Deepwater Challenges
Pipeline Installation Case

Seminar Nasional Oceano, ITS, 28 March 2011, Surabaya

Gunawan Suwarno, 28 March 2011

DeepLay Energy Services
Deepwater Development

Offshore Scope

- 2 x 30” Import Pipelines (ca. 120km)
- 2 x 6½” MEG Lines (ca. 120 km)
- 2 x Umbilical (ca. 120 km)
- 1 x 6½” Infield MEG Lines (ca. 3 km)
- 1 x Infield Umbilical (ca. 3 km)

Template A
-850m

Template B

Storegga Slide Edge

Control Umbilicals And MEG

-250m

Nyhamna

Langeled to UK

DeepLay Energy Services
email: marketing@deep-lay.com
Deepwater Challenges (For Subsea Pipeline)

Design
- Design (Issues on Lateral Buckling or Pipeline Walking, for HPHT Pipeline)
- Seabed (Issues on Freespan, Seabed Intervention, Seabed Movement)

Installation
- Installation (Issues on Lay Tension Requirement)
- Installation Risks Management (typically issued flooded Pipe)

DeepLay Energy Services
email: marketing@deep-lay.com
Pipeline Installation Method (Slay and Jlay)

DeepLay Energy Services
email: marketing@deep-lay.com
Pipeline Installation Method (Slay and Jlay)

For the same angle, by Considering Equilibrium, the H on Slay will be much larger than Jlay because of Stinger Contact Forces.

Tension can be reduced When Angles are closed to 90 Degrees.
Deepwater Challenges (Installation)

Typically the main issues is the lay tension requirement, deep water will require bigger tension (on Slay and or Jlay) because the length of catenary line.

The length of catenary line can be reduce by having almost vertical lay angle (while on Slay, the selection of the angle is depending on the stinger radius)

Selection of Stinger Radius is depending on allowable Stress / Strain during Installation
Pipeline Installation Limits

Traditional Code

Static : 0.72 SMYS (DNV Stress – DnV 1981)
Dynamic : 0.96 SMSY (DNV Stress – DnV 1981)

Or DnV OSF101 – Simplified Criteria

<table>
<thead>
<tr>
<th>Table 13-5</th>
<th>Simplified criteria, overbend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criterion</td>
<td>X70</td>
</tr>
<tr>
<td>I</td>
<td>0.270%</td>
</tr>
<tr>
<td>II</td>
<td>0.325%</td>
</tr>
</tbody>
</table>

Sagbend

For combined static and dynamic loads the equivalent stress in the sagbend and at the stinger tip shall be less than

$$\sigma_{eq} < 0.87 \text{times } f_y$$

(13.17)
Relation Between Stress and Strain (X65)

<table>
<thead>
<tr>
<th>Stress (Mpa)</th>
<th>Elastic % to Yield (%)</th>
<th>Strain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>436.3</td>
<td>0.97</td>
<td>0.350</td>
</tr>
<tr>
<td>430.2</td>
<td>0.96</td>
<td>0.305</td>
</tr>
<tr>
<td>418.5</td>
<td>0.93</td>
<td>0.250</td>
</tr>
<tr>
<td>394.0</td>
<td>0.88</td>
<td>0.200</td>
</tr>
<tr>
<td>310.7</td>
<td>0.69</td>
<td>0.150</td>
</tr>
</tbody>
</table>

Figure 3
Reference for plastic strain calculation

Guidance note:
The yield stress is defined as the stress at which the total strain is 0.5%. As an example for a 415 grade C-Mn steel, a unidirectional strain of 0.5% corresponds to an elastic strain of approximately 0.2% and a plastic strain of 0.3%.
DnV Local Buckling Checks
- Load Controlled Condition (LCC)

\[
\frac{\gamma_m \cdot \gamma_{SC} \cdot \frac{|M_{SD}}{\sigma_c \cdot M_p(t_2)}}{\left(\gamma_m \cdot \gamma_{SC} \cdot S_{SD}\right)^2} + \frac{\left(\gamma_m \cdot \gamma_{SC} \cdot \frac{P_e - P_{min}}{p_c(t_2)}\right)^2}{\gamma_m \cdot \gamma_{SC}} \leq 1
\]

-Displacement Controlled Condition (DCC)

\[
\frac{8_{SD}}{\epsilon_{c}(t_2,0)} \leq \frac{P_e - P_{min}}{p_c(t_2)} \leq 1 \quad D/t < 45, \quad P_{min} < P_e
\]

\[
\alpha_c = \frac{(1 - \beta)P_e}{P_s} \quad \beta = \begin{cases} 
0.5 & \text{for } D/t < 15 \\
\frac{60 - D/t}{90} & \text{for } 15 < D/t < 60 \\
0 & \text{for } D/t > 60
\end{cases}
\]

