‘What If’ Scenario Testing of Deepwater Ropes - New Mooring Practices

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Lankhorst Ropes
Offspring International Ltd.

- Founded in 1991, over 20 years experience in the Offshore Industry
- Based in the UK with a branch office in the USA, and agents worldwide
- Worldwide sales & marketing agent for Lankhorst Ropes – Offshore Division
- Industry leading, single point mooring and deepwater mooring projects
Agenda

• Deepwater Mooring
• Rope Testing
• Rope Installation Offshore
• New Pre-Tensioning Regime
• Implications for Deepwater Mooring
• Implications for FPSO Mooring
• Conclusions
Deepwater Mooring

• Typically in water depth over 800m with ‘next generation’ ultra-deepwater moorings planned for 3,000m

• Mooring line - up to 1,200m chain / wire / chain, over 1,200m lengths of synthetic fibre rope, connected by shackle / H-links with short lengths of top chain and anchor chain

• Mooring configuration taut leg - lines anchored to sea-bed - small footprint - well suited to cluttered seabed
Deepwater Mooring

Tahiti Spar

4,200 ft (1,280m)

1,063 ft (324m)

6,670 ft (2,030m)

Houston - JP Morgan Chase Tower, 1,002 ft (305m)

Seabed
Offshore Mooring – Installation Vessels

- Complexity and engineering of deepwater moorings – specialist installation sub-contractors
- Dedicated offshore installation vessels
- Cost of Installation rising as moorings go deeper
- Vessel day rate’s driving changes to mooring deployment methods.
Rope Installation Offshore

• Pretension to remove bedding-in stretch
  • Historical from Noble Denton Engineering Design Guide JIP
  • 40% pre-tension in original version of API 2SM

• Typical pre-tension scenario
  • Load up to 10% - 15% MBL as lines connected
  • Load up to 40% MBL and hold for 3 hours
  • Relax to 15%

• Now an industry “mindset” rather than an option
Rope Installation Tensioning

- Elastic deformation during installation
  - Pure elastic
  - Delayed elastic
  - Permanent extension (bedding-in)
Platform Mooring – Rope Performance

Before Storm

During Storm
Elastic Rope Behaviour

Manufacture Rope Length = 1,935m

Load to 40% MBL. New Length 2,035m

Reduce Load to 15% MBL. Post Installation Length = 2,000m

Storm Load to 60% MBL. Total Length 2,070m

Immediately After Storm. Length = 2,000m
Tension approx. 8% MBL

Several Days After Storm. Length = 2,000m
Line Tension approx. 12% MBL

Note: Estimated values (not tested) for Lankhorst Ropes.
Fibre Rope Testing

- Fibre Rope Stiffness characteristics dictates that rope testing is essential.

- Lankhorst rope test machine
  - Up to 4.5m stroke
  - Maintains peak load within 10kN
  - Wave frequency simulation
  - Calibrated to Class 0.5 (ISO 7500-1:2004)
Current Testing Regime

• Higher MBL ropes, >2,500 T → safety issues and significantly higher installation costs. New installation methodology required and new test methods to simulate.

• Beyond capacity of existing rope test machines.

• Current rope test methods: Not representative of real life.
  I. Monitor change in length (from extensometer) when holding at a fixed load.
  II. Monitor change in load due to a change in pin to pin displacement (which is distorted and un-representative of a long continuous length due to the splice and eye effects).
New Testing Regime

Software modifications required to control test machine from extensometer data output.

• New testing regime: monitor change in tension (load variation) when tether is recovering at a fixed length following storm or other environmental event.
• More representative of rope performance in-service
New Pre-Tensioning Regime

• Two installation scenarios:
  • 40% MBL, reduced to 10% MBL post-installation
  • 30% MBL, reduced to 15% MBL post-installation
  • Alternative options without loading to 40% MBS

• Effect of 30% MBL
  • Post-installation stiffness reduced
  • Maximum storm offset increases
  • Safer and easier to achieve the pre-tension

• Effect of 15% post-installation MBL
  • Higher tension 'shortens' rope length → minimise maximum offset
  • Exposure to 40% MBL (storm) → additional permanent extension → restore to 10% MBL after storm
New Pre-Tensioning Regime

- Series 1
- 50 percent
- 10 percent
- 40 percent
- 30 percent
- 20 percent

Force [%] vs. Extension [%]
New Pre-Tensioning Regime

40% pretensioning down to 10% mean tension. Same line length achieved if use lower 30% pretensioning held at 14% mean tension.
40% pretension down to 20% mean tension, same line length if 28% pretension held at 28% mean tension.
Implications for Deepwater Mooring

• Variable loads at fixed rope length:
  • Pre-tension to 40% loading not essential
  • Perform 'what-if' scenarios, comprising series of lower pre-tension tests to simulate lower installation loads. Allow nature to perform the bedding in of the rope during storm conditions. Compensate for additional bedding in by calculating rope change in length and having higher initial post installation load.

