HDPE anti-corrosion pipe coating system with outstanding performance

www.bhrgroup.co.uk
Who we are

- First French Chemistry
- 3 segments:
  - Vinyl product
  - Industrial chemicals
  - Performance product
- 5633 million € turnover 2008
- 80 plants in the world (EU, US, ASIA)
- 14980 employees worldwide

Associated for delivering innovative solutions to the pipe coating industry
WHY to improve performances of anti-corrosion pipe coating?

Market requirements have become more severe

More and more coaters & end users request better guarantees than specifications

Oil & gas production is extending towards geographic areas with more extreme conditions
WHY to improve performances of anti-corrosion pipe coating?

Effective corrosion prevention requires a combination of
1) a Durable HDPE topcoat
2) a High adhesion between epoxy and PE layers

➔ Development of a new HDPE anti-corrosion system with outstanding performance
How to access to higher performances?

1) Development of Durable HDPE TOP COAT

Total Petrochemicals has many years of experience / know how in producing PE bimodal resins using hexene as comonomer

- **HDPE BIMODAL POLYETHYLENE COMPOUND**
  - combines good processability + excellent ESCR
  - has substituted LDPE, MDPE compounds thanks to higher performance

- **HEXENE as COMONOMER**
  - provides benefits regarding mechanicals properties and ESCR performance
Advantages of Bimodality for PE

Bimodality principles

- Good processability
- Good mechanical properties
- Stress crack resistance
- Impact resistance

Ease of Processing
Rigidity

Molecular weight
Advantages of Hexene Comonomer for PE

**Butene**

2 C branch, partly (70%) still incorporated in crystallite (butene copolymer) → few tie molecules

**Hexene**

4 C branch, efficiently excluded from crystallite (hexene copolymer) → many tie molecules

More tie-molecules with HEXENE (C6) than with BUTENE (C4)

**HIGHER OVERALL PERFORMANCES**
### HDPE TOPCOAT: Characteristics

<table>
<thead>
<tr>
<th>Physical properties</th>
<th>Test method</th>
<th>unit</th>
<th>Typical value</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>ISO 1183</td>
<td>kg/m³</td>
<td>955</td>
<td>&gt; 940 (950)</td>
</tr>
<tr>
<td>MFR (190 °C / 2.16 kg)</td>
<td>ISO 1133</td>
<td>g/10 min</td>
<td>0.4</td>
<td>0.1 to 0.8</td>
</tr>
<tr>
<td>Carbon black content</td>
<td>ISO 6964</td>
<td>%</td>
<td>2.25</td>
<td>2 to 2.8</td>
</tr>
<tr>
<td>Tensile strain at break 23°C</td>
<td>ISO 527</td>
<td>%</td>
<td>&gt; 600</td>
<td>&gt; 600</td>
</tr>
<tr>
<td>Vicat softening temperature</td>
<td>ISO 306</td>
<td>°C</td>
<td>124</td>
<td>&gt; 120</td>
</tr>
<tr>
<td>Hardness shore D</td>
<td>ISO 868</td>
<td>/</td>
<td>61</td>
<td>&gt; 60</td>
</tr>
<tr>
<td>ESCR (50°C / 10%)</td>
<td>ASTM D1693</td>
<td>h</td>
<td>F0 &gt; 3000</td>
<td>F0 &gt; 1000</td>
</tr>
</tbody>
</table>

No failure after more than 3000 hours (requirement is F0 > 1000 h)
**HDPE TOPCOAT: Heat Ageing Performance**

**Heat ageing**
Topcoat exposition in a hot air oven at 100°C & 110 °C
Control of MFR and Elongation at break variations.

<table>
<thead>
<tr>
<th></th>
<th>Requirements</th>
<th>2400 h</th>
<th>4800 h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MFR variation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 °C</td>
<td>&lt; 35 %</td>
<td>Passed</td>
<td>Passed</td>
</tr>
<tr>
<td>110 °C</td>
<td>No requirement</td>
<td>Passed</td>
<td>Passed</td>
</tr>
<tr>
<td><strong>Elongation at break</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 °C</td>
<td>&lt; 10 %</td>
<td></td>
<td>&lt; 10 %</td>
</tr>
<tr>
<td>110 °C</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
</tr>
</tbody>
</table>

HDPE bimodal compound meets the requirement even at 110°C
**HDPE TOPCOAT: Light Ageing Performance**

**Light ageing**

Topcoat exposition to UV in WOM (Atlas Ci 35A)

Control of MFR and Elongation at break variations.