DeepLay Energy Services
email: marketing@deep-lay.com
Pipeline Installation Limit, Local Buckling Check

- For Steep Slay For Deep Water Slay Application
  At OverBend Section / Stinger, used Displacement Controlled Condition (Similar to Reeling)
  At Stinger Tip, used Load Controlled Condition
- Avoid Contact or High Load on Stinger Tip

Stinger curvature / radius will be based on DCC which will give a high allowable strain limits (It could go above 0.5%)

--- > Smaller Radius (But Beware of Residual Strain), Near Vertical Stinger Angle --- > Less tension Requirement

DeepLay Energy Services

email: marketing@deep-lay.com
Pipeline Installation Limits

The New Pipeline Code allows us to use a smaller stinger radius which will give a possibly to lay pipeline on a deeper water depth.

But Smaller radius will create a high strain during installation which will effect the residual strain post installation. (some case will create pipe rotation, It will become an issued on pipeline with In Line Structures)

The residual strain will effect the residual Pipeline Ovality and Pipe Ovality will reduce the maximum Pipe Collapse Capacity Pipeline on Deepwater.

And High Strain/Stress level will also have impact on maximum fatigue standby time during installation.

DeepLay Energy Services

email: marketing@deep-lay.com
Deep water lay vessel is usually powered by DP (Dynamic Positioning, positioning based on thrusters and reference system)
* Not limited to water depth
* More control on positioning
* Mooring/anchor handling spreads not required
For Pipelaying, the Thruster Force is used to positioning the vessel against the catenary Horizontal Load.

DeepLay Energy Services

email: marketing@deep-lay.com
## Typical Examples of DP Station keeping

### Limiting Conditions at most unfavourable wind directions

<table>
<thead>
<tr>
<th>Case</th>
<th>Pipelay Tension (Te)</th>
<th>Wind Speed (Knot)</th>
<th>Wind Direction (Deg)</th>
<th>Wave Hs (m)</th>
<th>Wave Tz (Sec)</th>
<th>Current Speed (Knot)</th>
<th>Thruster Off (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>150.0</td>
<td>32.80</td>
<td>90.00</td>
<td>3.30</td>
<td>6.00</td>
<td>1.00</td>
<td>None</td>
</tr>
</tbody>
</table>

**Input file reference:** SAPURA_3k_final_with_stinger-d.scp  
Last modified: 2005-08-16 13:33 (v. 2.4.0)

- **Length overall:** 151.2 m
- **Length between perpendiculars:** 144.0 m
- **Breadth:** 37.8 m
- **Draught:** 6.2 m
- **Displacement:** 27000.0 t
- **Longitudinal radius of inertia:** 36.0 m
- **Pos. of origin ahead of Lpp/2 (Xo):** 0.0 m
- **Wind load coefficients:** Calculated (Blendemann)
- **Current load coefficients:** Calculated (Strip-theory)
- **Wave-drift load coefficients:** External file input

- **Tidal current direction offset:** 0.0 deg
- **Wave direction offset:** 0.0 deg
- **Wave spectrum type:** Pierson-Moskowitz
- **Wind spectrum type:** NPD
- **Current - wave-drift interaction:** OFF
- **Load dynamics allowance:** 1.0 °/orf thrust demand
- **Additional surge force:** -150.0 ft
- **Additional sway force:** -0.0 ft
- **Additional yawing moment:** 0.0 ft.m
- **Additional force direction:** Fixed
- **Density of salt water:** 1026.0 kg/m³
- **Density of air:** 1.23 kg/m³

**Power limitations:** OFF

- **# Thruster:**
  - X [m]: Y [m]: F+ [ft]: F- [ft]: Max [%]: Pe [kW]: Rudder
  - 1: AZIMUTH: 64.1: 6.0: 42.3: -24.6: 90: 2400
  - 2: AZIMUTH: -49.4: -9.5: 42.3: -24.6: 90: 2400
  - 3: AZIMUTH: 49.4: 9.5: 42.3: -24.6: 90: 2400
  - 4: AZIMUTH: -20.6: 9.5: 42.3: -24.6: 90: 2400
  - 5: AZIMUTH: -82.7: 15.0: 42.3: -25.7: 90: 2400
  - 6: AZIMUTH: 82.7: 15.0: 42.3: -25.7: 90: 2400
  - 7: AZIMUTH: 40.6: 9.5: 42.3: -24.6: 90: 2400

**Limiting wind speed:** Automatic

**Significant wave height:** SAPURA

**Mean zero up-crossing period:** SAPURA

**Wind speed:** Automatic

**Rotating tidal current:** 1.00 knots

**Rotating wind induced current:** 0.000°/s

---

DeepLay Energy Services  
email: marketing@deep-lay.com
Slay Pipeline Installation Loads

The Tension capacity reflect the lay capabilities

DP Thrust / Bottom tension

DeepLay Energy Services
email: marketing@deep-lay.com

DP Thrust capacities show DP Station Keeping Capabilities during Pipelay
DeepWater Slay Load Check

Load checks During Pipelay Analyses (DP vessel)

- Maximum Dynamic Top Tension is below the maximum allowable Tensioner Capacity
- Maximum Horizontal Tension (Bottom Tension) is below the allowable DP Thrust Station Keeping Capacity with Sufficient weather Windows and emergency case of one of Thrust Failures.

