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Drilling Riser Conductor Monitoring: A Practical Approach for Operational Integrity Verification

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Abstract

With an increase in the number of drilling operations in harsh environments and ultra deepwater, combined with the limited availability of drilling rigs and qualified personnel, it is increasingly important to maximize safety and operability while minimizing structural damage to the riser, wellhead and conductor system. Great efforts to improve drilling equipment, safety features and overall structural integrity of drilling riser systems have occurred in recent years. Subsequently, trends have shifted the focus of integrity concerns from the drilling riser onto the wellhead and conductor system. The integrity of the wellhead and conductor system is of utmost importance – as it provides a vital barrier to contain hydrocarbons and drilling mud inside of the drilling system. A structural breach of this system could have catastrophic consequences and must be avoided at all cost.

Significant challenges remain in accurately predicting and tracking actual fatigue damage on wellhead and conductor systems. This papers details the findings of several monitoring campaigns designed to track the actual vibration of the BOP and LMRP stack due to riser VIV, and its contribution to wellhead and conductor strength and fatigue concerns. The measurements have been used to provide operational guidance, validate design tools and thus provide a more realistic fatigue and strength data set for wellhead and conductor systems.

The paper will discuss the monitoring application including state of the art sensor systems with practical attachment systems that can be retrofit installed via ROV or diver. Furthermore, is discusses data processing methodologies and software with the aim to provide operational guidance to the drilling team (while providing uninterrupted continuation of drilling operations). Furthermore, detailed engineering studies are presented that correlate conductor fatigue as a function of drilling riser VIV and stack excitation. Two case studies illustrate the application of these technologies.

Through research findings and field application, this paper summarizes the operational benefits of an integrity monitoring systems for the wellhead and conductor system from an operator perspective. The target is to increase the understanding of Drilling Riser VIV and its effect on the wellhead and conductor systems. This provides assurance to the operator that the system has not been compromised during a specific drilling campaign and that any risk and uncertainties have been captured and has been evaluated.

Introduction

The purpose of structural monitoring is to provide objective understanding of structural asset integrity, and improve operational efficiency. This is achieved through the use of monitoring instrumentation and software installed offshore, followed by data processing and management of the recorded data. Operators can then better understand the forces experienced by drilling systems, and make informed decisions about fatigue life.

The wellhead system is exposed to significant loads that are imparted into the well conductor from the environment loading of the vessel and the drilling riser system. The cyclic loads driving the wellhead systems include:

- Wave driven vessel surge and sway motions that are transferred to the drilling riser
- Wave driven direct hydrodynamic loading on the riser
- Vortex-induced vibration (VIV) of the drilling riser

While the drilling riser is connected to the wellhead system, these dynamic loads are transferred from the drilling riser to the wellhead system. Excessive fatigue accumulation may lead to the failure of the wellhead systems [1]. Fatigue damage generally accumulates at certain critical points (known as fatigue hotspots) which include certain welds and connectors from the base of the wellhead housing to a depth of 10-15m below the mudline.

Subsea wellhead and conductor systems are critical environmental barriers which prevent discharge of hydrocarbons and drilling fluids to the environment during drilling operations. These systems are subject to cyclic lateral loads from the connected drilling riser, due to a number of environmental factors listed above. In addition, as availability of both wellhead systems and drilling rigs is limited, configurations that are less than ideal are often selected for drilling campaigns due to these supply constraints. These can include:

- Semisubmersibles in shallow water (< 500m)
- Jack-ups in “deep” water (> 80m)

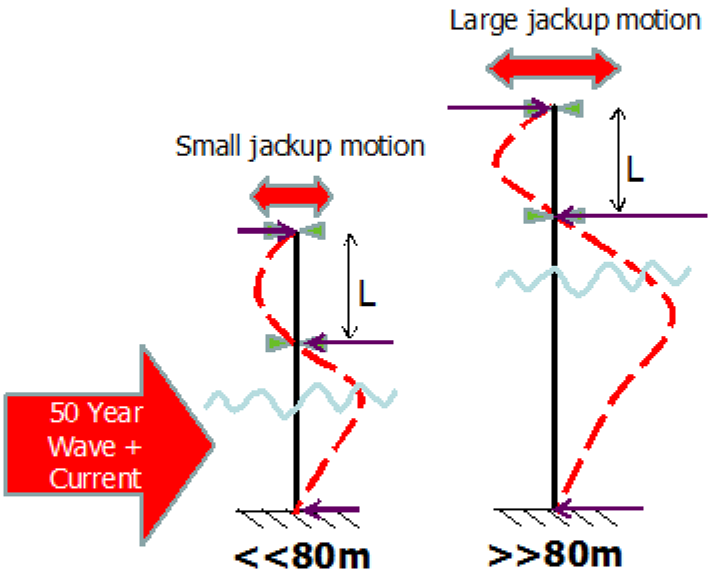

Figure 1 - *Jackup Limitations in “Deep” Water*

Offshore drilling operations have been completed successfully for several decades. However, the industry is facing deeper water depths and harsher environments, updated regulatory requirements, increasing size of BOP stacks with the 5th and 6th generation drilling rigs and increasingly complex completions. As a result, conventional wellhead systems are frequently found to show poor fatigue response in analytical predictions based on the conservative input data. Therefore, an additional method of instilling confidence in analytical predictions and managing integrity of the wellhead system is required. Real world monitoring provides key data to calibrate models and predict accumulated fatigue, as opposed to relying solely on analysis.

To implement a monitoring campaign, various types of sensors are installed to capture structural response.

Motion Monitoring Sensors

Motion monitoring systems are most commonly used in assessing structural integrity of key critical components of the riser, wellhead and conductor system. Motion sensors using combination of three axis acceleration and two axis angular rate sensors are distributed along the riser system and distributed such that the response of the riser and wellhead conductor can be independently measured and verified.

