DEPLOYMENT OF PIPE LAYING ON THE SEA BED

Based on the version presented at University of Liège on 9th Dec. 2011

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Outline

• Introduction: WPUT and FMTT
• Motivation for development of pipe laying technology
• Building pipeline
• Methods of pipeline laying
• Project of pipeline laying – scope of elaboration
• Examples:
  - Nord Stream pipeline
  - Baltic Beta-Władysławowo pipeline
Introduction: WPUT and FMTT

Szczecin: 405,000 inhabitants

Poland
Introduction: WPUT and FMTT

West Pomeranian University of Technology,

Szczecin

• Beginings in 1946
• 17 000 students
• 1 100 lecturers and researchers
• 10 faculties
• 17 rights to confer doctoral degree in 17 disciplines
• 9 full academic rights
Introduction: WPUT and FMTT

Faculty of Maritime Technology and Transportation

- 800 students
- 51 lecturers and researchers
- 7 departments
- 6 laboratories
- entitled to confer DSc in discipline Construction and Operation of Machinery (16 titles)
Introduction: WPUT and FMTT

Faculty of Maritime Technology and Transportation

1. Department of Ship Design
2. Department of Ship Structures, Mechanics and Technology
3. Department of Logistics
4. Department of Theoretical Mechanics
5. Department of Ship Engine Rooms
6. Department of Air-conditioning and Refrigerated Transport
7. Department of Ship Protection
8. Section of European Programmes
Motivation for development of pipe laying technology

Demand of crude oil and natural gas. Growing activity in areas of:
• search of underwater deposits of raw materials,
• exploitation of them,
• building mining and transport installations, including underwater pipelines.
Motivation for development of pipe laying technology

Over 450 production rigs on a shelf of the North Sea
Types of underwater pipelines

- **cumulative**
  - Ø 203.2 do 508 mm (8” - 20”),
- **transferring**
  - Ø 254 do 762 mm (10” - 30”),
- **feeding**
  - Ø 762 do 1219.2 mm (30” - 48”).
Pipeline construction – materials

- pipe of high grade steel – eg. X52, X60, X70,
- inner antifriction and anticorrosion layer – epoxy resin with corrosion inhibitors,
- outer anticorrosion layer – polyethylene,
- concrete coat (no in case of pipe lying by drum method).
Material of pipe
- carbon steel (X52, X 60, X70) & stainless steel (13Cr6Ni2.5Mo)

### Chemical components of steel

<table>
<thead>
<tr>
<th>Stal</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Ni</th>
<th>V</th>
<th>Nb</th>
<th>Ti</th>
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</thead>
<tbody>
<tr>
<td>X52</td>
<td>0.09</td>
<td>0.92</td>
<td>0.28</td>
<td>0.007</td>
<td>0.010</td>
<td>0.02</td>
<td>0.01</td>
<td>0.004</td>
<td>0.03</td>
<td>0.01</td>
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<tr>
<td>X60</td>
<td>0.21</td>
<td>1.52</td>
<td>0.19</td>
<td>0.012</td>
<td>0.003</td>
<td>0.16</td>
<td>0.15</td>
<td>0.05</td>
<td>0.03</td>
<td>0.01</td>
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<tr>
<td>13Cr6Ni2.5Mo</td>
<td>0.0124</td>
<td>0.51</td>
<td>0.26</td>
<td>0.014</td>
<td>0.003</td>
<td>12.53</td>
<td>6.33</td>
<td>0.028</td>
<td>-</td>
<td>0.13</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Mo</th>
<th>Al</th>
<th>Cu</th>
<th>N</th>
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<tbody>
<tr>
<td></td>
<td>2.33</td>
<td>0.042</td>
<td>0.086</td>
<td>0.01</td>
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</tbody>
</table>

### Mechanical properties of steel

<table>
<thead>
<tr>
<th>Stal</th>
<th>( R_{p0.2} ) (MPa)</th>
<th>( R_m ) (MPa)</th>
<th>( A_5 ) (%)</th>
<th>( R_{p0.2}/R_m )</th>
<th>HRC</th>
</tr>
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<tbody>
<tr>
<td>X52</td>
<td>486</td>
<td>610</td>
<td>22.5</td>
<td>0.80</td>
<td>11</td>
</tr>
<tr>
<td>X60</td>
<td>733</td>
<td>792</td>
<td>20.5</td>
<td>0.93</td>
<td>21</td>
</tr>
<tr>
<td>13Cr6Ni2.5Mo</td>
<td>667</td>
<td>897</td>
<td>21</td>
<td>0.75</td>
<td>27</td>
</tr>
</tbody>
</table>