- What If the unplanned flooded pipe happen due to wet Buckle?
Deepwater Installation Risks, Flooded Pipeline

The biggest Risks for Pipeline Installation in Deepwater is unplanned flooded pipe due to pipe buckle. This incident will increase the lay tension significantly (specially for big Diameter of Pipeline).

Typically, Contractor do not design the pipelaying vessel to be able to lay safely the flooded pipe but Contractor Pipelaying Vessel must be able to safely abandon the flooded pipe without free fall or damaging the main component of lay system (stingers or Jlay Tower).

For JLay, typically the collar need to be able to hold the flooded pipe.

DeepLay Energy Services  
email: marketing@deep-lay.com
In case of Flooded

Lay Tension increased significantly. The Lay Tension may be above the Tensioner capacity.

If Lay tension above the capacity, the Tensioner will be on breakmode, if beyond breakmode pipe will drop (freefall).

Bottom tension will increase in line with pipe lay Tension.

If Bottom tension above the DP Station Keeping Capabilities, the vessel will not be able to keep in Position (move Backward), Until equilibrium.

DeepLay Energy Services email: marketing@deep-lay.com
Flooded Case Load Check (Slay)

Load checks During Wet Buckles Case (DP vessel)

- Maximum Top Tension is below the maximum allowable Tensioner Break Capacity capacity
- Most likely, at Wet Buckle condition, the vessel will not able to hold the catenary (above the station keeping capabilities), So the vessel will move backward until reaching the equilibrium position (Horizontal Tension equal <= Capacity of DP Forces)
- At the above condition the Winch should capable to laydown the pipe safely on the seabed (Winch Tension Capacity is above the lay tension at drift position)
- The Stinger Structural should be verified against this loadings

DeepLay Energy Services

email: marketing@deep-lay.com
Sample Cases of Flooded Case Study

DeepLay Energy Services

email: marketing@deep-lay.com
## Sample Cases of Flooded Case Study

### Capacity and performance

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal tension</td>
<td>80 [mt]</td>
</tr>
<tr>
<td>Dynamic tension(^1)</td>
<td>100 [mt]</td>
</tr>
<tr>
<td>Max. tension pipe pulling through brake (both directions)</td>
<td>217 [mt]</td>
</tr>
<tr>
<td>Dynamic factor</td>
<td>1.25 [-]</td>
</tr>
<tr>
<td>Contact length</td>
<td>Approx. 3.7 [m]</td>
</tr>
<tr>
<td>Design friction coefficient for concrete coated pipe</td>
<td>0.3 [-]</td>
</tr>
<tr>
<td>Design friction coefficient for non concrete coated pipe</td>
<td>0.16 [-]</td>
</tr>
<tr>
<td>Maximum squeeze load using springs</td>
<td>Approx. 600 [kN/m]</td>
</tr>
<tr>
<td>Maximum squeeze load, springs blocked</td>
<td>Approx. 1000 [kN/m]</td>
</tr>
<tr>
<td>Type of drive</td>
<td>Electrical</td>
</tr>
<tr>
<td>Number of motors</td>
<td>4 [-]</td>
</tr>
</tbody>
</table>

### Movements and speeds

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed at maximum tension (lowering)</td>
<td>Approx. 30 [m/min]</td>
</tr>
<tr>
<td>Speed at maximum tension (pipe recovery)</td>
<td>Approx. 21 [m/min]</td>
</tr>
<tr>
<td>Speed in constant tension mode</td>
<td>12 average 21 maximum [m/min]</td>
</tr>
<tr>
<td>Vertical stroke of lower track</td>
<td>460 [mm]</td>
</tr>
<tr>
<td>Vertical stroke of upper track</td>
<td>2328 [mm]</td>
</tr>
</tbody>
</table>

### Weights and dimensions

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight of 1 assembly (tensioner)</td>
<td>Approx. 98 [mt]</td>
</tr>
<tr>
<td>Width</td>
<td>4500 [mm]</td>
</tr>
<tr>
<td>Length</td>
<td>7450 [mm]</td>
</tr>
<tr>
<td>Height</td>
<td>6600 [mm]</td>
</tr>
</tbody>
</table>

