LINKING SEABED TO SURFACE
How Deepwater Riser Monitoring Technology can Improve Knowledge of Mooring System Performance

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Criticality of Riser and Mooring Systems

- There are typically two critical systems that link the seabed to the surface, in floating drilling and production facilities:
  - Riser systems, which are critical in terms of hydrocarbon containment
  - Mooring Systems, which are critical in terms of facility station-keeping

- Riser and Mooring System design is built around complex mathematical analyses, based on numerous assumptions

- Designs are quite often marginal with respect to strength and fatigue, particularly in deeper water

- Achieving confidence in the adequacy of the analytical response predictions is key to ensuring integrity of Risers and Moorings

- Deepwater experience and operational data is relatively limited
Riser and Mooring System Analysis

• The accuracy of analysis results is dependant upon:

  ➢ The ability of the software to adequately solve the problem (software solution capability) and correctly model complex boundary conditions
  ➢ The accuracy of the assumptions inherent within the computer models (e.g. waves and currents, drag coefficients, inertia coefficients, damping parameters, etc)
  ➢ Accuracy of design assumptions regarding vessel motions, environmental data, produced fluids etc

• The above assumptions are subject to considerable degrees of uncertainty, any of which may have a dramatic effect on the accuracy of predictions

• This can lead to over-design (and probably higher than necessary cost), or under-design (and possible failure)
Riser and Mooring System Loads

- Loading on risers and moorings may comprise a complex combination of:
  - Drag loads due to currents, varying through the water column
  - Drag and Inertia loads due to waves
  - Wave Frequency vessel motions (first order motions)
  - Slow drift vessel motions (second order motions)
  - Wind Forces
  - Vortex Shedding
  - Thermal loads
  - Pressure loads
  - Etc

- One of the key inputs to any mooring or riser analysis is environmental wind, wave and current data

- This will typically be based on statistical analysis of available weather information

- This environmental data will be a key analysis input and may require a large number of load cases to be considered

- The actual conditions that do occur may well be somewhat different to the predicted data, used in the design process

- There is significant volume of evidence to indicate that we are not particularly capable in predicting environmental data (e.g. the 2005 hurricanes in the GOM)
Riser and Mooring System Considerations

• Significant considerations may include:

  ➢ Vessel motions
  ➢ Wear
  ➢ Corrosion (global and pitting)
  ➢ Effects of sour service on weld performance
  ➢ Structural overload
  ➢ Fatigue endurance uncertainty (e.g. weldments, stress concentrations, S/N curves, connectors, fracture performance etc)
  ➢ Fairing and strake performance (VIV Suppression)
  ➢ Fabrication quality and ability to detect significant defects
  ➢ Installation damage
  ➢ etc


**Local and Global Response Monitoring**

- Monitoring of Riser and Mooring Systems has three objectives:
  - To establish if the actual local responses occurring in the field, for known combinations of loading, are within those predicted by analyses (KPI – Key Performance Indicators)
  - To collect data that allows the global response to be determined and correlated with predictions, and the data to be fed into integrity management processes
  - Determine and log the accumulation of fatigue damage with time, and ensure that the fatigue capacity of the systems are not exceeded

- Riser and mooring system response is complex

- Responses at critical locations are often difficult to accurately predict

- Preferred Monitoring approach
  - Monitor local response at key locations in the system
  - Determine predicted global response using analytical domain
  - From global response determine predicted response at critical locations
  - Compare critical location response with analytically derived Key Performance Indicators
Monitoring System Specification and Design

• In order to gain benefit from a riser (or mooring) monitoring system, it must be suitable for the intended purpose

• To achieve this the following must be clearly understood:
  - Structural design and hardware in the system to be monitored
  - Expected responses of system to be monitored
  - Aims of the monitoring system

• Monitoring system design must ensure that:
  - Sufficient data is captured at the appropriate locations, so that global response can be determined
  - Not interfere with operations/installations or itself impact the global response
  - Suitable storage and/or transmission method(s) are included
  - Data processing methods (to extract responses from recorded information) are clear and achievable
Monitoring Similarities

• In many respects, mooring and riser analyses and responses are similar.

• Consequently, many of the measuring, data processing and back-analysis methods can be common.

• Riser monitoring is now becoming more commonplace and routine.

• A range of monitoring equipment, and data processing techniques, have been developed for riser systems.

