Innovative manufacturing of polyethylene PE125 for multifunctional applications.
## Stages of polyethylene pipes development

<table>
<thead>
<tr>
<th>Generation</th>
<th>Period</th>
<th>Developments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>~ 1970’s</td>
<td>LD (PE32, PE40)</td>
</tr>
<tr>
<td>2nd</td>
<td>~ 1980’s</td>
<td>HD (PE50, PE63) MD (PE80) ~ 1990’s</td>
</tr>
<tr>
<td>3rd</td>
<td>~ presents</td>
<td>MD (Bimodal PE80) HD (Bimodal PE80, PE100, PE100+)</td>
</tr>
<tr>
<td>~</td>
<td>~ FUTURE</td>
<td>PE125</td>
</tr>
</tbody>
</table>
What is PE125?

This is a multimodal mix:

1) **LOW MOLECULAR** fraction, which gives:
   - Good processability
   - High stiffness
   - High crystallinity

2) **HIGH MOLECULAR** fraction, which gives:
   - High resistance to SCG (slow crack growth)
   - High creep resistance

3) **SUPER-HIGH-MOLECULAR** fraction, which gives:
   - High MRS (minimum required strength)
   - High creep resistance
   - High toughness
   - Increased wear resistance
The triad of basic market requirements for Polyethylene Pipe

- SCR: Notch (bar) → Aging resistance
- MRS (MPa) → Creep resistance
- RCP: Pressure / Temperature → Impact resistance
MRS (Minimum Required Strength) PE125

Pressure test ISO 1167-1:2006 MRS (Minimum Required Strength)

2,000 hours at 13.9 MPa

100 hours at 14.5 MPa
SCG (Slow Crack Growth) or ESCR (Environmental Stress Cracking Resistance)

What is SCG / ESCR:
- Long-term aging process leading to brittleness and cracking
- Increased by scratches and stones

How is SCG / ESCR measured:
- Test with 4 cuts on the tube
RCP (Rapid Crack Propagation)

What is RCP:

- Under extremely adverse conditions of high pressure and/or low temperature, exposure to - a blow to a pipe under pressure can lead to the rapid formation of cracks up to hundreds of meters in length.
### Basic requirements for PE125

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Optimal value</th>
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<tbody>
<tr>
<td>Density of ISO 1183 at 23C</td>
<td>950-960 kg/cm³ (max 980)</td>
</tr>
<tr>
<td>Melt flow index ISO 1133 at 21 kg load</td>
<td>0.2-5 g/10 min</td>
</tr>
<tr>
<td>Melt flow index ISO 1133 at 5 kg load</td>
<td>Less 0.2 g/10 min</td>
</tr>
<tr>
<td><strong>UHMWPE content in the blend (2-3.5 mil g/mol)</strong></td>
<td><strong>8-15% (Optimal)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>45% (Maximum)</strong></td>
</tr>
<tr>
<td>Carbon black content</td>
<td>1.5-3 w</td>
</tr>
<tr>
<td>Pressure test ISO 1167-1: 2006 (Minimum Required Strength, MRS)</td>
<td>2000 hours at 13.9 MPa</td>
</tr>
<tr>
<td></td>
<td>100 hours at 14.5 MPa</td>
</tr>
<tr>
<td>Resistance to «Sagging» effect ( creep) so-called «Eta747 value»</td>
<td>10 times more than that of HDPE</td>
</tr>
</tbody>
</table>
Triad of technologies Graft-Polymer and applications

- Films
- Sheets, panels
- Injection molding
- Coatings
- Powder additives for polymers
- Self-reinforced polymers
- Solid-phase grafting
- SSME dispersion
- Pipes
- Thread
- Filament 3D
- Self-reinforced polymers
Production of MP-UHMWPE

The Graft Polymer specialists have developed a technology for the extrusion synthesis of melt-processed MP-UHMWPE.

Properties of material MP-UHMWPE:
1. Easily processed (in the melt) into any products on a standard polymer equipment (extruder, injection molding machine, calender)
2. Physical and mechanical properties are significantly higher than those of standard UHMWPE (ultra high molecular weight polyethylene)
3. Tribological properties are the same as for standard UHMWPE
4. High crystallinity (94% compared to 60-85% standard)
5. Excellent biocompatibility (for medical applications)
6. Easily welded (unlike standard UHMWPE)
7. Easy stretchable
8. Homogenized (fully combined) with different HDPE grades.
9. Efficiency of grafting (vaccinations) in the solid phase of UHMWPE of a new generation significantly higher than standard (due to morphology)

Changes in the morphology and structure of UHMWPE

Particle morphology of standard UHMWPE (right) and New-UHMWPE (left) - spongy structure is clearly visible
Process Flow Diagram production MP-UHMWPE

Basic HDPE + Graft Copolymer + Chemical reagents + Powder UHMWPE → Compound MP-UHMWPE

Extrusion cascade line
Main applications of MP-UHMWPE

- Heavy-duty thread (solvent free)
- Additives for polyolefins and engineering plastics
- Additive for rubber
- Injection molding parts (medical implants)
- Grafted UHMWPE
- Heavy Duty Tape and Film
- Filters and membranes
- Extrusion sheets
- Insulation Cathodic Protection Cable
Challenges in PE125 manufacturing

So, for example, to obtain polyethylene according to the standards PE125 (with an indicator of minimum strength MRS > 13.8-14 MPa, in comparison PE100 has MRS only 10 MPa), a significant improvement in resistance against hydrostatic pressure is required.

For the usual bimodal HDPE, this indicator is difficult to achieve, since it directly correlates with the impact strength / density indices and with simple extrapolation it turns out that the required index for PE125, it’s just not realistic to achieve a bimodal HDPE matrix.

There is another problem - it is the difficulty in maintaining the geometric stability of the pipe (the thickness at the top of the pipe is often less than at the bottom) due to the "sagging" effect (phenomenon gravitational flow of polymer melt).

This phenomenon is more pronounced for thick-walled pipes. Specific MP-UHMWPE solves these aforementioned problems.
Process Flow Diagram of PE125 manufacturing

- Basic HDPE
- Chemical reagents
- Compound MP-UHMWPE

Extrusion Line (Megacompounder)
Microphotos of materials comparison

Dispersed compound MP-UHMWPE using Graft Polymer technology

The dispersion of the compound UHMWPE using standard extrusion technology