\(^1\) No of Tensioner: 3

Max Lay Tension: 3 * 100te = 300 Te

Max breakmode Tension: 3 * 217te = 661 Te

DeepLay Energy Services  
email: marketing@deep-lay.com
Samples Case of Flooded Case Study

DeepLay Energy Services  
email: marketing@deep-lay.com
### Static Pipelay Analyses - Nominal Case

<table>
<thead>
<tr>
<th>Water Depth (m)</th>
<th>Stinger Angle 1 (Deg)</th>
<th>Stinger Angle 2 (Deg)</th>
<th>Lay Tension (kN)</th>
<th>Bottom Tension (kN)</th>
<th>Touch Down Point (m)</th>
<th>Pipe Length (m)</th>
<th>Max Strain</th>
<th>At Stinger &amp; Ramp Bend (%)</th>
<th>React (kN)</th>
<th>Strain (%)</th>
<th>Separat (m)</th>
<th>React (kN)</th>
<th>Strain (%)</th>
<th>Separat (m)</th>
<th>React (kN)</th>
<th>Strain (%)</th>
<th>Separat (m)</th>
<th>React (kN)</th>
<th>Strain (%)</th>
<th>Separat (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000.00</td>
<td>20.00</td>
<td>19.10</td>
<td>1050.1</td>
<td>658.8</td>
<td>1836.93</td>
<td>324.20</td>
<td>0.24</td>
<td>0.05</td>
<td>87.5</td>
<td>51.9</td>
<td>162.6</td>
<td>162.6</td>
<td>0.211</td>
<td>89.1</td>
<td>201.0</td>
<td>88.9</td>
<td>0.203</td>
<td>0.00</td>
<td>87.1</td>
<td>0.202</td>
</tr>
<tr>
<td>1000.00</td>
<td>20.00</td>
<td>19.10</td>
<td>1075.1</td>
<td>683.8</td>
<td>1872.10</td>
<td>319.20</td>
<td>0.23</td>
<td>0.05</td>
<td>88.6</td>
<td>53.2</td>
<td>164.6</td>
<td>164.6</td>
<td>0.211</td>
<td>91.2</td>
<td>202.0</td>
<td>91.0</td>
<td>0.203</td>
<td>0.00</td>
<td>88.9</td>
<td>0.203</td>
</tr>
<tr>
<td>1000.00</td>
<td>20.00</td>
<td>19.10</td>
<td>1100.0</td>
<td>708.8</td>
<td>1907.08</td>
<td>314.50</td>
<td>0.21</td>
<td>0.05</td>
<td>89.7</td>
<td>54.6</td>
<td>166.6</td>
<td>166.6</td>
<td>0.212</td>
<td>93.2</td>
<td>203.0</td>
<td>93.1</td>
<td>0.204</td>
<td>0.00</td>
<td>90.7</td>
<td>0.203</td>
</tr>
<tr>
<td>1000.00</td>
<td>20.00</td>
<td>19.10</td>
<td>1125.0</td>
<td>733.8</td>
<td>1940.92</td>
<td>310.00</td>
<td>0.21</td>
<td>0.05</td>
<td>90.8</td>
<td>55.9</td>
<td>168.6</td>
<td>168.6</td>
<td>0.213</td>
<td>95.3</td>
<td>203.0</td>
<td>95.2</td>
<td>0.204</td>
<td>0.00</td>
<td>92.5</td>
<td>0.204</td>
</tr>
<tr>
<td>1000.00</td>
<td>20.00</td>
<td>19.10</td>
<td>1150.0</td>
<td>758.8</td>
<td>1973.97</td>
<td>305.60</td>
<td>0.21</td>
<td>0.05</td>
<td>91.8</td>
<td>57.3</td>
<td>170.7</td>
<td>170.7</td>
<td>0.213</td>
<td>97.3</td>
<td>204.0</td>
<td>97.3</td>
<td>0.205</td>
<td>0.00</td>
<td>94.3</td>
<td>0.204</td>
</tr>
</tbody>
</table>

**Static Dry at 1000m water Depth**

- The required Tension is below the max Tensioner Capacity
  - OK

DeepLay Energy Services

email: marketing@deep-lay.com
Sample Cases of Flooded Case Study

The required Tension is below the max Tensioner Break Capacity

OK

DeepLay Energy Services
email: marketing@deep-lay.com
Static Wet Buckle at Low DP Thrust for abandonment

The required Tension is below Winch Capacity OK
Flooded Case Load Check (Slay)

Beside the above, there is also Stinger Integrity Check, to make sure that Stinger and its connection does not fail structurally under the above accidental load.

DeepLay Energy Services
email: marketing@deep-lay.com
Terima Kasih