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Top Tensioned Riser Challenges and Solutions for Dry Tree Facilities in Asia Pacific

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Presentation Agenda

1. Objectives
2. Top Tensioned Riser (TTR) Selection Drivers
3. Critical TTR Design Aspects
4. Riser Modeling and Analysis Challenges
5. Implications for TTR Design for Asia Pacific
6. Conclusions
Presentation Objectives

1. To present selection drivers for TTRs and dry tree floating production

2. To demonstrate the key design aspects for TTRs and how they influence riser design and installation

3. To highlight some of the key issues for TTRs in the Asia Pacific Region and compare against the use of TTRs in other regions
Why select a TTR?  
Influence of Facility Selection Drivers

1. Benefits of Dry Tree Unit + TTRs
   - Ability to drill &/or complete &/or workover from host
     • Wet tree unit higher OPEX (MODU workover) traded for dry tree unit higher CAPEX - drilling & W/O Rig
   - Ability to manage reservoir risk

2. However, DTU facility selection requirements:
   - Reservoir(s) accessible from single host
   - Pipeline infrastructure or storage (no DTU storage)
   - Risers need to be technically feasible
Key TTR Design Drivers

1. Riser Weight

- WD
- Des. Pressure
- No. Casings
- Materials
- Completion

- Inner Casing typ. designed for Shut-in Pressure
  5ksi to 10ksi => ≈ 60% weight increase
- Outer casing typ. designed for collapse
  5,000 -> 10,000ft => ≈ 35% increase in outer casing WT

- Tensioner / can size
- Riser cost
- DTU Capacity
- Wellbay dims.
- Installation
2. **Tension and Stroke:**
   - **Tension**
     - Determines tensioner capacity or
     - Determines Air Can size (length/diameter)
   - **Stroke**
     - Determined by facility motions and
     - Tensioner stiffness or buoyancy can dims.

   Also affect:
   - Hull and well-bay dimensions
   - Installation (size of can, offshore lift etc)
   - Cost (of tensioners/facility)
TTR's
Key Design Drivers

- TLP (or Semi)
  - Direct Acting Hydro-pneumatic (typically)
- Spar
  - Direct Acting Hydro-pneumatic tensioners
  - Buoyancy Cans – weight not taken on hull
TTR Critical Design Aspects
Riser Tension

1. Provide Sufficient Riser Tension to
   - Avoid damaging buckling in any portion of the string (casings and tubing) during:
     • Installation, Production, Well control, Workover
     • Storm shut-in, Completion
   - Control fatigue damage in riser casings, tubing and ancillary equipment
     • Top Tension affects VIV and wave fatigue of riser
   - Avoid excessive stress under strength loads (Cyclonic storms etc)
Experience that Delivers

TTR Critical Design Aspects
Riser Tension

• Top tension conveniently described by a Top-tension Factor (TTF)
  – applied to apparent weight of riser
  – key parameter which defines the operational and other tensions for which the riser is designed
• For convenience, we work in terms of Effective Tension
  – a key indicator of riser global buckling stability
  – Negative effective tension induces buckling load
Based on Wall tension as below and considering effect of internal and external pressure in riser:

\[ Te = Tw - PiAi + PoAo \]

\[ = Tw - \text{Apparent Wt} \]

- concept provides for simple mathematical treatment of tension to analyse buckling
- +ve Te provides indication of riser (static) stability
- More complex consideration of Pi and Po for multiple strings (external p, annulus 1, annulus 2, tubing), but theory is similar
1. Initially Riser hanging-off from hook
2. Latch up at wellhead (or downhole) and overpull.
3. Above process for installation of outer casing, inner casing and tubing and final fit-up at tree.
4. Overpull accounts for all possible losses of tension without compromising global buckling stability of riser
   – during operation, workover and other conditions
   – including accidental (one or two tensioners / mooring line etc)
Important also to consider:

i. Poisson’s ratio effect on axial strain (longitudinal contraction under radial pressure expansion)

ii. Riser temperature effect on elongation & spaceout
   - Seawater temperature during installation
   - Production fluid temperature during operation

iii. Metocean conditions
   - Tidal elevation during each stage of installation
   - Environmental effects of current on spaceout

iv. Vessel conditions
   - Lateral offset of vessel affects riser stroke
   - Vessel draft condition affects riser spaceout

v. Final design elevation of tree relative to hull
Important to consider other effects (continued):

vi. Riser set down as inner casing or tubing is landed out in tree
- Landing in tree reduces tension as elevation drops
- Complexity of achieving correct fit-up at tree to ensure correct overpull of each of casings and tubing in service

vii. Completion design and downhole effects
- Landing force, thermal effects downhole, deviation of well etc.
- Tubing tension taken at packer
- Whether a mudline tubing hanger is used - reduces weight and stretch of riser, especially for deep well

Non-trivial; Consequence could be:
- excessive load in one of the casings in extreme load case
- helical buckling of tubing under hot production condition
TTR Design
Modelling and Analysis Challenges

• Aircans:
  – Guides through hull & keel are stick-slip friction interfaces
  – Fluid in enclosed well-bay produces (Froude-Krylov) forces on riser/aircan as well-bay seawater accelerates laterally
  – Effect of can pull-down on buoyancy for open-bottom cans

• Hydro-Pneumatic Tensioners
  – Effect of stroke on riser tension – requires stiffness curves

