The cutting edge in Flexible Pipe technology: PA12 for Flexible Flowlines and Risers

Jan Berger
Weihong Du, Andreas Dowe
June 5th, 2013
1. Evonik High Performance Polymers
2. PA12 in Unbonded Flexible Pipes
3. Material qualification and Material properties
4. Summary and Outlook
Evonik Industries
> 160 yrs industry experience

- Degussa (1843)
- Hüls (1938)
- SKW Trostberg (1908)
- Goldschmidt (1847)
- Degussa-Hüls (1999)
- SKW (1999)
- Degussa (2001)
- Steag (1937)
- RAG Immobilien (1977)
- Evonik Industries (2007)
A presence in over 100 countries

Puzzle of success: Production sites and sales offices in 52 countries
Evonik Industries - O&G as a strategic area of growth

EOGG: Evonik Oil and Gas Group
Overview - Thermoplastic Materials

- Cost Driven
- Performance Driven

High Performance Polymers
- PAI
- PPSU
- PI
- PES
- PMMI
- PSU
- Transp. PA
- VESTAKEEP®
- VESTAMID® HTplus
- VESTAMID® NRG

Engineering Polymers
- PMMA
- PPE
- PBT
- PET
- PA6 / PA66
- VESTAMID® NRG

Commodity Polymers
- ABS
- PS
- SAN
- PVC
- PP
- PE
- PE-LD
- PE-HD

amorphous
- crystalline

= Polymers from Evonik
Oil & Gas Application
- working team

Innovation Management
J. Franosch, J. Berger, R. Tuellmann, C. Behrens, H. Beyer

Marketing & Sales
W. Du, V. Lavini, A. Simoes, K. Ogenia, A. Gadkari, M. Delgado, K. Goldstein

Business Leader
A. Dowe
1. Evonik High Performance Polymers

2. PA12 in Unbonded Flexible Pipes

3. Material qualification and Material properties

4. Summary and Outlook
Innovation to increase the melt viscosity let to large diameter tubes and pipes

Advantages of PA 12

- High chemical resistance
- Exceptional notch impact strength
- Excellent resistance to stress cracking
- Low water absorption
Unbonded Flexible Pipes
- Application

Flexible riser with Vestamid NRG
Flowlines with Vestamid NRG
Jumper with Vestamid NRG
Unbonded Flexible Pipe
- Standard structure

Carcass
(e.g. Alloy 316L)

Pressure Armor Layer

Tensile Armor Layers

Pressure Sheath
(PE, PA11, PA12, PVDF)*

Anti Wear Tapes
(PA, PVDF, PEEK)

Jacket Sheath
(static: PE, dynamic: PA)

Anti Bird Caging Tape

*: depending on temperature and certain conditions in the field
1. Evonik High Performance Polymers
2. PA12 in Unbonded Flexible Pipes
3. Material qualification and Material properties
4. Summary and Outlook
Result of approval program (API 17 TR2):

Vestamid NRG1001 has very similar properties compared to existing Polyamide Solutions for Flexible Pipes.

But also some advantages of NRG1001 found:

- Doubles the lifetime of flexible tubes vs. Nylon 11
- Maximum possible operation temperature is about 6°C higher than for Nylon 11 (PA11)
- Significant better methanol compatibility
- High ductility even at low temperatures (-50°C)
- Better resistance to heat aging
- Easy to process
- No pre drying is required before processing
Unbonded Flexible Pipes
- A clear improvement in aging performance

Arrhenius life time curves for PA in H2O without CO2

Time to reach initial acceptance criterion of CIV = 1.2 dl/g [years]

- pH=7 (API 17TR2)
- PA 11 H2O/no CO2 fit [years] CIV=1.2
- PA 11 H2O/no CO2 [years] CIV=1.2
- PA 12 H2O/no CO2 fit [years] CIV=1.2
- PA 12 H2O/no CO2 [years] CIV=1.2
Unbonded Flexible Pipes
- A clear improvement in aging performance

**Methanol compatibility of PA12 vs. PA11**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>PA12 Strain at Break</th>
<th>PA11 Strain at Break</th>
</tr>
</thead>
<tbody>
<tr>
<td>70°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90°C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing methanol compatibility of PA12 vs. PA11](graph.png)
Unbonded Flexible Pipes
- A clear improvement in heat aging
Unbonded Flexible Pipes
- High ductility and fracture toughness

