Risk and Challenges of Deepwater Pipeline Design and Installation

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A new company with 150 years of experience

DNV and GL Noble Denton joined forces in September 2013. We’ve drawn upon our proud heritages to create:

- Greater technical expertise
- Enhanced innovation capabilities
- Extended global reach
- An integrated service portfolio
An integrated approach across the asset lifecycle

Our common way of working and global sales model delivers industry best practice across the asset lifecycle. Core service areas include:

- Risk management advisory
- Technical advisory
- Noble Denton marine assurance & advisory
- Technical assurance
  - Certification and verification
  - Inspection and quality assurance
- Offshore classification
Deepwater Pipelines in unchartered territories

Outline of Presentation

- Some key risks and challenges
- Possible approach and solutions to overcome these
Risks and Challenges – Deepwater pipelines

Some key Risks and Challenges are:

1. Wall thickness design
2. Installation challenges
3. Flow Assurance - Prevention of Hydrates
4. System pressure test
5. Geohazards
6. Repair systems for ultra-deep waters
Deepwater challenge #1 – Pipeline collapse

- **Wall thickness design**

  Risks and Challenges:
  - High external pressure means pipeline collapse failure mode governs wall thickness design rather than pressure containment
  - Manufacturing of thick wall pipes may limit project options and project feasibility.

  Solutions:
  - Use of limit state design approach to optimize wall thickness design e.g. OS-F101 standards
  - Specify improved linepipe properties against collapse failure by improving compressive yield strength, balance between strength and toughness and improving linepipe roundness
  - Justify use of less conservative safety factors through technology qualification
Limit State Design approach to optimise wall thickness

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Ultimate Limit States</th>
<th>Serviceability Limit States</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bursting</td>
<td>Fatigue</td>
</tr>
<tr>
<td>Wall thickness design</td>
<td>X</td>
<td></td>
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<tr>
<td>Installation</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Riser</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Free-span</td>
<td>(X)</td>
<td>X</td>
</tr>
<tr>
<td>Trawling/3rd party</td>
<td>(X)</td>
<td>X</td>
</tr>
<tr>
<td>On bottom stability</td>
<td>(X)</td>
<td>(X)</td>
</tr>
<tr>
<td>Pipeline Walking</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Global Buckling</td>
<td>(X)</td>
<td>X</td>
</tr>
</tbody>
</table>

1) Typically applied as a simplified way to avoid checking each relevant limit state
Collapse capacity of pipelines – design requirements

DNVGL-OS-F101 Submarine Pipeline Standards: Sect 5 Design

307 For manufacturing processes which introduce cold deformations giving different strength in tension and compression, a fabrication factor, \( \alpha_{\text{fab}} \), shall be determined. If no other information exists, maximum fabrication factors for pipes manufactured by specific processes are given in Table 5-5.

The fabrication factor may be increased through heat treatment or external cold sizing (compression), if documented.

<table>
<thead>
<tr>
<th>Table 5-5 Maximum fabrication factor, ( \alpha_{\text{fab}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
</tr>
<tr>
<td>( \alpha_{\text{fab}} )</td>
</tr>
</tbody>
</table>

JFE TECHNICAL REPORT No. 18 (Mar. 2013)

3. Heavy Wall Linepipe for Deep Water Pipeline

Offshore gas pipeline development has been expanding toward deeper water region that requires pipes to have strong resistance against collapse by external pressure. The DNV standard, DNV-OS-F101 (DNV: Det Norske Veritas), is the major guideline for the design of offshore pipelines, which requires thicker wall to increase collapse resistance.
**Enhancing Collapse Capacity of UOE Pipes**

- Thick wall designs > 40mm is on the border of the capacity for linepipe manufacturing industry
- Pipe manufacturing process (UOE) reduces compressive yield strength by 15% (Ref: DNVGL-OS-F101)
- Industry claims that the strength can be restored by light heat treatment e.g. during application of external coating
- Focus on ovality caused by manufacture process (pipe forming)
- DNVGL has been involved in a technology qualification project with the aim of utilising this in design
Collapse capacity (D/t) vs water depth

