NTNU
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Faculty of Marine Technology
Department of marine structures

**Module TMR 4585: Underwater Technology – *Subsea Pipeline Technology***

# EXERCISE – Pipeline wall thickness design - Hydrodynamic stability check – Expansion check - Installation design

## General

This exercise is the one and only mandatory exercise related to the pipeline design part of the above module. The exercise is then meant to be merged into the project report.

## Reference documents

- Offshore Standard DnV- OS-F101 Submarine pipeline systems AUGUST 2012
- Recommended Practice DNV-RP-F109 On-Bottom Stability Design of Submarine Pipelines OCTOBER 2010

## Tasks to be carried out

A 150 km long 16" gas pipeline is to be installed from the Haltenbanken area to the Ranheim Industri Plant outside Trondheim.

1. Calculate the steel wall thickness needed along the route profile considering the bursting design criteria defined in DnV-OS-F101 considering the design and system test pressure cases. Use the DnV safety class definition to identify sections with different wall thickness.
2. With reference to the same standard, identify whether or not buckle arrestors will be needed along the pipeline.
3. On the basis of the concrete coating thickness specified, perform hydrodynamic stability design both with respect to vertical and horizontal stability, using the "virtual stable pipe" criterion and the generalised stability method in DNV-RP-F109 for horizontal stability. This includes both the offshore and inshore (Trondheim Fjord) sections. Assume that the steady and wave induced current velocities are acting perpendicular to the pipe and use the worst case scenarios from the route profile. Then specify the necessary concrete coating density (using the tabulated range) along relevant sections of the pipeline. If found relevant, identify sections where additional

stabilization is required and propose solution.The installation (empty pipe), system test (waterfilled) and operation (gas filled) load scenarios are to be considered. The installation is carried out in the summer season. Then the pipeline is left waterfilled over the winter season before it is put in operation.

4. Use the input parameters to obtain the steady state temperature profile along the pipe and identify which sections of the pipeline that will be exposed to global buckling during operation.
5. Calculate on the basis of DnV OS-F101 and the “Load controlled condition” with respect to combined loads, the most conservative maximum allowable free span length under the installation, system test and operation conditions. The system test and operation conditions both include the design internal pressure condition and the no internal pressure condition, with respect to the point at which these pressure are applied (20 m above the sea surface). Assume zero axial force and a bending moment $M=w_sL^2/12$, where $w_s$ is the submerged weight and L is the span length.
6. Use the critical bending moment found for the installation condition above and the catenary equation to calculate the minimum bottom tension needed during installation and the minimum radius of curvature applicable for the horizontal curves needed to establish the route in the horizontal plane.

## Input data

### Steel cross-section design

| **Pipeline cross-section related issues** | |
|---|---|
| Inside diameter | 406.4 mm |
| Design pressure | 25 MPa |
| Gas specific density | 300 kg/m$^3$ |
| Incidental to system test pressure ratio | 1.0 |
| Acceleration of gravity | 9.81 m/s$^2$ |
| System test to design pressure ratio | 1.33 |
| Water density used for system test | 1000 kg/m$^3$ |
| Reference level above sea surface where the system test pressure is applied | + 20 m |
| Sea water density | 1025 kg/m$^3$ |
| Corrosion allowance | 5 mm |
| Thickness fabrication tolerance | 10% |
| Material grade | X65 carbon steel, no temperature derating |
| Steel Yield stress | 450 MPa |
| Steel Ultimate stress | 1.15*yield stress |
| Steel density | 7850 kg/m$^3$ |
| Steel thermal conductivity | 43 W/m/K |
| Cross-section ovality | 0.005 |
| Corrosion coating thickness | 2 mm |
| Corrosion coating density | 1100 kg/m$^3$ |
| Corrosion coating thermal conductivity | 0.2 W/m/K |
| Minimum concrete coating thickness | 45 mm |
| Concrete coating density | 2200-3000 kg/m$^3$ |
| Concrete coating thermal conductivity | 0.5 W/m/K |

