SCR Response and Monitoring

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Presentation Structure

1. Introduction

2. Previous Allegheny SCR Monitoring

3. Recent Back Analysis

4. Future SCR Monitoring Recommendations
1 - Introduction to Integrity Monitoring and SCR Fatigue
SCR Design is Driven by Fatigue and Weld Defects

- Risers are dynamically loaded welded structures using high strength steel with thick walled pipe
- All welds contain defects and SCFs. Defects grow and eventually propagate
- Integrity relies on:
  - Achieving weld quality through specification, testing & inspection
  - Accurate knowledge of riser response and weld load history
Monitoring and Riser Integrity Management

MONITORING STRATEGY
- R&D – benchmark software
- Confirm validity of design assumptions
- Optimise IMR
- Optimise operational windows
- Identify design and installation errors
- Early identification of problems – prevent failure

COMBINED SYSTEM APPROACH
- Riser design & analysis
- Electronics & Instrumentation
- Signal processing and back analysis
Recent 2H Monitoring Programs

- **SCR**
  - Agip Allegheny, 600m GoM (x2)

- **Drilling Risers**
  - BP Sakalin 100m
  - BP Algodoal, Brazil, 1300m
  - BP Rebecca and Reki, Brazil, 1000m
  - BP Schiehallion, WoS, 360m
  - BP Svinoy and Assynt, Faroes, 1000m
  - Total Donggalla HP Drilling Riser 1800m
  - Thunder Horse Enterprise (1800m)

- **TTR**
  - BP Holstein (1800m)
  - Conoco Magnolia
  - BP Mad Dog

- **Completion Riser**
  - BP Thunder Horse Enterprise CWOR1 (1800m)
  - BP Thunder Horse PDQ CWOR2 (1800m)

- **Pipe Spans**
2 - Allegheny SCR Monitoring
Full Scale Riser Monitoring - Allegheny

- 12” diameter simple catenary gas export riser
- 3300ft (1005m) GoM
- Atlantia Seastar mini TLP
- ADCP current data to 650m
- Wall thickness of 0.688” (17.48 mm)
- Departure angle of 12°
- Hang-off position at 25 m below MWL
- Strake fitted along the top 580 ft of the riser
- Strake height 0.16 D, pitch of 15 D

- Instrumented by 2H August 1999 - 13 loggers
- Low cost (<$250k)
Allegheny - 2H ROV Retrievable Loggers

- Mk I triaxial accelerometers
- GRP holders
- Anti-fouling coating
- Logger ROV retrievable/installable
- Sampling 10Hz, 20min/6 Hrs
- 192 hours of data / logger
STRIDE JIP Phase II - Allegheny Riser Monitoring

ALLEGHENY GAS EXPORT LINE MEAN INSTALLED POSITION

Distance Along Seabed (m)

- TOP 8 DATA LOGGERS SPACED OVER 760FT
- BOTTOM 3 DATA LOGGERS SPACED OVER 120ft

Distance Above Seabed (m)

- Strakes
- ADCP
- Loggers

Allegheny Gas Export SCR
Eddy Juggernaut - January 2000
Current And Direction Data

- Current data from ADCP system on Atwood Hunter.
- Focus on period between 28/12/99 and 5/1/00
- Currents 1 - 1.8 knots
- Currents from East
- Gas SCR aligned at 30 degrees East from North.
- Out of plane current on riser
RESPONSE SUMMARY (From Stride)

<table>
<thead>
<tr>
<th>Date</th>
<th>A/D &lt; 0.2</th>
<th>Small or no response</th>
<th>Small response</th>
<th>Wave induced response</th>
<th>VIV response</th>
<th>Mixed Response</th>
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<tbody>
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<td>19-Nov</td>
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<td>06-Jan</td>
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<td>10-Jan</td>
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</table>

**Graphical Representation:**
- **<C1>:** Small or no response
- **A/D < 0.2:** Small response
- **<C2>:** Wave induced response
- **<C3>:** VIV response
- **<C4>:** Mixed Response

**Graphs:**
- Top graph: Speed [knots]
- Bottom graph: Direction [deg]
Original Allegheny Conclusions

- Actual response much lower than predicted by Shear7
- Predicted frequencies higher than measured
- Strake system appears more efficient than expected
- Variation in current direction through the water column may cause a damping effect
3 - Recent Allegheny Back Analysis
Allegheny VI V Monitoring - FFT Spectra