<table>
<thead>
<tr>
<th>Time of Exposure</th>
<th>MFR variation</th>
<th>Elongation at break variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 h (1.2 GJ/m²)</td>
<td>&lt; 25 %</td>
<td>&lt; 20 %</td>
</tr>
<tr>
<td>2400 h (3.6 GJ/m²)</td>
<td>&lt; 25 %</td>
<td>&lt; 20 %</td>
</tr>
<tr>
<td>4800 h (7.2 GJ/m²)</td>
<td>&lt; 25 %</td>
<td>&lt; 20 %</td>
</tr>
</tbody>
</table>

HDPE bimodal compound

- contains finely dispersed carbon black
- has excellent Weathering and UV resistance
HDPE TOPCOAT: Hardness Performance

Surface Hardness

Measures the resistance of coating to the penetration of a test cylinder. At different temperatures, is an indication of the mechanical properties and upper operating temperature.

<table>
<thead>
<tr>
<th>Indentation at</th>
<th>Requirement</th>
<th>MDPE</th>
<th>HDPE bi</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 °C</td>
<td>&lt; 0.2 mm</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>50 °C</td>
<td>&lt; 0.3 mm</td>
<td>0.13</td>
<td>/</td>
</tr>
<tr>
<td>70 °C</td>
<td>&lt; 0.3 mm</td>
<td>0.20</td>
<td>0.14</td>
</tr>
<tr>
<td>80 °C</td>
<td>/</td>
<td>/</td>
<td>0.17</td>
</tr>
<tr>
<td>90 °C</td>
<td>/</td>
<td>/</td>
<td>0.24</td>
</tr>
<tr>
<td>100 °C</td>
<td>/</td>
<td>0.31 (0.06)</td>
<td></td>
</tr>
</tbody>
</table>

The surface hardness is significantly better than with MDPE topcoat, with 100°C as possible upper operation temperature.
HDPE TOPCOAT: Improved Performances Design

For a Durable HDPE TOP COAT

- Optimized molecular design achieved through the polymerisation process & catalyst allows to boost the product performances.
- The latest generation of bimodal hexene based compound offers extraordinary tolerance to operating conditions, as demonstrated by the following results:
  - Excellent Resistance to UV and thermal ageing
  - Excellent Stress cracking resistance
  - Improved Surface Hardness resistance

However, effective corrosion prevention requires a combination of
1) a Durable HDPE topcoat
2) a High adhesion between epoxy and PE layers
Pipe Coating Process

3-layer polyolefins

“Three-layer” coating line with one-station pre-heating

1. pipe rotation drive
2. heating by induction
3. epoxy application station
4. extrusion of adhesive

Blasting unit

- extrusion of PE
- pressure roller
- cooling by sprinkling water

2.5mm HDPE
2.5mm STEEL

Roughness ISO 8502, class 2

114mm
NEW ADHESIVE GENERATION

2) Development of a new product with high PE/epoxy adhesion

- ARKEMA has developed a new adhesive generation dedicated to the pipe-coating application
- Based on Polyethylene, grafted with maleic anhydrid allowing a good mobility of the chains

Simplified reaction between Epoxy and Anhydrid groups
NEW ADHESIVE: Evolution of Properties

![Graph showing the evolution of properties for copolymers and grafted polyethylene.](image)

**Copolymers**
- **Old**
- **New**

**Grafted polyethylene**
- **Old**
- **New**

- **meltingPt**
- **vicat**

**Temperature °C**

Laurent Quillet / Pascal Nathiez
Pipeline Protection 18 – Antwerp November 4-6, 2009
Adhesion Properties: Higher Peeling Strength

Peeling Strength (N/cm)

23°C 60°C 80°C

Peeling temperature (°C)

- New
- Old

+30%
Adhesion Properties: Higher Temperature limit

Peeling temperature (°C)

Peeling Strength (N/cm)

new
old
+30%
NEW

+30%