(St3 – tension strength of 375 Mpa)
Types of underwater pipelines

- single wall pipelines
- pipe bundle pipelines
- pipe-in-pipe pipelines
Other types of underwater pipelines

Pipeline Configurations
Cased Bundles

- multiple inner product lines
- internal coatings
- external insulation
- external corrosion coatings
- weight coatings
Other types of underwater pipelines

At present:

app. 1 % of installation length – pipelines of another kind
Methods of pipeline laying

Method 1: successive flooding of pipe sections, screwing or welding on a sea bottom
- flooding of pipe sections and lowering on a sea bottom
• screwing pipe sections on a sea bottom
• welding pipe sections on a sea bottom
• welding in a habitat
Methods of pipeline laying

Method 2: pipeline assembly on a surface and its flooding as a hole pipeline or in sections, continuously:

- pipeline assembly on a seashore, towing and flooding,
- pipeline assembly on an ice field, flooding and towing,
- pipeline assembly on a floating object and flooding.
• pipeline assembly on a seashore, towing and flooding

✓ assembly on a beach

seashore

towed bundles

Transporting a single pipe
pipeline assembly on a beach, towing and flooding

✓ towing
✓ pipeline towing

Variations:
- towing on the sea surface,
- towing in the depth,
- towing above the sea bed,
- overhauling on the sea bed.
✓ towing on the sea surface
towing in the depth

- phases of lifting and sinking of connected pipeline sections
• pipeline assembly on an ice field, flooding and towing or pulling above a sea bed
• pipeline assembly on an ice field, flooding and towing or pulling above a sea bed
• pipeline assembly on a floating object and submerging

Floating objects applied in pipeline laying:

✓ platform,
✓ ship,
✓ barge.
✓ platform

- work possible in bad sea conditions (sea state up to 8 of Beaufort scale),
- efficiency ~ 5 km in twenty-four hours,
- high cost of work,
- pipeline laying depth of 10÷1500 m.
Platform Viking Piper
Accommodations for 300 workers, two shifts on board.
Total engines power 13 827 kW.
- work dependent on weather conditions,
- application of a system of dynamic position keeping (no accompanying vessels), anchor system.

- efficiency: ~ 5 km in twenty-four hours,
- low cost of work,
- pipeline laying depth of 10÷3000 m.
✓ barge
- work strongly dependent on weather conditions,
- barge towing using anchor lines,
- efficiency: ~ 5 km in twenty-four hours,
- low cost of work,
- pipeline laying depth of 10÷300 m.
• Classical methods of pipe laying
  ✓ parallel method,
  ✓ „S” method,
  ✓ „J” method.

- assembly of pipeline on the work deck using prefabricating pipe sections,
- pipeline lowering on a sea bed using stinger.

Platform, ship or barge moves along designed route.

• Reel method of pipe laying

  Pipeline is unrolled from a reel (vertical or horizontal axis) and lowered on a sea bottom.
✓ parallel method

- small depth down to 100 m, long stinger, without tension equipment, floaters possible,
- efficiency: ~ 2 km in twenty-four hours.
✓ „S” method
- depth down to 500 m, declining horizontal stinger, tension equipment,
- efficiency: ~ 1.6 - 5 km in twenty-four hours.
✓ „S” method
✓ „J” method
- depth >500 m, short vertical stinger, tension equipment,
- efficiency ~ 0.65 - 1.6 km in twenty-four hours.
Curves of pipeline for various depths

Pipeline lowering from barge deck using stinger

Stinger
Pipeline-stinger system geometry and lay-out of basic forces and moments in the S" methods of pipeline laying on a sea bed
Floating object equipped with:
- horizontal reel or
- vertical reel.

Efficiency: up to 3200 m/h
(≠ 76 km in twenty-four hours!).

