Understanding Fatigue Risks (in wellheads...)

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Agenda

- Sources of fatigue
- Fatigue assessment
- Understanding risk
- Case study
Sources of Fatigue
Fatigue Sources: Wave Fatigue

**Vessel Motion**

The wave motion acting on the vessel. The vessel motion (RAO) then acts on the riser.

**Wave Loading**

The wave loading acts directly on the riser due to the drag of the riser system.

**High Damage**

Water depth <300m
Most commonly occurring waves Tp ~ 7s, Hs ~ 3m
Riser/BOP resonance
Fatigue Sources: VIV Fatigue

Current Loading
Current loading acting on a drilling riser causes vortex shedding. Vortices create pressure wave across structure.

Natural Frequency
VIV fatigue of concern when vortex shedding frequency matches one or more natural frequencies of the riser.

High Damage
Currents > 1 m/s  Water depth > 300 m
Small diameter risers  On-Off Effect
Riser/BOP resonance
Challenges for Existing Wells

- Design is fixed
  - Can not design-out fatigue through component selection

- Limited data
  - No records of the environmental loading history for the wellhead
  - Limited availability of equipment design and as-built data
  - Lost details of intervention operations performed
  - Unknown current condition, e.g. cement levels etc.

- Unconventional, lower-specification equipment
  - Relatively poor weld quality
  - Large SCFs at housing hotspots
  - Smaller conductors and non-rigid lock wellheads
  - Not designed for loads from larger, heavier modern BOP stacks with natural frequencies close to wave periods
Typical Points of Concern

Fatigue Critical Locations:
- Low pressure wellhead housing weld
- High pressure wellhead housing
- All additional welds for extensions, gimbal profiles, cement return ports, anti-rotation tabs, lifting lugs, etc
- Conductor connector welds
- Conductor connector
- Casing connector
- Casing connector

Typical Points of Concern

- Low pressure housing weld
- High pressure housing weld

Fatigue Life (Years)

Elevation from Mudline (m)

- HPH H-4 Profile: HS-Class, SCF 4.47, FoS=10
- Top Of HPH
- Top Of LPH
- Base Of LPH
- Mudline
- Conductor Seam Weld: B2-Class, SCF 1.0, FoS=10
- Casing Connector: B1-Class SCF 5.0, E-Class SCF 1.3 FoS=10
- Conductor Connector: B1-Class SCF 5.0, E-Class SCF 1.3 FoS=10

High pressure wellhead housing
Low pressure wellhead housing
Conductor
Mudline
Surface casing
Fatigue Assessment
S-N Curve Method

1. Test samples and quantify the number of stress cycles to failure at different stress ranges

2. Draw best-fit lines through the results (an S-N curve)

1. Generate a stress timetrace for the loads expected

2. Compare the number of expected cycles (n) to the allowable number of cycles (N) at each stress range

3. Add the results from all stress ranges to generate damage expected

4. Apply a safety factor to account for variability
S-N Curves

S (MPa) vs N

Mean curve
Design curve
Design Code Safety Factors

- To account for variability in loading
- To account for uncertainties in design data
- To ensure the probability of failure associated with the fatigue life result is appropriate for the activity
- Typically factors of safety between 3 and 10 are used in fatigue analysis, based on code guidance
Defining the Objective: Fatigue Life Requirement

- Need to assess current baseline of fatigue accumulation in installed equipment
- Residual 'fatigue life' must be sufficient for planned P&A

'Fatigue Life' = time with riser connected before the chance of a fatigue failure is higher than allowable
Background

- Abandonment operations planned for E&A well in the CNS
- Water depth 90m
- Wells drilled in mid 1980s with a 3rd generation semi-sub MODU
- Operations took place in winter and lasted 36 days
- Wells left temporarily suspended

- 3rd generation semi-submersible MODU to be used for P&A

- Analysis performed to calculate remaining fatigue capacity for abandonment operations

<table>
<thead>
<tr>
<th>Safety class</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Where failure implies low risk of human injury and minor environmental and economic consequences.</td>
</tr>
<tr>
<td>Normal</td>
<td>For conditions where failure implies risk of human injury, significant environmental pollution or very high economic or political consequences.</td>
</tr>
<tr>
<td>High</td>
<td>For operating conditions where failure implies high risk of human injury, significant environmental pollution or very high economic or political consequences.</td>
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</tbody>
</table>
Overcoming Old-Well Challenges

- Design is fixed

- Limited data
  - Dates of drilling campaign known, but no weather data
  - Hindcast data procured for period of previous operations
  - Data screened to extract extreme seas above disconnect limit
  - Daily drilling reports used to extract riser tension
  - Sensitivity analysis of cement shortfall – confirm lower bound

- Unconventional, lower-specification equipment
  - Manufacturer input to confirm fatigue details for known components
  - Load path response of critical components examined
P&A Fatigue Life Results

<table>
<thead>
<tr>
<th>Component</th>
<th>Unfactored Historical Fatigue Damage</th>
<th>Allowable Duration of Future Operations (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Firstly At &quot;Normal&quot; Safety Class</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spring</td>
</tr>
<tr>
<td>HP Housing</td>
<td>23.5%</td>
<td>0.0</td>
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<tr>
<td>Weld</td>
<td></td>
<td></td>
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<tr>
<td>LP Housing</td>
<td>27.6%</td>
<td>0.0</td>
</tr>
<tr>
<td>Weld</td>
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</table>

Central North Sea Abandonments
Allowable Duration of P&A Operations
Worst Case Well

Historical Operations

P&A Operations

DFF 10 "High" Safety Class
DFF 6 "Normal" Safety Class
DFF 3 "Low" Safety Class

Number of Days

Remaining Allowable Unfactored Damage

Summer
Winter
Analysis Informed Recommendations

Risk assess whether a “low” safety class is appropriate at the start of operations.

- Yes:
  - Proceed with operations with no further mitigations
  - Schedule P&As of onerous wells in summer months

- No:
  - Reconfirm SCF of HP and LP housing welds using old part numbers and procedures – likely to be available?
  - Proceed with P&A of less onerous well first, in summer months
  - Conduct structural monitoring to calibrate analytical model
  - Refine fatigue damage calculation for more onerous wells
Summary

- Fatigue analysis of subsea wells, prior to P&A, complicated by old equipment, lack of data.

- Codes define an acceptable level of fatigue usage depending on risk of operations.

- Informed selection of analysis methodologies and understanding of safety philosophies can give efficient and effective quantification of risk.

- Analysis results can form a key part of operational planning.
Questions?
Thank you

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