HPHT - Subsea Design Challenges

J. McGrail

SUT - Subsea Communities - HPHT
Jan. 2011
HPHT - Subsea Design Challenges

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20th January 2011

Learn more at www.2hoffshore.com
Overview

- What is HPHT
- The subsea design problem
- Solutions

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Context - Challenges & Risks - HPHT

Courtesy: Dave Turner BP

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Where is the HPHT?

- North Sea,
- Norway,
- GOM
- Brazil (Sub Salt/Presalt)

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Deep Water

HPHT - The Design Problem?

HP
>10,000psi
Internal
Shut-in

HT
>121 Deg C Max
Operating Temp

Corrosive conditions

Problem Relative Magnitude

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How to Design for HPHT

- Bigger
  - Standard technology, just bigger
- Stronger
  - Higher strength materials
- More resistant
  - Improved corrosion resistance

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Bigger - Pipe Wall Sizing

10,000ft Water Depth, 300kg/m³ Fluid, 135 Deg C Design Temp
X65 Grade Pipe, 3mm Corrosion Allowance, 12 Deg Top Angle

Pipe Manufacturing Limit?
Bigger - The Knock-on Effects

- Extreme self-weight loads compound wall thickness requirements

- Results in loads at the limit of:
  - Installation vessels
  - Host production vessels

- Introduces fatigue issues from fluctuating axial loads

- Thicker walls
  - Impact pipe weldability
  - Increased cycle times
  - Reduced fatigue performance
  - Reduced pipe availability
  - Reduced flow area
Stronger: Increased Material Grade

- Stronger materials essential to maintain line pipe size feasibility for standard line pipe manufacturing processes
- Alternative is forged pipe – expensive and lack of availability
- But – weldability is a problem…….

- Example HP deepwater drilling riser sizing data below:

<table>
<thead>
<tr>
<th>Minimum Required Wall Thickness (mm)*</th>
<th>Water Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5000</td>
</tr>
<tr>
<td>Internal pressure (psi)</td>
<td></td>
</tr>
<tr>
<td>5000</td>
<td></td>
</tr>
<tr>
<td>OD (in)</td>
<td>13-3/8</td>
</tr>
<tr>
<td></td>
<td>16</td>
</tr>
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<td></td>
<td>19-1/2</td>
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<td>10000</td>
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<td>OD (in)</td>
<td>13-3/8</td>
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</tr>
</tbody>
</table>

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Stronger Flexible Pipe: Design Limits?

Flexible Pipe Present Range of Application

(Adapted from TECHNIP's Presentation at Dry Tree & Riser Forum)

• The 7.5-inch ID flexible pipe developed for water injection on Thunder Horse is a landmark as it established important records:
  Design Pressure (shut-in) = 10,000psi
  Design Water Depth = 6300ft (1920m)
  Allowable lifetime = 16.5 years (limited by sour service)

• More recently, Telemark 4-inch ID oil production flexible pipe has been developed for installation on:
  Design Pressure (shut-in) = 12,500psi
  Design Water Depth = 4500ft (1372m)
  Allowable lifetime = 20 years

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More Resistance: Corrosive Conditions

- HPHT = Internal corrosion problems

- HPHT wells often associated with corrosive / sour conditions:
  - CO₂
  - H₂S

- Sour service performance sensitive to:
  - Partial pressures of H₂S present, and pH of the production fluid
  - Stresses in the pipe
  - Material properties of the pipe – flaws/grain structure
  - Hardness of the steel

- Problem for high pressure, high strength steel, high load applications (i.e. HPHT scenarios)

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**CO₂ Corrosion (Sweet Corrosion)**

**Corrosion Rate vs Partial Pressure and Temp**

Heavy Pitting and General Wall Loss

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H$_2$S Fatigue Life: Reduction Factor 10-100

Source: High pressure riser designs for ultra deepwater; J. Murray et al,

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Material Selection

- **NACE**
  - Low alloy steels
- **Non NACE**
  - 13% Cr (410, F6NM)
  - Super Duplex
  - Inconel 625

Source: Oilfield Metallurgy – Lloyd-Thomas Consultancy

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Clad Pipe - Inconel 625 - Metallurgical or Mechanically Lined

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Installation: Large Wall Thickness / Cladding

- **Time / Cost:**
  - Installation is Majority of Pipeline / Riser CAPEX
  - 12-3/4” OD x 12.7 mm wt pipe joint
    - 45 minutes to weld, inspect and apply insulation field joint on
  - 12-3/4” OD x 40.0 mm wt pipe joint
    - 100 minutes
  - Clad pipe a further impact

- **Loads:**
  - Heavy pipe = large lay tensions
  - Demanding vessel specifications

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The HPHT Solutions - Materials?

Materials Technology – key requirement:
- Higher strength steels
  - 70-80ksi offshore weldable
  - 125ksi for use with mechanical connectors
- Cost effective base material cladding
- Development of alternative materials:
  - Titanium / Aluminium alloys
  - Composites

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The HPHT Solutions - Installation?

- More efficient offshore welding processes
  - Higher speed
  - Higher strength materials
  - Improved AUT and ECA capability for thick walled / clad pipe

- Friction welding?
- Electron beam welding?
- Laser welding?

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The HPHT Solutions?

- **Installation**
  - Greater lift / lay capacity for heavier pipelines and risers

- **Other Equipment**
  - HPHT qualification required for:
    - Flexible pipe – HT qualification program ongoing (150ºC target)
    - Flexible joints (HPHT containing)
    - Connection system & sealing technology (flanges, connectors)

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Summary

- HPHT is not a linear extrapolation, ‘bigger’ won’t work just on its own – Technology changes are necessary
- Material and welding technology is critical to success
- Alternatives to conventional welding are needed that are faster and can work with higher strength steel
- Alternative materials – lightness, strength and corrosion resistance
  - Composites
  - Titanium / Aluminium

- Alternatively........... Subsea HIPPS / subsea processing? Solve some of the problems away from long pipeline / riser sections

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Questions?

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