• There is no reason why monitoring could not be similarly commonplace on mooring systems.
Monitoring Approach

1. Design/Analyse Mooring/Riser System
2. Define Monitoring Needs
3. Specify Monitoring System
4. Install Monitoring System
5. Capture Raw Response Data
6. Store Raw Response Data
7. Analyse Raw Response Data
8. Review Measured Responses
9. Compare With Predictions
10. Identify Discrepancies
11. Modify Analysis Assumptions
12. Back Analyse
13. Refine Response And Fatigue Predictions
14. Refine Future Assumptions
15. Take Actions Necessary In the Field
Recent/Current Monitoring Programs

- Steel Catenary Risers
  - 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)
  - Atlantis DDII (1800m)
  - Thunder Horse PDQ (Underway)
- Top Tensioned Risers (Production)
  - BP Holstein (1800m)
  - Conoco Magnolia
  - BP Mad Dog
- Completion Risers
  - BP Thunder Horse Enterprise CWOR1 (1800m)
  - BP Thunder Horse PDQ CWOR2 (1800m) (Underway)
What has been learned (so far) from riser monitoring?

- A number of conclusions relating actual to predicted responses – typically project specific – very useful for analysis calibration
- Design tools can overestimate fatigue damage, possibly by between 10x to 100x
- Identification and successful resolution of serious issues arising through design/installation phases
- Rapid confirmation of system integrity following (possibly unexpectedly) extreme storm events
- Data fed into optimised (and therefore cost effective) Integrity Management programs
- Increased confidence in ongoing riser integrity
How can System Responses be measured?

- Strain Measurement - Strain gauges, Fibre Optic gratings, Fibre Optic curvature mats, etc. Main issues are
  - Location on pipe surface – interface issue with coatings
  - Reliability – sealing, bonding fatigue, wire damage, calibration

- Riser Flexjoint/Balljoint angles – applicable to drilling risers

- Motion Measurement - Accelerometers, Inclinometers, Angular Rate
  - Non intrusive, corrosion resistant, easy to seal/install
  - Highly reliable
  - Cost effective
  - Small weight and size – possible to deploy and recover by ROV
Preferred Data Gathering Options

- “Simplistic” Methods, using stand alone motion measurement data loggers
  - No online data
  - Data non synchronised
  - ROV recovery required
  - Onshore data processing
  - Lowest costs and simplest interface
  - Good for fatigue monitoring

- Comprehensive Online Monitoring
  - Online data and offshore processing
  - Data synchronised or partially synchronised
  - Installation impact – needs to be fitted when system installed
  - Highest cost
  - Rapid use of data e.g. after a storm
  - Assistance with operational decisions
Stand Alone Instrumentation – Main Issues

• Lowest cost solution
• Rapid mobilisation
• Minimum offshore impact
• Provides essential data
• 2H Capability / Scope
  • Pre-analysis
  • Appropriate sensor selection
  • Optimised monitoring plan
  • Riser interface design
  • Installation & offshore support
  • Data and signal processing
  • Reporting and Conclusions
Typical Drilling Riser Monitoring

1 logging location on the Vessel

5 logging locations on the 4th, 5th, 6th, 7th, 8th joints

1 logging location on the LMRP
ROV Installed Loggers and Brackets – BP Holstein/Mad Dog
Mooring Chain Angle Monitoring

- Ease of diver attachment
- Angle measured using accelerometer
- ADXL203
- Angle resolution <0.1deg
- Tension resolution typically 1-2Te
- Instrument error <0.5%
- System error ~0.5% (due affect of waves)
- Total error ~1% (for 95% seastates)
- Worst case error <5% (averaged min/max)
- Catenary or taut leg
Mooring Chain Dynamic Tension Monitoring
Summary

• The benefits of riser monitoring are starting to be realised, these being:
  - Unexpected responses have been discovered and understood, resulting in improved analyses
  - Responses have been correlated to back-analyses, reducing assumption uncertainty for future work
  - Cases of overload, which might have gone undetected, have been identified

• If monitoring programmes are to be successful, then:
  - The monitoring needs to be well planned and implemented
  - The response(s) to be monitored must be well defined and understood
  - The monitoring equipment needs to be capable of capturing the required responses
  - The storage and/or transmission capabilities of the monitoring system must be adequate
  - Data processing requirements need to be identified, planned and resourced into the project
  - Back-analysis requirements need to be identified, planned and resourced into the project
  - Conclusions from the back-analysis results need to be well documented, communicated and incorporated into future work
Summary (cont’d)

• Much of the experiences from riser monitoring could be equally well applied to mooring monitoring
• Riser monitoring equipment and techniques are available, and are becoming increasingly field proven
• Such techniques and equipment could equally well be applied to mooring monitoring
• Mooring monitoring could become a more routine operation, in the same way that riser monitoring is becoming more routine at the present time
• The benefits that mooring monitoring would produce are:
  ➢ Verification of present analysis methods
  ➢ If present methods cannot be verified, new methods could be developed
  ➢ Improved predictions of extreme responses
  ➢ More reliable mooring systems
  ➢ Ability to “predict” when mooring maintenance is necessary