Pipe 12” (305 mm) requires a reel of 25 m diameter.
- ship with vertical reel
- ship with horizontal reel

Stinger
Pipeline on the sea bed - protection

Manners of pipeline protection:
• no protected on a sea bed,
• ballasted,
• on supports,
• on beds,
• sunk,
• anchored,
• backfilled by gravel,
• backfilled in natural manner,
• covered by concrete casing.
• no protected on a sea bed

Correction of pipeline lowering and route

Pipe before sea bed penetration

Pipe after sea bed penetration
• lowered in a trench

Trenching

Bottom plough PL3: mass 180 t, length 22 m, trench depth of 2.5 m
• lowered by jet aggregate crawling on the sea bottom
• lowered by jet aggregate floating in an abbys
• pipeline anchoring to a sea bed
• covering by gravel
Pipeline crossing

1 – existing pipeline
2 – new pipeline
3 – concrete supports
4 – stone blocs
5 – bag with concrete
6 – hard gum saddle

7 – separator
8 – concrete injection
9 – pipes to press mortar
10 – pipe in clamp, supported
11 – grid support
12 – ground anchor
Technological design of pipeline laying
- scope of elaboration

1. Pipeline.
2. Pipeline laying object.
3. Protection system.
4. Positioning system.
5. System of extra equipment.
1. Pipeline

- Technical characteristics of a pipeline.
- Conditions of lying: route, impact of/on environment, restrictions of sea conditions, regulations.
- Conditions of pipe over bending (stinger, feeder).
- System of pipe connecting to exploited system: preparation of ends, manner of segments joining, non-destroyed tests, manner of connecting.
- Supply system of pipes, reloading system: cranes, storing place, conveyors.
- System of pipeline submerging and tensioning.
- System of fastening and protection on a sea bed.
- Possibilities of pipeline repairing.
2. Pipeline laying object (rig, ship, barge)

- Restrictions and exploitation requirements.
- System of mooring and anchoring of the laying object.
- Stinger type and its matching.
- Manner of pipeline submerging.
- Analysis of loads, stresses and buoyancy.
- Procedure of the laying object application.
3. Protection system

- Operational schemas.
- Measurements of pipeline laying parameters.
- Monitoring of static and dynamic stresses.
- Computer simulation of pipeline laying.
- Programming and system instrumentation.
4. Positioning system

- Operational schemas.
- Satellite system of positioning.
- Control system of anchoring.
- Tracking system of the laying object position.
- Tracking system of the pipeline position.
5. Extra equipment

- Surface and underwater supporting objects.
- Special equipment.

Monitoring ułożenia i stanu technicznego rurociągu
Process efficiency

- efficiency of pipe laying [m/24 hours],
- total time of pipe laying on the route depend on:
  - pipe laying method applied,
  - manner of anchoring of a floating object,
  - welding technology,
  - inspection and monitoring of welding joints.

### Characteristics of pipeline laying methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Depth</th>
<th>Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>barge</td>
<td>10-300 m</td>
<td>do 5000 m/doba</td>
</tr>
<tr>
<td>platform ship</td>
<td>10-1500 m</td>
<td>do 5000 m/doba</td>
</tr>
<tr>
<td>ze statku</td>
<td>10-3000 m</td>
<td>do 5000 m/doba</td>
</tr>
<tr>
<td>równoległa</td>
<td>do 100 m</td>
<td>do 2000 m/doba</td>
</tr>
<tr>
<td>S</td>
<td>do 500 m</td>
<td>1600-5000 m/doba</td>
</tr>
<tr>
<td>J</td>
<td>powyżej 500 m</td>
<td>650-1600 m/doba</td>
</tr>
<tr>
<td>bębnowa</td>
<td>do 3000 m</td>
<td>do 3200 m/h</td>
</tr>
</tbody>
</table>
Case study I: Nord Stream pipeline building - disputable!
Route: Wyborg - Greifswald