The sensors are deployed either directly during riser run or conveniently using ROV (Remotely Operating Vehicles). Figure 2 shows motion sensors deployed on the BOP/LMRP stack, and Figure 3 shows a motion sensor deployed on the low pressure housing both using ROV friendly magnetic holders.

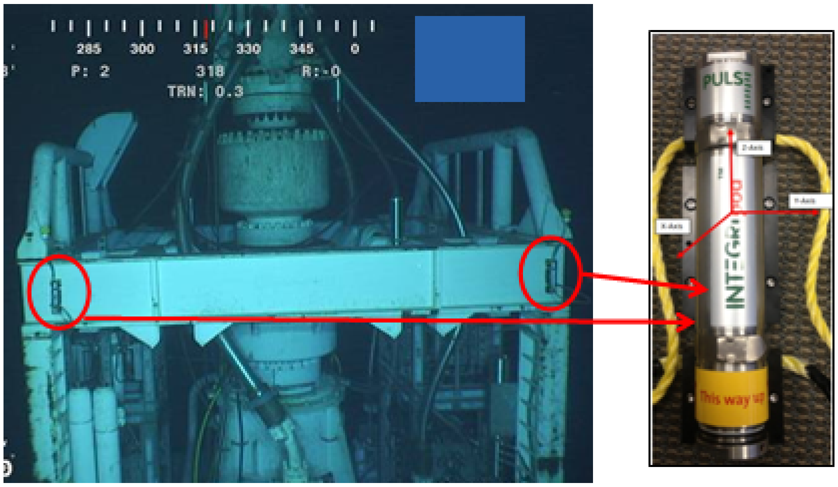

Figure 2 - *Motion Monitoring Loggers Deployed on BOP/ LMRP*


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Figure 3 - *Motion Monitoring Loggers Deployed on Low Pressure Housing*

In addition to motion monitoring instrumentation, strain monitoring sensors are also utilized to directly monitoring the strain of riser and drilling system components.

Strain Monitoring Sensors

The advantage of the localized strain measurement system is that it eliminates the assumptions required for modal response prediction from the motion sensor data, such as damping coefficients. Measuring strain directly requires minimal data post processing and provides accurate strain range and amplitude frequency information. A simple rain flow calculation can be used to determine accurate fatigue damage rates and total accumulated fatigue damage of any riser system component. Thus directly monitoring the strain at fatigue critical locations is advantageous in conjunction with motion monitoring systems. Basic strain measurement systems consisting of bonded foil type strain gauges have been successfully used for drilling riser monitoring systems, however; the surface preparation application requirements for bonded strain gauges are difficult to achieve in a production drilling environment. Therefore, this application may not always be suitable. Alternatively, an off the shelf strain sensor system may be considered. The strain sensors may be mounted at critical locations in order to capture the strain response of fatigue critical areas. A typical strain sensor application used on production drilling riser is shown in Figure 4. To capture the smallest dynamic curvature changes, the strain stick measurement resolution is +/-2 Micro strain. This high sensitivity allows capture of the smallest anticipated bending moment the riser will experience.

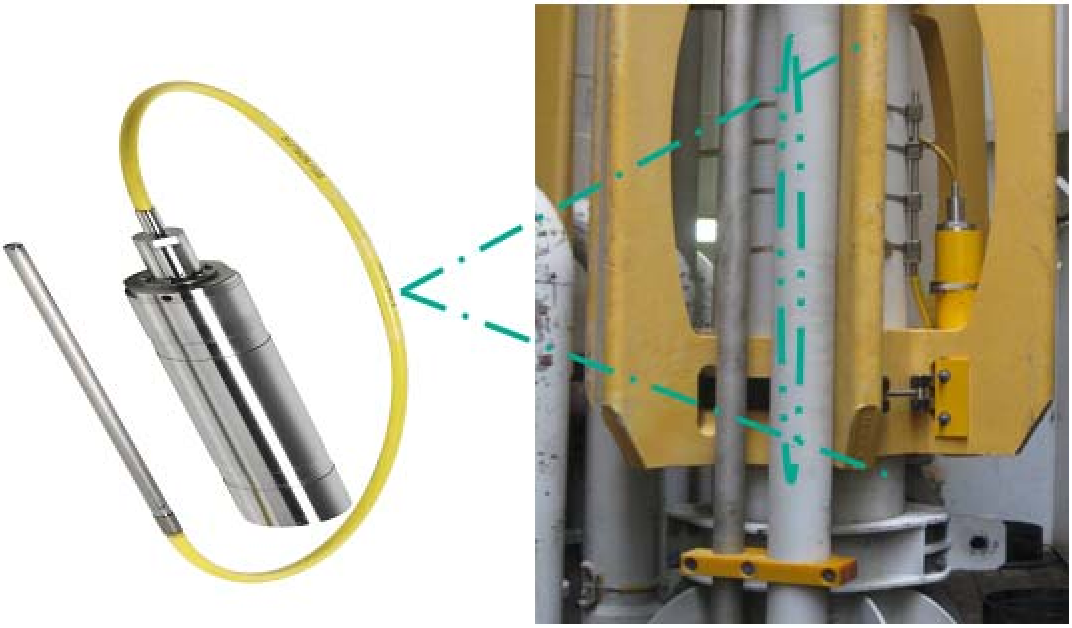


Figure 4- *Dynamic Strain Monitoring on Drilling Riser*

Once motion and strain measurements have been taken, sound communication methods are essential to ensure transmission of the data back topsides.

Communication Methods

In order to conduct safe and controlled drilling operations, many operators, as part of their Integrity Management (IM) program, require instant or on demand availability of monitoring data of the drilling riser and conductor system. As determined by the overall monitoring strategy and requirements for data availability, it is recommended to clearly define and specify the preferred communication method. Table 1 shows available communication strategies along with consideration factors.

