Establishing Operational Fatigue Limits for Intervention Risers

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Establishing Operational Fatigue Limits for Intervention Risers

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Agenda

• Background
• Riser Fatigue Life Assessment
• Monte Carlo Approach
• Case Study
• Summary & Conclusions
Motivation/Demand from Temporary Conditions

- **Operational conditions** e.g., completion/workover
- **Environmental conditions**: Wave/Current actuality vs. Metocean statistics
- Operations – Environment interaction
  - Operational disconnect in extreme weather
  - High day rates vs. risk of operation in extreme conditions

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Standardized Approach/Guidance

- No “one size fits all” approach for intervention risers
- Code guidance for strength assessment:

<table>
<thead>
<tr>
<th>Duration</th>
<th>Return Period</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;6 mo.</td>
<td>100yr</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>3 days – 6 mo.</td>
<td>10yr</td>
<td>$10^{-1}$</td>
</tr>
<tr>
<td>&lt;3 days</td>
<td>Most probable maximum</td>
<td></td>
</tr>
</tbody>
</table>

- **Design** for events with probability between $10^{-2}$ and $10^{-4}$ (accidental)

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Riser Fatigue Life Assessment

- **Limited guidance** for fatigue assessment
  - Riser fatigue sustained during an **extreme event**?
  - **Duration** of extreme event?
- Fatigue Damage Estimation can be done using
  - Long-term fatigue seastates (**probability of failure**) 
  - Long-term fatigue seastates (**factor of safety**)
- Typical probability of failure assessed: $10^{-4}$ to $10^{-6}$/year
- Typical factor of safety: 10
- **Directional** data (Waves from North, East or Southwest)

### Acceptable Failure Probabilities
(annual per riser vs safety class)

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Normal</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_f$</td>
<td>$&lt;10^{-3}$</td>
<td>$&lt;10^{-4}$</td>
<td>$&lt;10^{-5}$</td>
</tr>
<tr>
<td><strong>FoS</strong></td>
<td>2 to 3</td>
<td>6 to 7</td>
<td>10</td>
</tr>
</tbody>
</table>

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Riser Fatigue Life Assessment

• Challenges
  – Non-linear dynamic response
  – Excitation at a resonance
  – Heavy surface equipment
  – Aging infrastructure at the wellheads
  – Use of non-fatigue tolerant couplings and joints

• Solutions for Temporary Operations
  – Seasonal Metocean statistics
  – Monte Carlo simulations

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Monte Carlo Simulation

- Tool for managing **uncertainty**
- Uses **random** number generation
- Can be used to weight for seasonal variations

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Monte Carlo Simulation

Riser FEA Model (500 Nodes) => Seastates (100) => FEA Software => Fatigue Life [500 x 100] => Seastate Probability => Probability-Scaled Fatigue Life [500 x 100] => Location-Specific Total Fatigue Life [500x1] => Long-Term Fatigue Damage (Standard Approach)

- Identify Bin for each Fatigue Life
- Use Random Numbers to calculate Fatigue Life for trial seastates [500 x 72]
- Location-Specific Total Fatigue Life for Identified Period [500 x 1]
- Average/Statistical Norm of Location-Specific Measured Fatigue Life [500x1] => Compare Results For QA => Monte Carlo Approach

Repeat N=10,000 runs

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Case Study

- Riser model applicable to short-term intervention operations

<table>
<thead>
<tr>
<th>Direction</th>
<th>Probability</th>
<th>Minimum Fatigue Life (Years)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum</td>
<td>Head</td>
<td>Quarter</td>
<td>Bow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(100% Probability)</td>
<td>Aft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>35%</td>
<td>5.85</td>
<td>5.85</td>
<td>23.26</td>
<td>2.50E+10</td>
</tr>
<tr>
<td>Quarter Aft</td>
<td>35%</td>
<td>7.75</td>
<td>30.30</td>
<td>7.75</td>
<td>31.25</td>
</tr>
<tr>
<td>Beam</td>
<td>15%</td>
<td>9.01</td>
<td>1.48E+11</td>
<td>35.71</td>
<td>9.01</td>
</tr>
<tr>
<td>Quarter Bow</td>
<td>15%</td>
<td>6.76</td>
<td>27.03</td>
<td>7.41E+06</td>
<td>27.03</td>
</tr>
<tr>
<td>Total (Prob. Scaled)</td>
<td>100%</td>
<td>12.87</td>
<td>12.87</td>
<td>15.53</td>
<td>29.94</td>
</tr>
</tbody>
</table>

Important to account for directional variations

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Case Study

### Minimum Fatigue Life Along Riser

<table>
<thead>
<tr>
<th>Direction</th>
<th>Quarter Bow</th>
<th>Quarter Aft</th>
<th>Head</th>
<th>Beam</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability (%)</td>
<td>15</td>
<td>35</td>
<td>35</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>Fatigue Life (Years)</td>
<td>5.85</td>
<td>7.75</td>
<td>9.01</td>
<td>6.76</td>
<td><strong>12.87</strong></td>
</tr>
</tbody>
</table>

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Case Study

Monte Carlo simulations for fatigue assessment and factor of safety/failure rate determination

Monte Carlo Runs Probability Scaled Damage Probability of Exceedance
No. Trials = 72

Fatigue Life Vs Probability Of Occurrence
Monte Carlo vs Probability-Based Long-Term Fatigue Life

90% Non-Exceedance level

97.7% or $\mu+2\sigma$ Non-Exceedance level

Notes
1 Trial = 1 hr. of seastate
10,000 runs = $10^{-4}$ failure probability

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Summary & Conclusions

• A rational approach to determining fatigue damage based on Monte Carlo simulations for temporary operations is presented.

• Can be used to identify whether/not to proceed with operations.
  – For e.g., identify disconnect under extreme wave/current loads with minimal disruption.

• Approach requires minimal additional work.

• Account for extreme loads and seasonal/directional environment variations.

• Factors of safety and failure rates can be determined based on duration of operations.

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Guiding Codes & Standards

- API Spec 17G (DRAFT): Specification for Subsea Well Intervention Systems
- API RP 2RD (2006): Design of Risers for FPSs and TLPs
- API STD 2RD (2013): Dynamic Risers for FPSs
- DNV OS F201 (2010): Dynamic Risers
- DNV RP C203 (2011): Fatigue Design of Offshore Steel Structures
- DNV RP F204 (2010): Riser Fatigue

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Questions