# Nord Stream pipeline – technical data

## Facts & Figures

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route:</td>
<td>Offshore pipeline from Portovaya Bay near Vyborg, Russia to the coast of Germany near Greifswald, Mecklenburg-Western Pomerania. Constructed by Nord Stream AG</td>
</tr>
<tr>
<td>Gas capacities:</td>
<td>55 bcm per annum (2 pipelines with 27.5 bcm capacity each)</td>
</tr>
<tr>
<td>Pipeline length:</td>
<td>1220 km - Nord Stream is one of the longest offshore pipelines in the world</td>
</tr>
<tr>
<td>Max. water depth:</td>
<td>210 m</td>
</tr>
<tr>
<td>Project start:</td>
<td>2005</td>
</tr>
<tr>
<td>Completion of the first line:</td>
<td>According to plan – in 2011</td>
</tr>
<tr>
<td>Completion of the second line:</td>
<td>According to plan – in 2012</td>
</tr>
<tr>
<td>Technical Data</td>
<td>Details</td>
</tr>
<tr>
<td>---------------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>Pipeline diameter:</strong></td>
<td>1.220 mm / 48 inches</td>
</tr>
<tr>
<td><strong>Design pressure:</strong></td>
<td>220 bar / 200 bar / 170 bar</td>
</tr>
<tr>
<td><strong>Pipe steel standard:</strong></td>
<td>DNV Offshore Standard OS-F101; Steel grade: X-70</td>
</tr>
<tr>
<td><strong>Wall thickness:</strong></td>
<td>26.8-41.0 mm</td>
</tr>
<tr>
<td><strong>Coating:</strong></td>
<td>Interior antifriction coating of 0.06 mm epoxy layer; Exterior anticorrosion layer; Passive anticorrosive protection is ensured by aluminium sacrifice bracelet anodes</td>
</tr>
<tr>
<td><strong>Gas supply resources:</strong></td>
<td>Yuzhno-Russkoye oil and gas reserve, Yamal Peninsula, Ob-Taz bay and Shtokmanovskoye fields</td>
</tr>
<tr>
<td><strong>Estimated investment:</strong></td>
<td>€ 7.4 billion</td>
</tr>
<tr>
<td><strong>Shareholders:</strong></td>
<td>OAO Gazprom (51%), Wintershall Holding AG (20%), E.ON Ruhrgas AG (20%), N.V. Nederlandse Gasunie (9%)</td>
</tr>
</tbody>
</table>
Nord Stream Pipeline – prefabrication

Logistics chain – From production to installation

NORD STREAM PIPELINE

- Plate Production
- Pipe Production
- Interior Antifriction Coating
- Exterior Anticorrosive Coating
- Pipe-Laying
- Stock Building at Marshalling Yards
- Concrete Weight Coating


Tadeusz Graczyk
Nord Stream Pipeline – laying

Efficiency: 3 km in twenty-four hours
(125 sections x 24 m)
The pipeline-laying process step-by-step

1. A transportation vessel delivers the pipes to the pipe-laying vessel.
   - Pipe length: 13.2 m
   - Concrete weight: 60–110 mm
   - Steel: 27–41 mm
   - Rust protection: 3 mm

2. Two pipes are connected...
   ...and welded together on both, the inside and outside.

3. The pipes are attached with the already completed section. In total, approx. 100,000 pipes are welded together.

4. The pipe-laying vessel moves in the same pace as the gas pipeline is laid.

Facts about the gas pipeline:
- Two parallel pipelines. Planned commissioning of the first pipeline in 2011, the second in 2012.
- Total capacity: 55 bcm per year.
- Will meet about 25% of the additional gas import needs of Europe in 2025.
- Cost: 7.4 billion Euro

Source: Nord Stream

Gas pipeline

Uneven areas of the seabed will be avoided
- Radius of several kilometres
- The gas pipeline can be laid in a wide band around larger unevenness.

Emplacement over uneven areas of the seabed
- The seabed is thoroughly examined for obstacles before the pipes are lowered into the sea.

The gas pipeline is positioned on the seabed. The total length is about 1,220 km.
Nord Stream Pipeline – laying
- pipes delivery
Nord Stream Pipeline – laying

- store of pipes of 12 m long and assembling workshop
Nord Stream Pipeline – pipe-laying sequence

• First, two 12-metre pipe joints are welded together in a “double-joint welding station” to form a 24-metre long “double joint” with both an interior and exterior welding pass.

• After “double-joint welding,” the weld is inspected, and if found acceptable, the double joint is then released to the firing line. All double-joint welds undergo a very precise additional test. This allows even the smallest welding defects to be detected.
Nord Stream Pipeline – pipe-laying sequence

• The pre-fabricated 24-metre long double joint is then conveyed into the central assembly line, known as the “firing line.” Here, the double joint is connected to the pipeline end and welded together with semi-automatic machines. Welding of the numerous girth weld layers takes place in five to six welding stations in order to achieve high productivity.