Communication Protocol	Qualification Level [API]	Robustness	Data Availability	Installation Requirement	CAPEX
Standalone	Qualified [TRL7]	high	After Retrieval	low	low
Hardwired	Low [TRL3]	medium	Continuous	high	high
Acoustic / Optical	Low [TRL3]	medium	On Demand	medium	high

Table 1 - *Comparison of Communication Strategies*

Basic standalone systems require sensors that have self-contained power and on-board memory - these sensors have proven to be robust and have been successfully deployed for many years with great success. The drawback of this assembly is that the sensors have to be retrieved via ROV, or upon retrieval of the drilling riser to access the data. Operational decisions cannot be made without first retrieving and processing the data. This approach is the most cost effective CAPEX (capital expenditure) option, and is recommended for drilling applications that require long-term fatigue tracking in benign areas.

Hardwired or “real-time” monitoring systems have also been successfully deployed on drilling risers, but this system is the most expensive in terms of CAPEX. However, it provides advisory information to rig personnel in real-time and minimizes OPEX (operating expenditures) since it does not require ROV time. Two options for hardwired solutions are available:

- Independent cable that is installed and clamped to the riser or choke and kill lines during the riser run
- Use of the existing MUX cable systems that are used to provide power and communication to BOP pressure, temperature and other vital drilling parameters

Both options require careful planning during the specification stage and strong focus on installation constraints. Consideration regarding benefits versus risks has to be taken when deciding which communication strategy to employ.

Acoustic and or Optical communication system have been in use in the offshore drilling industry such as Dynamic Position Systems (DPS) for years. Currently, strong efforts are being undertaken to incorporate integrity monitoring systems into this existing infrastructure. The benefits of this system are not requiring installation of a hardwired cable, and providing data availability on demand. The limitations in the amount of data able to be transmitted acoustically require that each instrument process measured data into power spectral density or basic statistical information. An acoustic or optical transponder then uploads the information topside. Full data sets are stored locally in each MDL and upon recovery or via optical link with the ROV recovered or downloaded in full. Careful consideration needs to be taken to the system design, architecture and overall integration into existing communication system to satisfy required monitoring strategies and defined KPIs.

After the data has been successfully communicated topside, effective software interfaces and robust data processing approaches are needed for valuable conclusions to be drawn.

Data Processing and Software Interfaces

Wellhead and conductor system fatigue presents critical risk during the drilling operation. Determining fatigue from environmental loading is necessary for risk management and confirmation of the long-term fatigue integrity of the drilling riser, wellhead and conductor system. The goal of the monitoring system is to establish wellhead and conductor fatigue response based on BOP and LMRP measurements. The subsea component of the monitoring system comprises of accelerometer and angular rate sensor near the top of BOP frame and strain sensors on conductor, as shown in Figure 5.

Post processing of the measured data in both the time and frequency domain allows for the source of the motions to be identified as wave-induced or VIV. The amplitude of the measured motions is then processed into stress range and combined with number of cycles measured to obtain fatigue accumulation. The measured motion response also allows for the analysis model’s calibration.

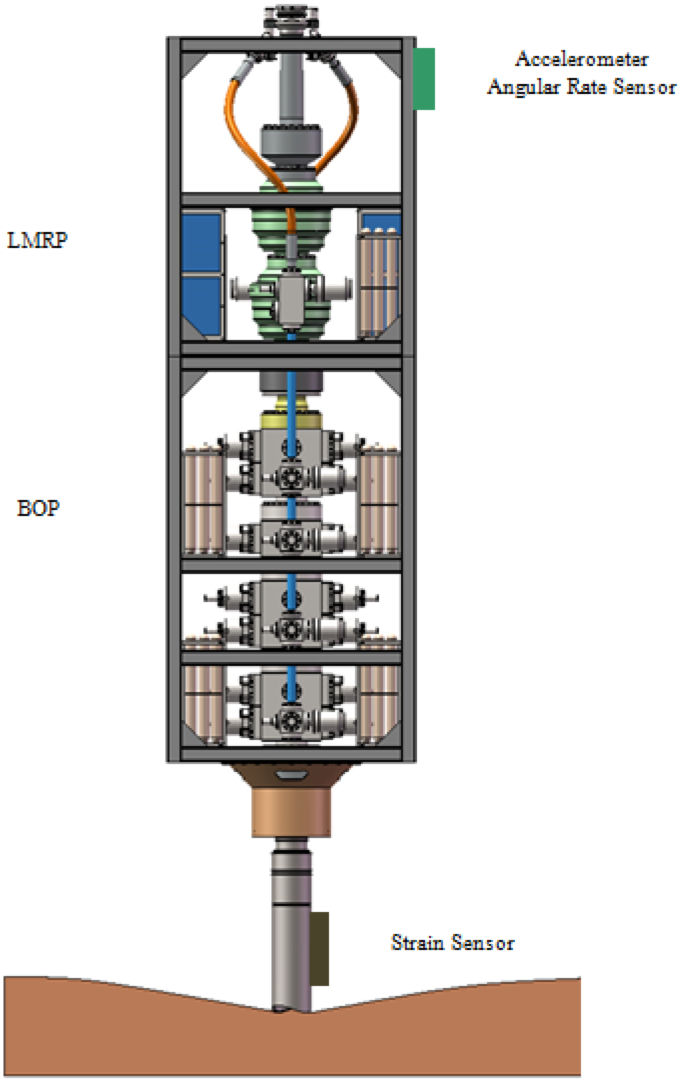


Figure 5 – *Example Monitoring System*

The accelerometer allows stress calculation anywhere along the conductor pipe with the use of finite element (FE) model. Bi-plane angular rate sensor is used to calculate the dynamic angles with respect to the vertical and subsequently is used to remove the gravity component from lateral acceleration data obtained from tri-axial accelerometer. Overall data processing flow chart is shown in Figure 6.