• Modeling Riser–Hull Guides
  – Compliant guides vs. gap - contact & slip-stick friction

• Composite vs. Multi-tube riser Analysis
  – Multi-tube model for analysis of individual riser strings
  – More complex FEA models for local analysis
TTR Feasibility for Asia Pacific

- TTRs a proven concept for Spars and TLPs. Several similar systems in GoM
- Challenge for large diameter production and export TTRs
  - radius limitations for top jumpers constrains
  - Export pigging may complicate
- Tensioners likely to be direct acting.
- Tubing and TTR jumper limits probably close to 7-inch.
  - Larger tubing affects inner casing tieback connector, outer casing wellhead connector, flexible jumpers, wellbay etc.
- SCR export may be preferred, especially if large diameter
  - Common in GoM TLPs and Spars
## Comparison of Metocean Conditions

<table>
<thead>
<tr>
<th>Location</th>
<th>Significant Wave Height $H_s$ (m)</th>
<th>Peak Period $T_p$ (s)</th>
<th>Significant Wave Height $H_s$ (m)</th>
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<th>Significant Wave Height $H_s$ (m)</th>
<th>Peak Period $T_p$ (s)</th>
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<tbody>
<tr>
<td></td>
<td>100 Year</td>
<td>1,000 Year</td>
<td>10,000 Year</td>
<td></td>
<td></td>
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<tr>
<td>Gulf of Mexico</td>
<td>15.2</td>
<td>16</td>
<td>17.0-20.0</td>
<td>17</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Brasil</td>
<td>7.6</td>
<td>13</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>North Sea</td>
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<td>18</td>
<td>-</td>
<td>-</td>
<td>19.5</td>
<td>20.0</td>
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<tr>
<td>West of Africa²</td>
<td>4.3</td>
<td>6-15</td>
<td>-</td>
<td>-</td>
<td>5.6</td>
<td>6-17</td>
</tr>
<tr>
<td>Australia</td>
<td>12.0-16.5</td>
<td>15</td>
<td>16.0-20.0</td>
<td>16.5-18.5</td>
<td>20.0-22.0</td>
<td>17.5-20.5</td>
</tr>
<tr>
<td>Malaysia</td>
<td>6.3</td>
<td>13</td>
<td>-</td>
<td>-</td>
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</tr>
</tbody>
</table>

Note 1. GoM hurricane conditions reflect the “updated” design conditions for hurricanes post 2004-5 storms.

2. WoA in Nigeria location - swell & sea components combined for $H_s$; individual $T_p$ values are presented.
### TTR Design Criteria

- **API RP 2RD Requirements**

<table>
<thead>
<tr>
<th>Design Factor</th>
<th>Operation</th>
<th>Extreme</th>
<th>Survival</th>
<th>Installation</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Yield Strength Allowed</td>
<td>67%</td>
<td>80%</td>
<td>100%</td>
<td>80%</td>
</tr>
<tr>
<td>Typical Design Environment</td>
<td>1yr</td>
<td>100yr</td>
<td>100yr-10000yr</td>
<td>~1yr</td>
</tr>
</tbody>
</table>
Design Storm Comparison between Regions

Experience that Delivers
Comparison of Fatigue Environments

<table>
<thead>
<tr>
<th>Location</th>
<th>Frequency of Occurrence for Significant ($H_s$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;1m</td>
</tr>
<tr>
<td>Gulf of Mexico</td>
<td>52%</td>
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<tr>
<td>Brasil</td>
<td>9%</td>
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<tr>
<td>North Sea</td>
<td>8%</td>
</tr>
<tr>
<td>West of Africa$^1$</td>
<td>22%</td>
</tr>
<tr>
<td>Australia – NW Shelf</td>
<td>3 - 35%</td>
</tr>
<tr>
<td>Malaysia</td>
<td>52%</td>
</tr>
</tbody>
</table>

Notes 1. Brasil/Australia swell an important contributor to fatigue
Comparison of Design Maximum Currents by Geographical Region

100 year Extreme Current Event Profiles

- Gulf of Mexico Loop
- Gulf of Mexico Near Bottom
- Offshore Brazil
- Western Australia
- Malaysia

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TTR Design for Deepwater Australia/Malaysia

- **Malaysia**
  - Lower extreme conditions may make operating conditions governing
    → importance of ambient metocean data
    → design code selection

- **Australia**
  - Onerous survival conditions (10,000yr) typically governing
    → high return period metocean data and reliability assessment

Both regions are relatively remote which creates issues with respect to:
- Pipeline infrastructure
- Demanning of platforms in severe storms
- Support vessel access
TTR Critical Design Aspects
General Conclusions

• **Importance of Tension Calculations**
  – Account for and reliably model all relevant factors that influence tension and riser elongation
  – Careful analysis to achieve operational tension factors on casings and tubing
  – non-trivial task, often under-worked

• **Important to reflect this in Installation**
  – Multi-disciplinary planning to ensure consistent procedures
    • Procedures must reflect what we designed
    • Wellhead elevation and spaceout measurement critical
  – Value of taking knowledge offshore for contingencies
TTR Critical Design Aspects
General Conclusions

• **Importance of Reliable Metocean Criteria**
  – Metocean studies need to be focused on governing conditions for design
  – Uncertainties in predictions can be important to consider
Thank you

Any questions?

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