Fatigue Monitoring and Life Extension for Top Production Riser Systems

Bulent Mercan, Mike Campbell – 2H, Clay Thompson – Occidental Petroleum

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Fatigue Monitoring and Life Extension for Top Tensioned Production Riser Systems

Bulent Mercan, 2H Offshore Inc.
Mike Campbell, 2H Offshore Inc.
Clay Thompson, Occidental Petroleum Corporation

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AGENDA

- Introduction
- Riser and Monitoring Systems
- Field Data Screening
- Impact of Top Tension
- Riser Fatigue based on Monitoring Data
- Conclusions and Recommendations

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INTRODUCTION

Challenges:
- Many TTRs installed worldwide more than 20 years ago are now reaching their design lives.
- The fitness-for-service assessment may require costly out-of-service inspections.

Potential Solutions for TTR Life Extension
- Conduct a risk-based assessment (developed as part of the TRACS JIP and discussed in a partner paper, Deka et al. 2021, OTC-31060-MS)
- Deploy a fatigue monitoring system to assure the long-term integrity (this paper)

Objectives of this work:
- To discuss the value of TTR field measurements and data analytics
- To show the impact of top tension on the TTR fatigue response using monitoring data

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A total of 6 TTRs are deployed from a spar operating in a water depth of approximately 5,000 ft.

Two of these TTRs are instrumented for this study.

TTR is a dual casing system consisting of a 12-3/4-inch outer casing and 9-5/8-inch inner casing.

The riser is tensioned using the upthrust provided by the buoyancy can and stem system.
RISER MONITORING SYSTEM

- Monitored two risers simultaneously for varying top tensions
- Installed 6 motion sensors on each riser
- Two monitoring campaigns are conducted for a total period of 18 days (2 days +16 days)
- The risers are filled with treated seawater
- Top tensions:
  - TTR1: 440 kips – 835 kips
  - TTR2: 545 kips – 675 kips

<table>
<thead>
<tr>
<th>Sensor Location</th>
<th>Water Depth (ft)</th>
<th>TTR-1</th>
<th>TTR-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Stem Pipe</td>
<td>545</td>
<td>517</td>
<td></td>
</tr>
<tr>
<td>450 ft Above Stress Joint</td>
<td>4,513</td>
<td>4,516</td>
<td></td>
</tr>
<tr>
<td>300 ft Above Stress Joint</td>
<td>4,663</td>
<td>4,669</td>
<td></td>
</tr>
<tr>
<td>150 ft Above Stress Joint</td>
<td>4,813</td>
<td>4,817</td>
<td></td>
</tr>
<tr>
<td>Bottom of Stress Joint</td>
<td>4,963</td>
<td>4,965</td>
<td></td>
</tr>
<tr>
<td>Wellhead</td>
<td>4,979</td>
<td>4,978</td>
<td></td>
</tr>
</tbody>
</table>
MOTION SENSORS

- Standalone (battery-operated) sensors
- Magnetically attached by ROV
- Each sensor records data continuously
- Logging at 10 Hz frequency
- Measure 3D accelerations and 2D angular rates

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DATA SCREENING

- Perform sensor validation
- Calculate the RMS accelerations for all sensors
- Correlate the RMS accelerations with the field operations and environment
- Conduct spectral analysis for each event
- Identify VIV and wave dominant events

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**RISER ACCELERATION STATISTICS**

- Both risers show comparable motions below the stem pipe
- Accelerations near the bottom are higher than those below the stem pipe
- Wellhead and bottom stress joint accelerations are negligible

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• Riser motions are in a good agreement with wave height measurements
• Measured riser response is dominated by wave induced effects
RISER RESPONSE IDENTIFICATION

Acceleration Spectra Indicating Riser VIV response

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TTR-1 accelerations near the bottom reduce by around a factor of 2 when the top tension increases from 440 kips to 835 kips.

For the same wave height, higher tension setting results in less scattered measured riser motions.

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RISER FATIGUE METHODOLOGY

• Derive transfer functions in frequency domain by performing dynamic analysis for different seastates or modes;

• Relate measured riser accelerations at a sensor location with bending moments along the riser using transfer functions;

• Derive fatigue damage using bending moment PSD and fatigue details (e.g. SN curves and SCF values);

• Suitable for the cases in which the riser is subjected to both wave and VIV effects.

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FATIGUE METHODOLOGY

Bending moment PSD is used to calculate bending moment histogram by means of Dirlik’s method

\[ G = \frac{(\Delta t)^2}{T} \left| \sum_{i=1}^{n} e^{-i\omega n} \right|^2 \]

\[ M_n = \sum_{k=1}^{m} f_k^n G_k(f_k) \partial f \]

\[ P(S) = \frac{D_1 e^{-\frac{Z}{Q}} + D_2 Z e^{-\frac{Z^2}{2R^2}} + D_3 Z e^{-\frac{Z^2}{2}}}{2(M_0)^2} \]

- \( G \) the power spectral density
- \( T \) the time
- \( \Delta t \) the time step of the logger (1/f)
- \( n \) the number of data points
- \( \omega \) the angular frequency
- \( M_n \) the \( n \)th spectral moment
- \( f \) the frequency
- \( m \) the number of frequency points

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Higher fatigue damage rates occur largely for the low tension periods.

For TTR-1, the fatigue damage rate reduces by a factor of approximately 10,000 after tension increase.

For TTR-2, changing top tension from 545 kips to 675 kips results in a reduction on fatigue damage rates by a factor of 10 on average.
CONCLUSIONS AND RECOMMENDATIONS

• Most of the TTRs are currently reaching their design lives and there is limited industry guidance addressing their life-extension programs.

• Riser monitoring can provide assurance for the system performance and integrity in service.

• Monitoring data considered in this study show that TTR fatigue can be highly sensitive to top tension provided by the air can during the service life of the riser.

• It is recommended to track the in-service operating tension of the risers as it is a key input for any life extension assessments.

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Acknowledgements / Thank You / Questions

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