Figure 6 – *Data Processing Flowchart*

Six (6) degrees of freedom motion processed from field measurements are applied to FE model of BOP stack and conductor to determine the stress at critical locations along the conductor. Strong correlation between top of LMRP acceleration and bending stresses on critical location on conductor are observed, as shown in Figure 6. Based on bending moment stress, time histories and stress histograms are generated by rainflow cycle counting method and fatigue damage is calculated for each histogram bin using the S-N curve design approach.

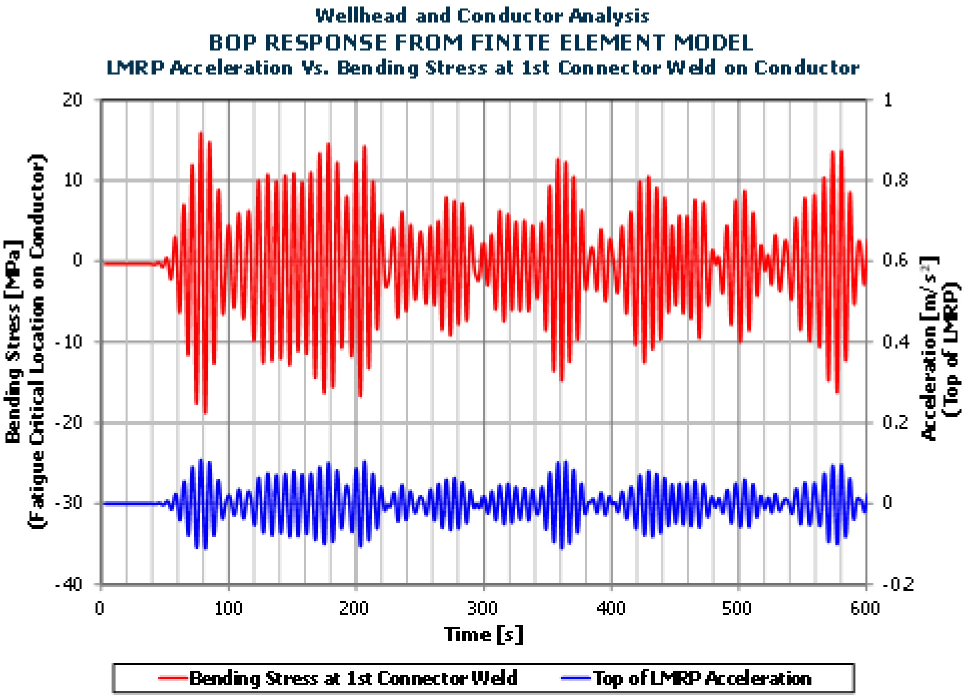


Figure 7 – *BOP Response and Conductor Bending Stress*

Strain sensors measure local bending strain of the structure where it is installed. This strain measurement can be converted into stress and from there, fatigue damage can be computed. Hence, if a strain sensor is installed on the conductor (above mudline) then the fatigue damage of the conductor at the sensor position can be computed directly. This requires that the soil stiffness and wellhead and conductor system be accurately modeled to achieve stress values at the fatigue critical locations on the conductor using a FE model. By using the strain sensor data on the wellhead system, the FE model can be calibrated. This calibration data can be used to refine the structural property of the wellhead and conductor system. The refined model can then be used to obtain the stress value at the fatigue critical location when the system is driven by the actual motion obtained from motion sensors. This stress value will be used to generate the fatigue damage at the fatigue critical locations. Furthermore, the soil stiffness can also be calibrated using the strain sensor data.

In summary, the advantages of having both accelerometer and strain sensor systems are as follows:

- Stress calculation anywhere along the wellhead and conductor using angular rate and accelerometer motion data applied onto finite element model
- Finite element model calibration using strain data
- Direct strain measurement for fatigue damage computation at the wellhead
- Soil stiffness calibration

Overall, wellhead monitoring and structural fatigue analysis captures and evaluates any risks and uncertainties and ensures the structural integrity of the wellhead and conductor system during drilling operations.

The measured data is useless unless it can be converted into information that can support day to day as well as long term decision making. Specially designed software as shown in Figure 8 collects and analyses the data from the sensors and a local display on the vessel can show measured performance in relation to pre-defined KPIs. Real time data can be communicated with shore based management to help with high level decision making and may also be stored locally to allow for further analysis and aid with the future calibration of wellhead fatigue models.

Figure 8 – *Example Software with Drilling Specific KPIs*

Thus far, this paper has presented the components and methodologies of an integrity monitoring system for the wellhead and conductor system. In the following two case studies, examples of field applications of these systems are provided to demonstrate the benefits from an operator perspective.