Validity range: D/t = 20-45
Risk and Challenges – Deepwater pipelines

1. Wall thickness design
2. **Installation challenges**
3. Flow Assurance - Prevention of Hydrates
4. System pressure test
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6. Repair systems for ultra-deep waters
Deepwater challenge #2 – Installation

**Installation**

Risks and Challenges:

- High strains coupled with high external water pressure with increased risks of local buckling and fracture
- High pipelay vessel tensioner capacity required. More stringent requirements to tensioner holding
- Ability to detect buckle and repair a wet buckle

Solutions:

- Use of limit state design approach to check against local buckling, ovalisation and to optimize wall thickness/pipe weight
- Use of Engineering Criticality Assessments for girth weld assessments
- Specify supplementary linepipe material properties for high strains and additional testing
- Specify supplementary dimensional properties – more stringent control
- Justify use of less conservative safety factors through technology qualification
- Self propelled buckle detector crawlers with remote sensors (e.g. microwave buckle detector used on S7000)

Courtesy: Saipem
Required tension capacity (J-lay)
Enhanced material and dimensional properties for fracture and buckling control

Table 7-25 Additional testing for Supplementary requirement P 1)

<table>
<thead>
<tr>
<th>Type of pipe</th>
<th>Type of test</th>
<th>Frequency of testing</th>
<th>Acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>All pipe</td>
<td>Tensile testing of the pipe body, longitudinal</td>
<td>Once per test unit</td>
<td>1303</td>
</tr>
<tr>
<td></td>
<td>specimen of proportional type 2)</td>
<td>of not more than</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>50/100 3) pipes</td>
<td></td>
</tr>
</tbody>
</table>

Tests for Manufacturing Procedure Qualification Test (all testing on strained and aged samples)

<table>
<thead>
<tr>
<th>Type of pipe</th>
<th>Type of test</th>
<th>Frequency of testing</th>
<th>Acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>All pipe</td>
<td>Tensile testing of the pipe body, longitudinal</td>
<td>One test for one of</td>
<td>1308</td>
</tr>
<tr>
<td></td>
<td>specimen, strained and aged 2)</td>
<td>the pipes provided</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CVN impact testing of the pipe body</td>
<td>for manufacturing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hardness testing</td>
<td>procedure qualification</td>
<td></td>
</tr>
<tr>
<td>Welded pipe</td>
<td>Tensile testing of weld metal (all weld test)</td>
<td></td>
<td>1308</td>
</tr>
<tr>
<td></td>
<td>CVN impact testing of the seam weld</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hardness testing of the seam weld</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1) Mechanical and corrosion testing shall be performed in accordance with Appendix B.
2) Proportional type specimens according to ISO 6992 shall be tested, see App B B1308.
3) Not more than 100 pipes with D < 508 mm and not more than 50 pipes for D ≥ 508 mm.

304 As part of qualification of the pipe material, the finished pipe shall be deformed either by full scale or simulated deformation (see App.B B1102 to B1110) as stated by the Purchaser in the linepipe specification.
Risks and Challenges – Deepwater pipelines

1. Wall thickness design
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6. Repair systems for ultra-deep waters
Deepwater Challenge #3 – Hydrate plugs

Formation of Hydrate plugs

Risks and Challenges:
- In the event of a small leakage, seawater ingress into a deepwater gas pipeline (external pressure > internal pressure) can lead to formation of hydrates.
- Large Hydrate plugs may form – How large? How to intervene?

Solutions:
- Passive prevention systems
  - Insulation (coating, PiP, bundle)
  - Trenching
  - Parallel trenched pipelines
- Active prevention systems
  - Injection of methanol/glycol
  - Heating – electrical, circulation of hot water
  - Dehydration of pipeline
- Hydrate remediation
  - Depressurisation
  - Injection of methanol/glycol
  - Heating
Risks and Challenges – Deepwater pipelines

1. Wall thickness design
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Deepwater Challenge #4 – Relevance of system pressure test

System Pressure Testing

Risks and Challenges:

- High system pressure test – external pressure is the challenge
  - Is the test relevant?
- Require gigantic compressor station to empty the pipeline
- System test may rather harm the pipeline:
  - Pipeline will expand due to internal pressure
  - Due to static pressure and high test pressure - large expansion
  - This can result in severe global buckling
  - Deepwater seabed often have soft soil which may give rise to high bending strains