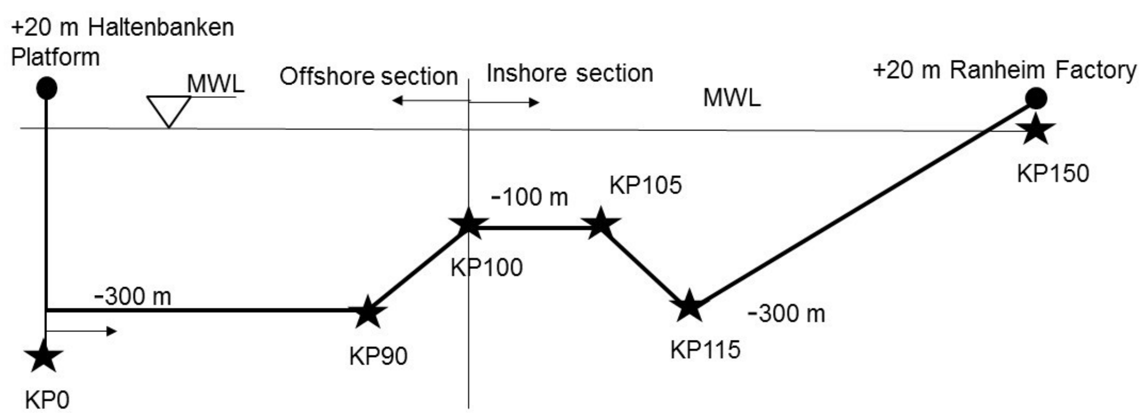
**Flow conditions**

| **Flow related issues** | |
|---|---|
| Operation inlet design temperature | 80 $^{O}$C |
| Flow velocity | 5 m/s |
| Specific heat capacity of flow | 2000 J/kg/K |
| Gas specific density | 250 kg/m$^3$ |

**Soil conditions**

| **Soil type: Clay along entire route** | |
|---|---|
| Friction factor | 0.2 |
| Dry unit soil weight | 18 kN/m$^3$ |
| Submerged unit soil weight | 8 kN/m$^3$ |
| Undrained shear strength, offshore section | 2 kPa |
| Undrained shear strength, inshore section | 5 kPa |

**Route profile**




**Wave Data**

Wave data to be applied are omni-directional data as follows

The seasons are defined for current and waves as follows:

| | | |
|---|---|---|
| Summer | - | June, July and August |
| Autumn | - | September, October and November |
| Winter | - | December, January and February |
| Spring | - | March, April and May |

Sea states are characterized by significant wave height, $H_S$, and peak period, $T_P$. The duration of a sea state is 3 hours.

Offshore section

| Parameter All year | Return Period (years) | | | |
|---|---|---|---|---|
| | 1 | 10 | 100 | 10 000 |
| Hs (m) | 11.7 | 13.9 | 16.0 | 20.0 |
| Tp (s) | 15.9 | 17.0 | 18.0 | 20.0 |

| Season | | Return Period (years) | | |
|---|---|---|---|---|
| | | 1 | 10 | 100 |
| Spring | Hs (m) | 9.3 | 11.4 | 13.3 |
| | Tp (s) | 14.6 | 15.9 | 17.0 |
| Summer | Hs (m) | 5.8 | 7.1 | 8.3 |
| | Tp (s) | 12.3 | 13.3 | 14.1 |
| Autumn | Hs (m) | 9.7 | 11.8 | 13.6 |
| | Tp (s) | 14.8 | 16.1 | 17.0 |
| Winter | Hs (m) | 11.7 | 14.0 | 16.0 |
| | Tp (s) | 16.0 | 17.2 | 18.0 |

Inshore section

| Parameter All year | Return Period (years) | | | |
|---|---|---|---|---|
| | 1 | 10 | 100 | 10 000 |
| Hs (m) | 2 | 2.5 | 3 | |
| Tp (s) | 4 | 5 | 6 | |

| Season | | Return Period (years) | | |
|---|---|---|---|---|
| | | 1 | 10 | 100 |
| Spring | Hs (m) | 1.5 | 2.5 | 3 |
| | Tp (s) | 4 | 5 | 6 |
| Summer | Hs (m) | 1 | 1.5 | 2 |
| | Tp (s) | 3 | 3.5 | 4 |
| Autumn | Hs (m) | 1.5 | 2 | 2.5 |
| | Tp (s) | 3.5 | 4.5 | 5.5 |
| Winter | Hs (m) | 2 | 2.5 | 3.0 |
| | Tp (s) | 4 | 5 | 6.0 |

**Current Data**

The extreme current profiles are to be applied to all pipeline sections.

| Water depth (m) | Return period (years) | | |
|---|---|---|---|
| | 1 | 10 | 100 |
| **5 m above seabed** | 0.50 | 0.55 | 0.60 |

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