Case Study 1

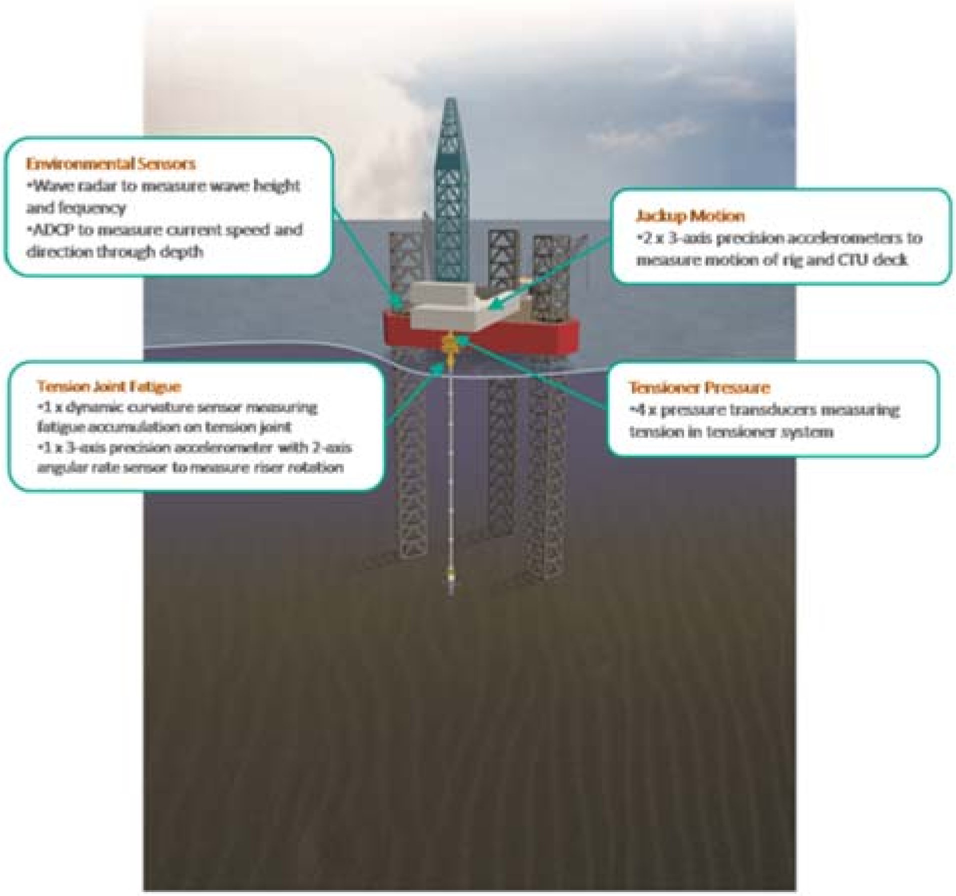
When a major upstream oil & gas company began development drilling and completion activities in the UK North Sea, the 300ft (91m) water depth meant the jackup was nearing the limits of its operational capabilities. Operating the rig near its limit resulted in reduced safety margin in the structural integrity of the jackup rig, the riser and the subsea wellhead than would normally be experienced.

A full bore, 24inch OD high pressure riser was used to drill and complete the wells on the field development. Engineering and analysis of the HP riser and wellhead completed prior to drilling showed that as a consequence of large motions of the jackup platform during service, the HP riser was subjected to high loads, high stresses and high levels of fatigue damage accumulation over one year of operations. Further, the rig was subjected to high loading at the interfaces to the riser equipment. These presented a number of potential structural integrity threats to the riser, along with additional threats identified through risk assessment.

In view of these findings, in addition to operating guidance for the riser based on weather forecasts, the drilling operator decided to implement a riser integrity management system (IMS) using structural monitoring as part of this to measure in-situ riser response data. A key objective of the system was to provide data to allow for verification and calibration of the analysis model used as a basis for design decisions, and also to ensure that the integrity of the riser is maintained throughout the drilling and completing activities. To achieve this objective, a range of “key performance indicators” were monitored including Jackup motion, CTU stroke range, CTU rotation range, CTU deck lateral load, riser tension (and CTU deck vertical loads), riser maximum bending moment, riser fatigue damage, wave height and current speed.

Monitoring System

The monitoring system provided was made up entirely of instrumentation placed above the water line. This allowed for quick and easy installation and decommissioning of the equipment, as well as avoiding the need to run subsea cables which are prone to damage. As no subsea instrumentation is present, the predictions of subsea response are inferred from the topside equipment based on the analysis model. Since the instrumentation was located in a safety critical region within the CTU deck area, it was required to be zone 1 rated and therefore installed in EExd rated housings. The system, the first online monitoring system to be installed on a jackup, consisted of four main components:



Environmental Sensors
- Wave radar to measure wave height and fequency
- ADCP to measure current speed and direction through depth

Jackup Motion
- 2 x 3-axis precision accelerometers to measure motion of rig and CTU deck

Tension Joint Fatigue
- 1 x dynamic curvature sensor measuring fatigue accumulation on tension joint
- 1 x 3-axis precision accelerometer with 2-axis angular rate sensor to measure riser rotation

Tensioner Pressure
- 4 x pressure transducers measuring tension in tensioner system

Figure 9 – *Location of Monitoring Equipment Supplied for the Jackup*

- Jackup Motion Sensors-to verify design information and assumptions made for the magnitude of jackup deflections under environmental loading, a precision accelerometer was installed on the conductor tensioning unit (CTU) deck, measuring 3 axis accelerations in real time. A second identical sensor was installed on the jackup in order to identify any differences between the cantilever and main hull and provide redundancy in case of a sensor failure.

Figure 10 – *3-Axis Precision Accelerometer in EExd d Housing*

- Tension Joint Sensors - To determine the fatigue damage accumulated to the HP riser, a dynamic curvature sensor was installed to the tension joint. This allowed confirmation that the fatigue accumulation remained within the design limits of the equipment at the critical connector on the tension joint. Consequently, decisions could be made as to when to inspect or change out the riser joints during the drilling operations. The curvature sensor was also used to measure the bending loads acting on the riser to confirm that load capacities of the HP riser equipment were not exceeded. The tension joint also had a precision 3-axis accelerometer and 2-axis angular rate sensor installed, to confirm that rotation of the riser within the CTU and stroke of the riser remained within acceptable design limits.

Figure 11 – *Dynamic Curvature Sensor Measuring Fatigue Accumulation on Tension Joint*

- CTU Deck Load Sensors - Because drilling was taking place near the limits of the cantilever, assurance was needed that the lateral and vertical loads acting on the conductor tensioning unit (CTU) deck remained within safe design limits. To allow measurement of the vertical loading, four pressure transducers were installed to the tensioner system (one on each tension cylinder). These allowed tension to be calculated from the pressure and therefore the vertical loading on the CTU deck to be established to confirm it remained within acceptable limits. The system also provided a status on the tensioner system, allowing identification of a loss in tension from the CTU should a failure in the tensioning system occur. Lateral loads on the CTU deck were estimated from the curvature sensor on the tension joint, based on the relationship between curvature and lateral load calculated from the model, to determine lateral loads also remained within acceptable design limits.