• Smaller installation vessels can be used

• No need for pre-installation tensioning
Using the new methodology to moor an FSO/FPSO

- Bow-mounted, turret moored FPSO, at 1,600m water depth

- 20 mooring lines: ground chain – fibre rope – surface chain

- 5 lines in 4 clusters

- Traditional approach:
  - Pre-tension lines individually to 40%
  - Then pass to FPSO.
  - Needs specialist vessels
  - Time consuming and expensive
Using the new methodology to moor an FSO/FPSO

• Alternative approach: Connect all 20 mooring lines and use FPSO to pre-tension lines by ballasting and de-ballasting. Assume 12m change in draft between full ballast and de-ballast.

• Assume On-board winch has 20% MBS capacity rating.

• Pre-tensioning sequence:
  • Winch tensioning at max. draft
  • Deballast to minimum draft hold for 3 hours
  • Ballast to maximum draft
  • Re-tension lines on winch
  • Repeat until installation complete
## Pre-tensioning an FSO/FPSO

<table>
<thead>
<tr>
<th>Action</th>
<th>Line length (m)</th>
<th>Chain length (m)</th>
<th>Total line length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hook up all 20 mooring lines using the extra 50m of chain.</td>
<td>1715</td>
<td>550</td>
<td>2265</td>
</tr>
<tr>
<td>If 15.4m of chain is inboard on all lines, then the nominal tension in each line will be 10% MBS</td>
<td>1735.4</td>
<td>534.6</td>
<td>2270</td>
</tr>
<tr>
<td>Ballast vessel to max. draft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pull in 21.1m of chain on each line - Increases tension to close to 400T on each line = winch max. capacity.</td>
<td>1756.5</td>
<td>513.5</td>
<td>2270</td>
</tr>
<tr>
<td>Deballast vessel changing draft by 12m. Stretch tethers by 17m. Tension increase to approx 550T.</td>
<td>1773.5</td>
<td>513.5</td>
<td>2287</td>
</tr>
<tr>
<td>Hold for 3 hours - Tension will drop to approx. 500 T. (similar to stretching 7.5m but line lengths fixed).</td>
<td>1773.5</td>
<td>518.4</td>
<td>2291.9</td>
</tr>
<tr>
<td>Ballast vessel, line contraction of 17m and tension will drop to approx. 250T.</td>
<td>1756.5</td>
<td>518.4</td>
<td>2274.9</td>
</tr>
<tr>
<td>Pull in as much slack as possible using 400T winch. Should get to optimum line length of 1770m.</td>
<td>1770</td>
<td>500</td>
<td>2270</td>
</tr>
<tr>
<td>Deballast vessel changing draft by 12m. Stretch tethers by 17m. Tension increase to approx. 700T.</td>
<td>1787</td>
<td>513</td>
<td>2300</td>
</tr>
<tr>
<td>Hold for 3 hours. Tension will reduce to approx. 600 T.</td>
<td>1787</td>
<td>513</td>
<td>2300</td>
</tr>
<tr>
<td>Deballast to normal operating draft. Assume 6m change in draft = 9m line length. Tension reduce to approx. 400T (20%)</td>
<td>1778</td>
<td>500</td>
<td>2278</td>
</tr>
<tr>
<td>Line lengths are correct for long term mooring.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After some time - Storm hits vessel increasing tension to 40% MBL for 3 hours or more.</td>
<td>1803</td>
<td>500</td>
<td>2303</td>
</tr>
<tr>
<td>Storm subsides.</td>
<td>1770</td>
<td>500</td>
<td>2270</td>
</tr>
</tbody>
</table>
Improved Deepwater Mooring

- Pre-tensioning rope based on variable loads at fixed rope length

- Necessitates more rope testing at start of project, but benefits of:
  - Safer (Lower) Installation Loads
  - Capital cost reduction – smaller and cheaper chain tensioning systems.
  - Option of smaller installation vessels.
  - Faster Installation time
  - Reduced installation costs
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Thank you – Any Questions?

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