• The “firing-line” welds also undergo a precise inspection to ensure defect-free welds. After acceptance of the weld, it is coated and the next 24-metre length is ready to be lowered to the seabed. This is done by moving the pipelay vessel 24 metres forward while keeping the pipeline under tension over the stinger.
Nord Stream Pipeline – pipe joining and protection
Nord Stream Pipeline – final tests

- After construction is completed, the pipeline will be filled with water and pressure-tested for at least 24 hours at a pressure higher than the maximum gas pressure during operation. This is done as a final test before starting operations to demonstrate that the pipeline is 100% impermeable and is sufficiently durable to transport gas at high pressures.

- After this test, the pipeline is emptied of water before the first gas is introduced.

- Filling up with gas.

Using this method, over three kilometres of pipes can be laid per day. The pipeline will rest on the seabed for most of the offshore route. In some areas, such as in the vicinity of the landfalls, the pipeline must be buried and backfilled with sand in order to assure sufficient stability. In areas with frequent marine traffic, the pipeline may also need to be buried and backfilled in order to protect it from anchor impacts.
Nord Stream Pipeline – laying

- effectiveness: 3 000 m/24 hours
- section 24 m long every 11.52 min

407 days?
Nord Stream Pipeline – menace of pollution

50 000 t of chemical ammunition (sulphur cyanide, clark I, clark II, adamsite, cyanide salts, prussic acid) flooded by Russians, 1945–1948 r. East of Bornholm and East of Gotland (40 000 in Bornholm abyss, 2800 sq km),

- flooded by East German Navy up to 1968,
- cans corroded in 75-90 %,
- accidents – 16 officially documented (chemical weapons):

- contamination of a beach in Kołobrzeg, Dziwnów, Darłówek – poisoned more than 100 children, July 1955
- contaminated crew of WŁA 206 cutter, 9 Jan. 1997
- many informal known accidents.
Nord Stream Pipeline – menace of pollution
Nord Stream Pipeline – menace of pollution
Nord Stream Pipeline – menace of pollution
Nord Stream Pipeline – menace of pollution

Alternative route
Nord Stream Pipeline – menace of pollution

Menace to natural environment caused by:

• lack of identification of ammunition deposits,
• ammunition flooded out of agreed regions,
• deposition of ammunition caused by near bottom streams,
• flooding of caught ammunition by fishermen in accidental regions.
Nord Stream Pipeline – facts

Nord Stream Pipeline Inaugurated

Nov. 8, 2011 The Nord Stream Pipeline became operational today and was hailed by political and business leaders as making a significant contribution to Europe’s long-term energy security...

CONSTRUCTION MONITOR

LINE 1
1,224 km finished

LINE 2
890 km finished
Nord Stream Pipeline – facts
Case study II: Baltic Beta – Władysławowo pipeline

Transferring gas pipe line from „Baltic Beta” rig (appr. 70 km North from Rozewie Cape) to heat and power generating plant in Władysławowo, 2002 r.
Material of pipe: Steel X65C

\[ \phi_{zew} = 114.3 \text{ mm} \]
\[ \phi_{nom} = 101.6 \text{ mm} \]
\[ g = 6.35 \text{ mm} \]

Re: \[ R_{e} = 455 \text{ Mpa} \]
Rm: \[ R_{m} = 540 \text{ Mpa} \]

Protection: 3 layers:
- Valspar epoxide material,
- Dupont epoxide polymer,
- polyethylene material.

Reel method:
- the segment was prefabricated on the land and reeled on a ship deck,
- in one passage a pipe segment of 11 km length was layed.
Technical data:

- lowering period – 03-06. 2002,
- pipeline length 82,5 km:
  53 km in Polish economic zone, 
  9 km in Polish territorial zone, 
  ok. 500 m on a beach in region, where pipeline riching a land, 
- in 8 routes of ship, 
- in one route pipeline section of 10–11 km has been lowered, in 60-84 hours, 
- First transmission of natural gas in August 2002, 
- first heating season using NG in Władysławowo – Autumn 2003 r.
Summary:

- further development of underwater pipelines, especially in shelf zone,

- technology verified down to 1500 m, challenge for engineers in greater depth,

- big ecological menace in the Baltic Sea,

- promising activity sector for economy of countries by the sea.
Bibliography

Thank you for your attention