Force-Deformation Plot [-30°C]

- VESTAMID LX9020
- BESN O P40 TL
- BESN O P40 TLX OS

Test parameters: virgin, ASTM E399; 10 mm/min; round-CT specimen; W=48.75mm
Advantages of VESTAMID NRG 1001
- Easy processing and no pre-drying

Influence of remaining moisture in granules on final CIV

Strong influence on processability and final material performance

Acceptance of moisture content for processing of Nylon materials
Hydrolysis Aging under Service Conditions - an extended aging model

lifetime prediction API 17TR2

- Temperature
- CO₂ saturation
- Elongation at break + CIV
- Temperature
- CO₂ saturation
- Elongation at break + CIV

- deionized water
- Hydrocarbons e.g. crude oil
- Salts in ocean water
- Oil production additives
- scCO₂ up to 700bar

additional influences
CIV vs. Elongation at break

CIV = 1.05
1. Evonik High Performance Polymers
2. PA12 in Unbonded Flexible Pipes
3. Material qualification and Material properties
4. Summary and Outlook
# Summary: Advantages of PA12

<table>
<thead>
<tr>
<th>Feature</th>
<th>Advantage</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol compatibility</td>
<td>Reliable, durable</td>
<td>Less maintenance costs, broaden maintenance technologies</td>
</tr>
<tr>
<td>Hydrolysis resistance</td>
<td>Lifetime, operation temperature</td>
<td>Cost reduction, adds safety</td>
</tr>
<tr>
<td>Ductility</td>
<td>Performance at low temperature</td>
<td>Adds safety at certain conditions: arctic installation and Joule-Thomson-Effect</td>
</tr>
<tr>
<td>Stable melt characteristics</td>
<td>Excellent processing</td>
<td>Cost reduction, no pre-drying, less scrap</td>
</tr>
</tbody>
</table>
VESTAMID NRG is the perfect choice for barrier layers and jacket sheaths of flexible pipes

- Lifetime up to 20 years at 65 °C
- Fully API 17 J qualified
- >800 km flexible pipes produced with PA12 pressure and/or jacket sheath since end of 2006
- Superior performance (e.g. arctic)
- Easy to process
TCR vs. SCR

- Stiffness a factor 10 lower than steel → smaller mean offset
- MBR a factor 8 or more smaller than steel, avoiding fatigue issues at the touch down point.
- Reduced top tensions and floater loading
- Lower friction and pressure drop, due to smooth liner surface.
- Significant improvement in fatigue resistance
- Lower thermal conductivity and higher heat capacity than steel, better thermal properties for flow assurance.
TCR vs. Flexibles

- one solid reinforcement layer supports all different load cases
- the all composite TCR is impervious to corrosion.
- improvement in fatigue resistance.
- because of the solid cross-section, load transfer at the end-fittings is more efficient and less complex.
- no friction between reinforcement layers
- reinforcing the liner creates a smooth bore inner liner with high collapse strength, avoiding carcass induced pulsations.
Liner for corrosion protection of carbon steel production pipelines in O&G fields. At Onshore fields the targeted applications are production pipelines operating at temperatures from 60 to 100°C. Onshore PE liner are limited to a maximum temperature of 60 °C.
PA 12 Liner - total costs comparison

- Initial cost (material, welding, etc.)
  - Duplex Stainless Steel
  - Clad pipe
  - Carbon steel + inhibitor

- PA12 lined Carbon Steel Pipe

- Running cost (protection, monitoring, etc.)

Life
PA 12 Liner
- The Integrated Lining Technology

Insertion Technology

Connection Technology

Venting Technology → required to vent off permeated gas in the event of a pressure drop in the pipeline
Swagelining PA12 liner system
- advantage of VESTAMID NRG

Length swelling in light oil of PA 12 at 105°C vs PE100 at 60°C

Low swelling vs. PE
→ less stresses
→ avoids axial buckling
Swagelining PA12 liner system - advantage of VESTAMID NRG

Tensile modulus vs. temperature of PA 12 and PE100
Virgin and saturated in light oil

High tensile modulus
→ max. stability of liner in service
→ max. collapse resistance of liner