- FFT Post-processing of Event timetraces is conducted to identify potential VI V Activity

Accelerations measured by logger attached to vessel indicate wave activity

VI V Activity at 3 Distinct Frequencies
Allegheny VI V Monitoring - Spectrograms

- Spectrograms are generated to ascertain whether VI V event is multimode or single mode

Event: 533 Pod: 008
Maxima Spectrogram

Allegheny Event 533 - Magnitude of Peak Response vs. Frequency

MULTI MODE
Allegheny VI V Monitoring - Spectrograms

- Spectrograms are generated to ascertain whether VI V event is multimode or single mode.

Event: 001 Pod: 008
Maxima Spectrogram

Allegheny Event 1 - Magnitude of Peak Response vs. Frequency
Allegheny VIV Monitoring - Strake Efficiency

- Measured current speeds and excited frequencies are compared using a Strouhal number relationship to identify expected excitation velocity.
- Results show current speed at or immediately below strakes is too high to excite riser frequencies measured.

![Comparison of Current Velocity with Expected Excitation Velocity](image)

- **Current Velocity at strakes much higher than expected excitation velocity**
- **Excited frequencies are as a result of currents between 0.2m/s & 0.4m/s**
Allegheny VI V Monitoring - Strake Efficiency

- Current profiles indicate that the expected excitation velocity is mainly found below straked region.
- This indicates that the strakes are damping the VIV effects of the high surface currents.
- Current speeds between 0.2-0.4m/s (0.4-0.8kts) are generally found at or below 250m depth.
Mode Shape Matching is conducted by comparing accelerations from gravity contaminated theoretical mode shapes and the logger accelerations for each logger location.

Poor correlation is obtained if all logger positions are used.

Much improved matching can be obtained by ignoring TDP logger accelerations due to:
- Theoretical mode shapes do not consider trenching / TDP Shift
- Event spectra show a degree of damping at TDP, theoretical mode shapes assume constant amplitude oscillation
• Mode shapes matched for Event 553 – A significant Allegheny Event due to high velocity loop currents occurring over this period.

Allegheny VIV Monitoring
Modal Accelerations
Event 553, Gravity Contaminated Modes

Note: Modes are absolute
• Good correlation is found for modes 17 and 18, Mode 16 only matches for half of the upper loggers due to mode switch between $x/L$ of 0.8 and 0.85
• Mode 16 is seen to switch to Mode 15 without a change in excitation frequency
To correlate TDP Loggers, theoretical mode shape accelerations from top loggers are extrapolated to seabed and compared with TDP Logger Accelerations.
Trends indicate change in TDP position, possibly as a result of SCR Movement on seabed or trenching.

Theoretical mode shapes are shifted by 15m to reflect this.

### Allegheny VIV Monitoring
#### Modal Accelerations

**Event 553, Gravity Contaminated Modes**

- **Mode 16**: 0.27Hz Logger Response
- **Mode 17**: 0.29Hz Logger Response
- **Mode 18**: 0.31Hz Logger Response
Event Spectra shows significant damping at the TDP for mode 18
- Possibly due to seabed interaction or redistribution of power between modes
• Mode 18 Amplitude is reduced by half to show effect of damping, all modes correlate well
Allegheny Back Analysis using SHEAR7

- Preliminary Analysis - SHEAR7 Parameters
  - St Code 200 (Strouhal number approx. 0.25)
  - Strake Lift reduction factor of 0.25, based on strake efficiency identified
  - Preliminary SHEAR7 predicted results show riser exciting modes 20/21/22
  - Strouhal number sensitivity shows that a Strouhal number of 0.195 excites modes 16/17/18 as identified by mode shape matching

<table>
<thead>
<tr>
<th>Mode</th>
<th>Measured Response Frequency (Hz)</th>
<th>SHEAR7 Frequency (Hz)</th>
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</thead>
<tbody>
<tr>
<td>16</td>
<td>0.270</td>
<td>0.288</td>
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<tr>
<td>17</td>
<td>0.290</td>
<td>0.310</td>
</tr>
<tr>
<td>18</td>
<td>0.310</td>
<td>0.332</td>
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</table>