- Environmental Sensors- An acoustic doppler current profiler (ADCP) was installed to measure current speed and direction through depth, and a wave radar was installed to measure wave height and frequency statistics. Both of these were located topside, on the jackup. The data from these instruments was used to confirm the system was operating within the pre-defined environment/pressure operating envelope during operations, and subsequent to operations allowed for the theoretical responses of the system to be determined from the analytical model when subject to the measured environmental data. This information is key to verifying and determining the calibration between the analytical model and measurements.

The instrumentation was hard wired back to a central control unit where the raw voltage data was calibrated into accelerations, pressures, angular rates and strains, and then further processed using a proprietary software into the required outputs of displacements, rotations, tension, bending moment and fatigue damage in real-time. The system included a communication link to allow this data to be transferred to onshore servers for further review and analysis by engineers, and also allows the system to be remotely monitored and maintained. As part of fulfilling the integrity management plan, the central control unit also allows key performance indicators to be defined, monitored, displayed and appropriate alarm states set if safe levels are exceeded.

Measured vs. Predicted Data Comparison
The data collected allowed for the structural response of the HP riser system to be monitored in real-time, with the data collected, then compared with the predicted response under the measured environmental conditions in order to verify the analysis model. Figure 4 shows an example of one of these comparisons, detailing the measured vs. predicted fatigue damage at the tension joint. The data was collected whilst the well was subject to intervention activities with an intervention riser and coiled tubing run through the HP riser's bore.

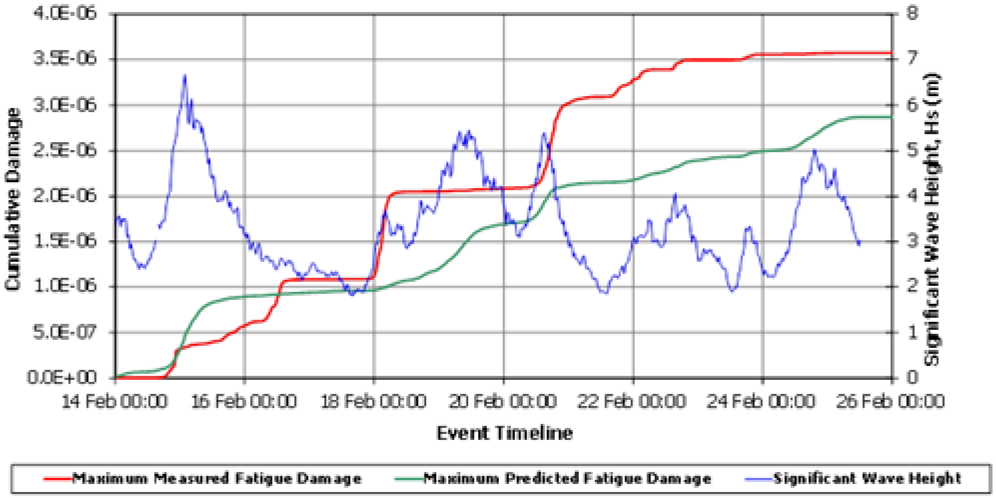


Figure 12 – *Measured and Predicted Cumulative Fatigue Damage at Tension Joint*

Although it was anticipated based on a conservative approach to the design that the analysis would conservatively predict the fatigue damage, it was observed for this intervention phase of the operation that this was not the case. The reasons for this under-prediction of fatigue damage were due to a number of factors:

- A number of conservatisms usually present in analysis models of riser systems were reduced based on sound engineering principles to ensure that an acceptable design was achieved, thus reducing the safety margin available.
- The measured fatigue damage incorporates all sources of fatigue loading, whereas the prediction relies only on wave induced fatigue damage accrual. Other fatigue sources may be present here, such as vortex induced vibration.
- The modelled jackup motions were generally under-predicted at significant wave heights of around 2-3m which, due to their high occurrence, are the most critical for fatigue damage accrual as they occur most frequently. This would be expected to lead to a tendency to under-predict fatigue damage generally.
- Other modelling assumptions are made due to difficulties in obtaining data, for example soil properties, which may lead to an under conservative model. However, data is not collected to verify these assumptions.
- The analysis model used to evaluate the riser design prior to operations did not represent all stages of operations. In this case, for example, the deployment of the 7 5/8inch intervention riser and coiled tubing within the HP riser was not modelled in the initial design work; however the use of the intervention equipment coincides with the observation of an increased rate of fatigue damage. Specific operational activities such as this can therefore have an impact on the overall fatigue damage; however they are generally not factored into the design process.

- A number of activities can be conducted to alleviate these factors and better calibrate the model against the measured fatigue damage. These include the more accurate representation of jack-up motions, calibration of hydrodynamic coefficients and soil properties. However, it is found that a full calibration for a single project is impractical due to the large number of potential variables that affect the model response.

Instead, the monitoring campaign gives an indication of the "calibration factor" (or experience factor) between the theoretical model and the in-situ riser. In this instance the measured data showed a calibration factor of approximately 30 is required for intervention operations (i.e. the predicted fatigue damage from the software must be multiplied by 30 to provide an improved prediction of the fatigue damage). Put another way, this would imply that the initial predictions of design fatigue life for the system would need to be reduced by a factor of 30 during intervention operations. This factor is location specific, and also changes dependent on the operations through the riser.

Despite the higher fatigue damage accumulation rate for intervention operations, the monitoring system demonstrated to the riser operator that the equipment was operated within its design limits during the intervention operation as the overall fatigue damage accumulated to the riser was less than 1%, due to relatively calm seas for the North Sea. Hence, 99% of the design fatigue life remained for further intervention activities (or other operations) and therefore there was no need to inspect the riser or change out riser joints for continuing operations on the well. However it is identified that intervention operations have increased the rate of fatigue damage accumulation. Although not required in this instance this could allow further review and analysis of this operation type, and then suitable mitigation measures put in place to reduce fatigue accumulation to the riser.