Solution:

- Adopt DNVGL-OS-F101 provisions for system pressure test waiver
  (Sec.5 B203)
Waiver for System Pressure Test (DNVGL-OS-F101)

DNVGL-OS-F101 Submarine Pipeline Standards (2013) : Sect 5

Table 5-1 Requirements to waive system pressure test

| Less than 75% of the pressure containment design resistance shall be utilised | Guidance note: The requirement implies that external pressure governs the wall thickness design. For deep water pipelines, the benefit of a system pressure test is limited, hence this criterion. The limitation implies that the wall thickness shall be at least 33% larger than required by the pressure containment criterion. ---e-n-d---G-u-i-d-a-n-c-e---n-o-t-e--- |

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Risks and Challenges – Deepwater pipelines

1. Wall thickness design
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Deepwater challenge #5 – Geohazards

- Installation
  - Risks and Challenges:
    - Steep slopes
    - Loose Sediments
    - Seismic activities
    - Earthquake causing seabed faults
    - Slope instabilities and mudslides
    - Turbidity flow
    - Uneven seabed causing long freespans
    - Lack of suitable methods for seabed intervention

  Solutions:
  - Adequate characterization of seabed and geomorphology
  - Optimized routing of pipeline considering potential hazards, safety, pre and post lay intervention requirements
  - Robust geotechnical engineering
  - Robust bottom roughness and freespan assessment
Some challenges of deepwater and complex seabed
Freespan assessment based on DNVGL-RP-F105

Advanced assessment of long freespans with multi-mode response can result in substantial cost saving in seabed intervention.
Deepwater challenge – Geohazards

DNVGL-OS-F101 Submarine Pipeline Standards (2013) : Sect 3

Areas where there is evidence of increased geological activity or significant historic events that if re-occurring again may impact the pipeline, additional geohazard studies should be performed. Such studies may include:

- extended geophysical survey
- mud volcanoes or pockmark activity
- seismic hazard
- seismic fault displacements
- possibility of soil slope failure
- mudflow characteristics
- mudflow impact on pipelines.

See also Sec. 3 C700 Seabed Properties
Risks and Challenges – Deepwater pipelines

1. Wall thickness design
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Deepwater challenge #6 – Repairs

- **Installation**

  **Risks and Challenges:**
  
  - Wet buckle during installation
  - Damage during operation
  - Ingress of seawater/ hydrate plugs
  - Unsuitable soil/ environmental conditions
  - Lack of diverless repair systems for ultra deepwater

  **Solutions:**
  
  - Emergency response procedures must be established
  - Develop and qualify repair methods suitable for specific pipeline system and environmental conditions
Deepwater challenge – Repairs

Consequently, pipeline repair in deeper waters has to be carried out based on remotely controlled techniques. A pipeline repair in general requires a range of planning and investigations prior to the actual repair:

- Investigation of the damage, the pipe condition and consequences for the pipeline operation, i.e. will any repair be required? Should pollution counter measures be started? Should water ingress in the pipe be limited?
- Planning of uncovering and seabed preparation for the repair including calculations of the pipeline response from this action.
- Planning the repair operation based on the state of emergency preparedness and the results of the investigations. (Planning, ordering of equipment and support)
- Seabed preparations, pipeline pressure adjustments, repair
- Test to confirm the repair quality, protection of the repaired section, clean up and finish.
Conclusion

Presented some of the key risks and challenges of deepwater pipelines.

1. Wall thickness design
2. Installation challenges
3. Flow Assurance - Prevention of Hydrates
4. System pressure test
5. Geohazards
6. Repair systems for ultra-deep waters

These can be mitigated by:

- Comprehensive geotechnical and environmental investigations to reduce unknowns;
- Using Limit State design approach to optimise and ensure consistent safety and reliability against all possible failure modes during installation, testing and operational phases;
- Specify enhanced/ supplementary properties of linepipe
- Address installation, testing and operational challenges at the design stage to improve layability, reliability and to minimise subsea intervention;
- Close surveillance during manufacturing, installation and testing to ensure design conditions and qualification assumptions are met.
- Use of appropriate standard, specifications and recommended practices
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