Developments in 3 layer Polyolefin Coating materials for Oil and Gas Pipelines

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Outline

- Introduction
- Steel Pipe coating Market
- Current Polyolefin solutions
- New innovations in PO Linepipe coating
- New innovations in PO Field Joint coating
- Conclusion
Speaker Profile

• Chemical Engineer from Jadavpur University (1986)
• Worked for IPCL in Technical Service and Application development for commodity thermoplastics (1986-2000)
• Worked in Borouge for Tech Service and Marketing (since 2001)
• Currently Application Marketing Manager for Pipe business.
• Expertise – Polymer processing, Multilayer film, Steel Pipe coating
• Four Borouge innovation awards
• Three application patents
Borouge... A successful joint venture combining resources, feedstock and technology leadership
Providing Solutions in Polyolefins

Infrastructure

Automotive

Advanced Packaging
Steel Pipe Coating Market

Total Market 411 Million m² in 2013

Total Market 537 KT in 2013

Fig. 1. External coating - Mn m²

Fig. 2. External coating - KT

Source: AMI study
Pipe Coating Market trends

- Pipeline construction continues at high pace
- Initiatives to reduce construction costs and introduce new techniques by IPLOCA and others
- Demand driven by economic and political needs to secure supply
- 3LPE increases domination of onshore coating market. Water pipelines taking significant market share
- Many innovations in field joint coating and inner lining to increase design life
- Offshore pipeline technology spurs growth in PP thermal insulation projects
Criteria for the selection of coatings

Coating materials are often selected acc. to the Operating temperature given in the specification

BUT: ISO21809-1 definition of Design temperature includes more:

“Temperature range including maximum and minimum temperature likely to be reached during transport, handling, installation and operation”

- Operating temperature 0° to +60°C
- Pipe storage temperature -10°C to +70°C
- Transportation temperature -20°C to +60°C
- Installation temperature -5°C to +70°C
- Design temperature for coating
Project experiences

Nord Stream Phase 1: 25% of pipes transported from Russia also during strong winter times, first spec. draft was PP.....!

Chad Cameroon Exxon oil pipeline: From Germany by ship, then by truck from Cameroon to Chad in hot climate and 2000km road transport

Different phases of IGAT and South Pars, Iran in extremely hot environment >40°C, sub zero in winter, rough handling, long distances

......and all done with Bimodal HDPE / grafted adhesive

*Pictures courtesy of M.Felt Universal
Moving over from Unimodal MDPE to Bimodal HDPE Top coat in 1999 – a step improvement

- Excellent ESCR (>5000 hours vs. 300-1000 hours for unimodal MDPE/HDPE)
- Processability far superior to Unimodal
- Design Temperature (85°C vs 75°C for MD and 80°C for HD)
- Higher Moisture barrier
- Higher Resistance to Abrasion
- Very high impact resistance (also at low temp)
Innovation targets: crossing the limits of standards

New innovations

- 3LPE system with better high temperature resistance
- 3LPP system with better low temperature resistance
- Field joint coatings to meet linepipe coating specifications
Greater Challenges in Hot climates

- Pipelines installed, stored and stacked in hot climates. Day surface temperature may reach 85-90°C
- Construction activities in remote and difficult terrain. More damage possibility to coating due to rock impingement
- More onshore projects with higher operating temperatures
- HDD with unpredictable conditions
- Long outdoor storage due to project delays
- Black PE is excellent against UV radiation, but temperature resistance is limited.
Bimodal PE Tailored for Warmer Regions

Requirements met by existing Bimodal PE products:
-50°C to +80°C

Demand for new PE products
-40°C to +90°C

Requirements met by existing Bimodal PE products:
-50°C to +80°C

90 deg C Design temperature covers most onshore Oil pipeline projects
Value creation through Innovation

- Bimodal HDPE
- Hexene Bimodal HDPE HE3450-H

Design Temperature

Mechanical Requirement
Moderate  High

© Borouge
How Does HE3450-H Resist Slow Crack Growth?

Regular PE

Crystalline areas
Crack
Amorphous areas
Stress

Tie molecules with larger side branches is the key

By using Hexene in place of Butene, side branch length is increased

This also allows to increase density without sacrificing ESCR and Impact

HSCR PE

Stress
Crack
Amorphous areas
No Crack

Tie Molecules
Stress

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Advantages of Bimodal Hexene Top coat over Previous Generation

• 90 C design temperature covers most onshore oil pipelines, for which 3LPP would have been specified in normal course.
• Black PE is far better than PP in UV resistance for long outdoor storage. (some of the projects can be converted from 3LPP to 3LPE with very high cost savings)
• Higher hardness = better scratch resistance = lower damage = lower number of pipe repairs
• More suitable for Directional Drilling
Qualified by GASCO, ZADCO, KOC, Oman Oil, PDO-Shell and many water cos….

