Mitigation and Control of Wellhead Fatigue

Workshop Geotechnical Input to Well Integrity Assessment
BP Helios Plaza Building (Houston)
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Overview

• Practical and Analytical Challenges in Wellhead Fatigue Determination

• (Real Time) Wellhead Fatigue Monitoring

• Wellhead Fatigue Mitigation Approach
Subsea Wellhead Fatigue

- Subsea wellheads subjected to fatigue load cycles when the riser is connected
- Extent of fatigue load dependent on environmental loading to the riser and the vessel
Assessment of Wellhead Fatigue

Vessel Motions:
• Sea States
• Vessel model (direct coupling or via RAOs)

Riser structural dynamic analysis:
• Input: vessel motions
• Boundary conditions (Soil Springs)
• Output: riser’s responses

Post-processing:
• Input: riser’s responses
• Output:
  • Strength unity check
  • Estimates of fatigue damage
Overview of Uncertainties

Geotech/Soil
- Shear Strength Variations
- Soil gaps / inhomogeneity
- Cement shortfall
- Soil modeling (py-springs, damping...)

Model
- Damping
- Model Simplification (e.g. Boundary Conditions...)

Environmental
- Design (Fatigue) Sea States
- VIV Currents

Damage per year (SCF = 1.0, FS = 1)

Fatigue Damage from Vessel Motions

- Upper Bound Soil Full Stiffness with no cement shortfall
- Upper Bound Soil 2/3 Stiffness with full cement shortfall
- Upper Bound Soil 1/2 Stiffness with full cement shortfall

Bin 2
Structural and Soil Damping
No Structural Damping
No Structural and Soil Damping
How Uncertainties will Affect

• Operation:
  − What is the Fatigue Life Remaining?
  − When is Inspection or Maintenance Required?

• Decision Making:
  − Design Life for Field Development
  − Life Extension of Equipment
  − Use of Alternative Equipment (e.g. Larger BOP?)

• Design:
  − Are Design Load Assumption Suitable or too Conservative?
  − Design Parameter Appropriate
Monitoring and Mitigation Strategy

Wellhead Fatigue Measurements

Build Data Base

Analysis Assessment

Operation
- Condition Monitoring: What is the Actual Fatigue Life Remaining?
- Variation of Design Sea State Conditions vs. Observations (Campaign Length)
- Actual Fatigue Damage Accumulation Rate vs. Prediction

Design
- Model Prediction vs. Observation (e.g., Soil Conditions, Sea State Loads, ...)
- Validation of Design Assumption
- \( \text{Actual Fatigue Damage Accumulation Rate vs. Prediction} \)

Decision Making
- Design Life for Field Development (Risk)
- Possibility of Extending Equipment Life for longer Activities or Larger BOPs (Cost/Risk)
- Faster Decision Making with near Real-Time Wellhead Data

OK -> No Action Required

Not OK -> Deploy TBOP
Current Challenges with Wellhead Monitoring

• Conventional motion monitoring performed using accelerometers attached to subsea components with the recorded data collected by ROV-recovery of the units in discrete campaigns of 2–3 weeks—hence all data is time lagged

• Operational decisions therefore often based on extrapolation of the pre-analysis results and not on actual data

• Real-time systems currently rely on use of cables to carry the high bandwidth data to surface for processing

• Cables can impact riser running and are susceptible to the major hydrodynamic
The purpose of a monitoring system is to measure directly the LMRP/BOP motions and transform these into nominal stresses.
Deployment Option

Flexible option for acoustic transceiver

- Over the side
- External deployment pipe
- Through hull penetration
Validation

TF Approach Frequency Domains:

- Calculate Damage in a direct Approach from Stress TH
- Use Transfer Function to Convert Acceleration to Stress and then Calculate Damage
Actual Fatigue Damage vs Design

- Comparison of observed fatigue to predicted fatigue (red vs. blue) covers conservatism both due to analysis uncertainty as well as met ocean uncertainty.

- Comparison of observed fatigue to Conditional Predicted Fatigue (red vs. green) eliminates the met ocean uncertainty and focuses all attention on the comparison of measured to predicted responses.

Measured data plotted in **RED** versus Prediction in **BLUE**
Support for Real Time Decision Making
Subsea Well Tethering System Overview

- **Objective**: Reduce fatigue in wellhead components by arresting movement of a BOP stack.
- **2013** – Proof of concept design and test (TRL 1 & 2)
- **2014** – Detailed design and SIT (TRL 3)
- **2015** – Production design and full order & TRL 4
- **2016** – 2 Deployments (North Sea & Caspian) working on TRL
Tethered BOP system

- BOP Interface:
  - Double Shackle (2)
  - ROV Hooks (4)
  - Load Pins (4)
  - Monitoring Screen (4)
  - Gravity Anchors (4)

- PTAs (5)
- Dyneema Rope (5)
Flexible BOP Interface

Recovery Padeyes
Display
Anode
Double Shackle
Battery
BOP Interface
Foundation types – Gravity Base vs. Pile
Technology Readiness Level (TRL): Testing

- Load Test
- Dynamic Test / Rope Stretch
- Submerge / Buoyancy
- Tension Monitor Test
- Pull Test
Technology Readiness Level (TRL): Analysis & Efficiency

Global Analysis:
- Quantification of Tether System Efficiencies in Terms of Fatigue Life Improvement
- Optimization of Tether Lines (Number of Lines, Locations, Length Stiffness, Orientation)
- Soil Sensitivity

Local Analysis:
- Strength and Local Fatigue Analysis for Design Check and Support
Fatigue Life Improvement

Fatigue Life vs. Tether Line Stiffness Factor

Untethered System

Tethered System
1.5" Dyneema (EA_{1.5})
80 days

Tethered System
2 x EA_{1.5}
1280 days

Tethered System
5 x EA_{1.5}
25600 days
Fatigue Results

Fatigue Damage @ 30 ft. below Mudline

Fatigue Damage @ 36 inch @ LPH

Summing up Fatigue Damage over Design Sea State Bin Results in

<table>
<thead>
<tr>
<th>Location</th>
<th>With</th>
<th>Without</th>
</tr>
</thead>
<tbody>
<tr>
<td>LP Housing at -30 ft.</td>
<td>133</td>
<td>7.5</td>
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Life - years
Questions?