Case Study 2

Project Background

A major oil & gas systems manufacturer contracted a semisubmersible drilling rig for a series of wells in the UK North Sea. The water depths for the drilling campaign range from 100-500m, causing concerns with small operating windows and conductor fatigue.

In response to this concern, the client requested a monitoring system to continuously measure differential flexjoint angles, tension and bending moment on the riser adaptor, and BOP motion and heading. As the system is providing real-time advisory information to the drilling rig, the requested system is required to fully redundant to ensure all parameters are continuously available.

Monitoring System

The monitoring system supplied is shown in Figure 13. The instruments are rated for a maximum water depth of 500m. Power and communication to the sensors is supplied through the vessel MUX system. The system is comprised of four types of sensors:

- MRU: Motion Reference Unit
- MRIU: Motion Reference Inclination Unit
- MRISCU: Motion Reference Inclination Subsea Compass Unit
- Strain Gauges

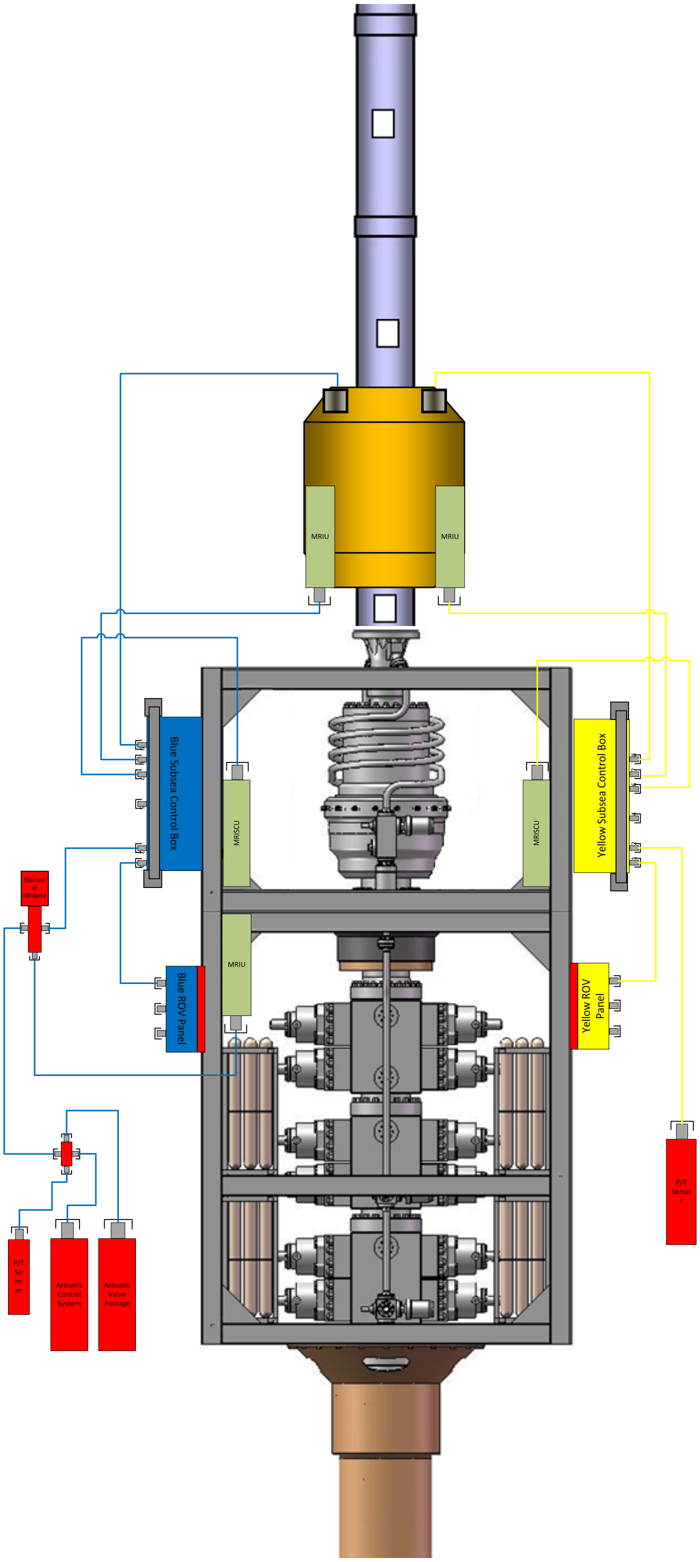


Figure 13 – *Drilling Riser Monitoring System Schematic*

MRU

The MRU measures motion of the BOP. This motion measurement is used to calculate accumulated fatigue on the conductor and wellhead. If the fatigue accumulation exceeds predetermined KPIs, the platform can be alerted and operations halted until conditions are favorable for drilling to commence. The unit is installed on the upper portion of the BOP. This is where the largest displacements along the stack will take place and hence provides the best resolution for motion measurements. The BOP sensor measures 3 axis acceleration and 2 axis angular rates

MRIU

The MRIU measures the inclination of the riser adaptor above the lower flexjoint. There are redundant MRIU sensors located above the lower flexjoint. The MRIU sensors measures 3 axis acceleration, 2 axis angular rates, and 2 axis inclination. The primary purpose of these sensors is to measure the inclination of the riser adaptor above the lower flexjoint.

MRISCU

The MRISCU measures the inclination of the LMRP below the lower flexjoint. There are redundant MRISCU sensors located at the LMRP below the lower flexjoint. The MRSCIU sensors measures 3 axis acceleration, 2 axis angular rates, 2 axis inclination, and heading of the LMRP assembly. The primary purpose of these sensors is to measure the inclination of LMRP and in conjunction with the MRIU to provide differential flexjoint angles during drilling operations.

