>LDPE</td>
<td>2.0</td>
<td>0.918</td>
<td>500 slip / 4000 AB</td>
</tr>
</tbody>
</table>
Dart Drop – ASTM D1709 Method A

Improves with PE Skins, mLLDPE or Impact Copolymer content
Dart Drop – Alternate Views of Results

**PE Skins**

- **mLLDPE**: 293, 182, 81
- **LLDPE**: 304, 116, 168
- **LDPE**: 171, 107, 96

**PP Skins**

- **mLLDPE**: 278, 179, 122
- **LLDPE**: 131, 81, 71
- **LDPE**: 96

**Legend**
- **I** = Impact
- **R** = Raco
- **H** = hPP

Improves with PE Skins, mLLDPE or Impact Copolymer content
Elmendorf Tear (Mach. Dir.) – ASTM D1922

Improves with PP Skins, mLLDPE or Impact Copolymer content
Elmendorf Tear (MD) – Alternate Views

**PE Skins**

- **mLLDPE**
- **LLDPE**
- **LDPE**

<table>
<thead>
<tr>
<th>Layer Material</th>
<th>mLLDPE</th>
<th>LLDPE</th>
<th>LDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact</td>
<td>131</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Raco</td>
<td>60</td>
<td>14</td>
<td>11</td>
</tr>
</tbody>
</table>

**PP Skins**

- **I = Impact**
- **R = Raco**
- **H = hPP**

<table>
<thead>
<tr>
<th>Layer Material</th>
<th>mLLDPE</th>
<th>LLDPE</th>
<th>LDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact</td>
<td>147</td>
<td>108</td>
<td>44</td>
</tr>
<tr>
<td>Raco</td>
<td>122</td>
<td>37</td>
<td>33</td>
</tr>
</tbody>
</table>

**Improves with PP Skins, mLLDPE or Impact Copolymer content**
1% Secant Modulus (Mach. Dir.) – ASTM D882

Depends on material choice, not location within structure. hPP gives higher modulus to structure.
Haze – ASTM D1003

Controlled by surface layers, but some “internal” haze contribution
Interlayer Adhesion

- Polypropylene / Polyethylene structures uncommon in industry
  - Limited awareness of adhesion performance between layers
  - Adhesion important to heat seal performance

- Performance Testing
  - Heat seal multilayer films (PE skins) to fusion
    - 275 kPa, 2 seconds dwell time, 168°C
  - Test seal strength by tensile T-peel test
    - 305 mm/minute crosshead speed
mLLDPE shows enhanced adhesion to all 3 PP types

0.77 kN/m = 2000 grams/inch
## Conclusions

### Polyethylene Skins

<table>
<thead>
<tr>
<th>Material</th>
<th>Impact</th>
<th>Raco</th>
<th>hPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>mLlDPE</td>
<td>+++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>LLDPE</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>LDPE</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

### Polypropylene Skins

<table>
<thead>
<tr>
<th>Material</th>
<th>Impact</th>
<th>Raco</th>
<th>hPP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

- **Highlighted cells** indicate improved performance based on material type and layer choice.
- **Cell contents (+/- signs)** indicate relative rank for that property.
  - Only listed if significant differences present.
Potential Application Benefits

- Modulus improvement
- Down-gauging opportunities
- Density improvement
- Heat resistance improvement
- Improved hot-tack performance
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