Excitation Frequency Comparison
Allegheny Back Analysis using SHEAR7

Current profiles are only measured down to 300m above seabed
VIV Amplitude shows good match to measured logger response
Sensitivity analysis conducted with assumed bottom currents show further improvements due to increased damping

<table>
<thead>
<tr>
<th>Mode</th>
<th>Amplitude of Vibration (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measured Response</td>
</tr>
<tr>
<td>16</td>
<td>0.31</td>
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<tr>
<td>17</td>
<td>0.16</td>
</tr>
<tr>
<td>18</td>
<td>0.18</td>
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</table>
**Allegheny Back Analysis using SHEAR7**

- SHEAR7 shows that VIV excitation is caused by fast, sheared currents below straked region.
- Current directionality is perpendicular to SCR, ideal for out of plane VIV activity.

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- MWL: 992m
- Mode 18: 822m
- Mode 17: 780m
- Mode 16: 754m
- Mode 16: 717m
- Mudline: 0m
- Current Data from MWL to 298m above Mudline

Allegheny Summary

- Wave induced and Current induced VIV identified
- VIV mode shapes matched based on upper loggers
- Results used to identify shift in TDP position and its sensitivity
- Efficiency of strakes found from current profile comparisons
- SHEAR7 calibrated based on findings
- Accurate comparisons between SHEAR7 and measured amplitude, mode and frequency
Lessons Learnt

- Batch processing conducted previously is prone to missing critical events and understanding nature of response
- All events that do not show signs of VIV activity must be removed to identify trends
- Accurate current profiles are crucial for back analysis
- VIV excitation of SCRs is highly dependent on current direction and riser-seabed interaction
- Multimode activity may only occur for a fraction of the logged event
- Impact on damage estimates must be better understood
4 - Recommendations for Future Monitoring
How is Response Best Measured?

- Global response required **not** local response

- 10-15 locations minimum along riser

- Motions are as good as stresses (Accelerations and Rotations)
  - Non intrusive - Does not need contact with steel pipe
    - No corrosion problems
    - No thermal problems
    - No sealing problems
    - Reduced procurement complexity
  - Good reliability and can be replaced or moved to different locations
  - Small size and low weight for ease of deployment
  - Does not drift and are not effected by pipe temperature
  - High sensitivity to capture actual response
  - Low component cost and overall system cost
## Logger Specification - High sensitivity / Low Power

<table>
<thead>
<tr>
<th>Sensor</th>
<th>RMS Electrical Noise Level</th>
<th>Minimum Resolution</th>
<th>Measurement Range</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Typical</td>
<td>Best</td>
<td>Typical</td>
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<tr>
<td><strong>Accelerometer</strong></td>
<td>0.03</td>
<td>0.002</td>
<td>0.006</td>
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<tr>
<td>(m/ s²)</td>
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<tr>
<td><strong>Angular Rate</strong></td>
<td>0.06</td>
<td>0.0035</td>
<td>0.003</td>
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<tr>
<td>(deg/ s)</td>
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<tr>
<td><strong>Inclinometers</strong></td>
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<td>0.003</td>
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<td>(deg)</td>
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</table>
ROV Installed Loggers and Brackets
Recommended Monitoring Approach

- Carefully plan how data will be processed prior to implementation
- Ensure suitable logger design with respect to sensitivity, noise
- Optimise logger locations and logging schedules
- Data for fatigue does not need to be online – annually is OK
- Conduct instrumentation simulations to confirm approach
- Appreciate complexity of signal processing
- Use processed data to calibrate analysis and recalculate fatigue life
- Short term monitoring (1-2 years) feasible / acceptable
- Stand alone loggers retrieved annually is acceptable for TDP fatigue
- Hardwired loggers at upper flex joint gives useful real time data
- At least one riser on every development should be instrumented
Summary and Conclusion

- SCR technology is not as mature as many people would like to think and is generally more complex.
- Shear7 getting better – and we able to drive it better.

**More measured data is required**
- Characterise response
- Benchmark software
- Improve design guidelines and design factors
- Feed into IMR and integrity management

- Monitoring does not need to be too complex or expensive – keep it simple!
- Collaboration eg through JIP or Deepstar is cost effective and increase breadth of data base.
- Good potential for further ‘data mining’ of existing data.