- ZADCO UZ750 MOL: 60km 42” pipeline
- ZADCO was interested in evaluating HE3450-H if it can pass various tests including CD at 90 C (against ISO21809 requirement of 80 C)
- A PQT was conducted at NPCC, UAE using 3LPE system HE3450-H / ME0420 / 3M 226N
- HE3450-H was approved by ZADCO for the project

<table>
<thead>
<tr>
<th></th>
<th>Results</th>
<th>Requirement (ClassB)</th>
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<tr>
<td>Peel Strength @ 90 C</td>
<td>122 N/cm</td>
<td>15 N/cm @ 65 C</td>
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<tr>
<td>Impact Strength @ 90 C</td>
<td>25 J passed</td>
<td>18 J @ 23 and 50 C</td>
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<tr>
<td>Cathodic Disbondment @ 90 C</td>
<td>Passed</td>
<td>≤ 15</td>
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<tr>
<td>Shore D Hardness</td>
<td>63.6</td>
<td>≥ 55</td>
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Time for a real low temp PP system

- Often the buried pipeline’s operating conditions are not as crucial as the conditions beforehand.
- In recent pipeline projects in Russia, the transport of PP-coated pipes through the harsh winter conditions was a challenge as standard PP coating systems would not survive these extreme conditions.
- Therefore a tailored system was developed for lower temperatures consisting of a PP-based adhesive and low temperature PP top coat which still fulfils the ISO21809-1 requirements.
- In Russia, coated pipes were evaluated in full scale impact tests using different epoxies in a freezing chamber under controlled conditions starting from +23°C, going down to 0°C and then in 10°C steps down to -40°C.
3LPP solution offered to for South Stream project for winter months

<table>
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<tr>
<th>Drop height (m)</th>
<th>Impact energy (J/mm)</th>
<th>TEKNOS InfraLit EP8074 + BB108E-1199 + BB127E</th>
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<td>-</td>
<td></td>
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<tr>
<td>2.0</td>
<td>-</td>
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Coating thickness: 5.0 mm

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<th>Drop height (m)</th>
<th>Impact energy (J/mm)</th>
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<td>6.7</td>
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<tr>
<td>0.7</td>
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<tr>
<td>2.0</td>
<td>26.9</td>
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Coating thickness: 4.3 mm

Project Spec: >10 J/mm impact @-20°C
Standard PP: failed at 12.7 J/mm
LT-PP: Failed at 26.9 J/mm
Full Scale impact testing at – 20 ºC at Vyksa in Jan 2014
South Stream Pipe : 813mm x 39 mm X 12.3 m : 9156 kg

LT-PP : Upto 21.4 J/mm passed at –20ºC

South Stream / Gazprom specification require >10J/mm at – 20 ºC
System: Standard 3LPP

10 J/mm passed at –20°C

BUT

10.8 J/mm already cracked at –20°C

11.0 J/mm cracked at –20°C

11.5 J/mm cracked at –20°C
Standard 3LPP system in Russia after storage at – 30 °C
Standard 3LPP system in Russia after Railway Wagon impact trial at – 33 ºC
System : LT-PP

For LT-PP coated pipes, the first impact cracks were only detected at -40°C and the non-critical temp was found to be -35°C.

At -30°C the impact could still be increased to roughly 16J/mm.

After each low temp step the temp was raised to +23°C and then cooled down again.

At the end of this total temperature cycling, the adhesion performance at +23°C was unaffected and still greater than 250N/cm (far above the ISO21809-1 requirement).
Continuous improvements of mill applied coatings, but what about field joints?
Field joints are potential weak points in the corrosion protection systems

“There is a need for compatible, reproducible and cost effective solutions”

Shrink sleeve after soil stress

Corrosion on a pipe joint below the FJC

Photos courtesy David Norman Associates
Target: Field Joint coating to meet the requirements of Linepipe specification

- KWH Pipe Ltd: Plastics machinery know how and processing
- Borealis: Polymer development and steel pipe coating know-how
- Field Joint (FJ) Coating method based on Hot applied melt film technique - based on PATENTED SOLUTION, WO 2008/132279 A1
- Machine rotates around the pipe and applies molten PE or PP material
Blast cleaning of the field joint area

Rz = 50-100 µm
SA 2½

Filling of the machine with molten polymer
Machine is lifted onto the pipe
Induction heating and automatic FBE application

First induction step 120-140°C
WehoCoat machine rotates and applies the polymer

Second induction step 180-190°C
WehoCoat machine is lifted off
A hermatically welded system which is fully moisture resistant

1. Welded Pipe Joint
2. Steel Pipe
3. Factory Epoxy Coating
4. Factory Adhesive and Top Coat
5. Teknos Infralit EP8064 Powder Epoxy
6. Borcoat ME3000FC Top Coat

- $A =$ Overlap Distance  min. 10 mm beyond beveled area
- Teknos Infralit EP8064 (epoxy thickness) minimum 100 $\mu$m
- Borcoat ME3000FC (top coat thickness) minimum 3 mm
Scratch test performance of Wehocoat - Borcoaat system vs. shrink sleeves

Scratch test performed with different loads on:
- shrink sleeve (left side),
- Line pipe coating (middle)
- and New field joint coating system (right side)
Value creation through Innovation

- 3LPO coating solutions for corrosion protection of steel pipelines have come a long way and continuous innovations are taking place.
- Bimodal Hexene PE system and Low Temp PP system will help to broaden the design window for 3LPO coating.
- New field joint coating solution will increase the reliability of the 3LPO coated pipeline system as a whole.
- All these will help to satisfy the unmet needs of value chain.
Summary

• 3LPO coating solutions for corrosion protection of steel pipelines have come a long way and continuous innovations are taking place.

• Bimodal Hexene PE system and Low Temp PP system will help to broaden the design window for 3LPO coating.

• New field joint coating solution will increase the reliability of the pipeline system as a whole.

• Involvement of the raw material suppliers in early design stage will help in designing a better project specification with the most suitable solution.

• All these will help to satisfy the unmet needs of value chain.
Thank you!