Strain Gauges

The strain gauges measure tension and bending moment at the riser adaptor. The gauges are installed at the riser adaptor above the lower flexjoint and measure tension and bending at 90 degree increments around the circumference of the joint. There are two independent sets of sensors installed to provide redundancy to the yellow and blue MUX systems.

The instrumentation is hard-wired to a central control unit through the MUX cables where the raw voltage data is calibrated into accelerations, angular rates, inclinations, and strains. Other third party sensors also pass through the system and are communicated to the vessel control system through the DAQ. Signals are sent to the main vessel control system and then further processed into the required outputs of displacements, rotations, tension, bending moment and fatigue damage in real-time.

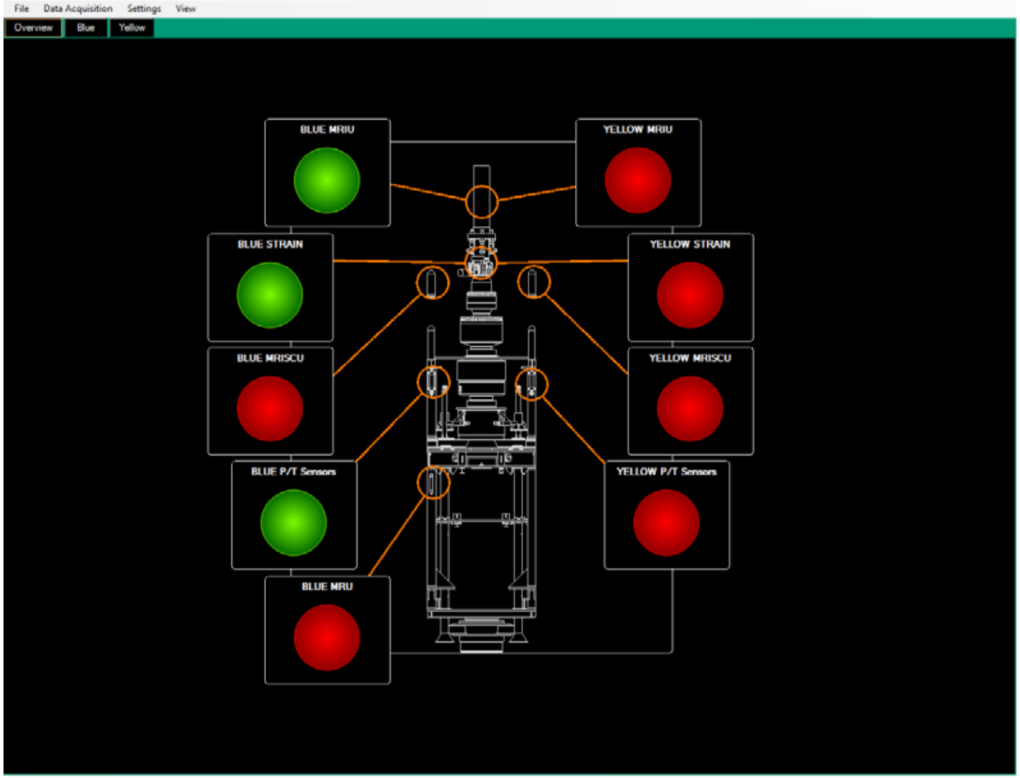


Figure 14 – *Drilling Riser Monitoring Software Screenshot*

Summary of Benefits of Drilling Riser Monitoring System
The system described in Case Study 2 successfully monitored the drilling rig while it experienced conductor fatigue and limited operating windows. The solution continuously measured differential flexjoint angles, tension and bending moment on the riser adaptor, in addition to capturing BOP motion and heading. The system was also fully redundant for operator confidence, and supplied real-time advisory information. The strategically placed assembly of MRU, MRIU, MRISCU and strain gauges worked in conjunction with additional sensors and display instruments. These presented measurements to allow the operator to make real-time decisions to optimize the drilling operations and minimize accumulated fatigue damage to the wellhead and conductor

CONCLUSION

Many environmental factors are transferred to the wellhead and conductor system when connected to a drilling riser and can cause fatigue issues on the wellhead system. The fatigue damage accumulation is further exacerbated with the increasing BOP stack size, non-optimal wellhead system design, and vessels operating at design limitations. As a result, finite element analysis may show marginal wellhead fatigue performance, especially in shallow waters.

Structural monitoring provides critical data for integrity management of the wellhead systems. It involves component level motion and strain measurements which allows for the actual fatigue accumulation to be determined. Riser, BOP stack, vessel and jacket as well as wellhead motions can be measured using accelerometers and inclinometers. Strain monitoring devices can also be used to measure tension and bending loads.

Careful planning of sensor types, sensor locations, installation, data management and analysis is required to conduct a successful structural monitoring campaign. A structural monitoring system can be designed for on demand feedback using acoustic or hardwired communication, or be configured as standalone system with on-board memory for long term fatigue assessment. The optimum communication method is selected based on the project requirements.

Fatigue tracking tools are enabling technologies that can help in situations where the fatigue life predictions are marginal. Field measurements also provide critical data that can be used to calibrate the models for future analysis.

Definition of Acronyms

ADCP	Acoustic Doppler Current Profiler
BOP	Blow Out Preventer
CAPEX	Capital Expenditures
DAQ	Data Acquisition System
DPS	Dynamic Positioning System
HP	High Pressure
KPI	Key Performance Indicator
LMRP	Lower Marine Riser Package
MDL	Motion Data Logger
MRISCU	Motion Reference Inclination Subsea Compass Unit
MRIU	Motion Reference Inclination Unit
MRU	Motion Reference Unit
MUX	Multiplexer
OPEX	Operating Expenditures
ROV	Remotely Operated Vehicle
VIV	Vortex Induced Vibration

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