DEEP WATER DRILLING RISER TECHNOLOGY, VIV & FATIGUE MANAGEMENT

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ABSTRACT

Drilling in deep water presents many challenges and current guidance for configuration and operation of drilling risers for deep water, harsh environment applications needs to be extended. An overview of the recently produced Drilling Riser Integrity Mangement Guidelines developed by the AMJIG group is given. The scope of application of these guidelines and a summary of the key findings obtained from assessment of deep water risers in the Gulf of Mexico (GoM), West Africa, West of Shetland and Brazil are given.

While riser analysis is necessary for riser optimisation and assessment of fitness for purpose, it may suffer from a number of limitations and generally involves some conservatism. Such conservatism can be costly in terms of VIV fatigue damage prediction and hence inspection requirements. Monitoring of riser response provides a means of reducing this conservatism. Different approaches for monitoring riser response, in order to minimise conservatism and rationalise inspection requirements are discussed.

INTRODUCTION

Exploration in the Gulf of Mexico and West Africa is moving into water depths of over 2000m and in the harsher areas West of Shetland and in the Voring Basin into water depths of over 1000m. The increased water depth and severe currents experienced in most of these areas place more severe design requirements on the drilling riser system. These conditions can not simply be compensated for by increasing riser tension or use of buoyant joints. All stages of riser operation from installation through to disconnect become more difficult and significant reduction in riser utilisation may be experienced unless the riser configuration is carefully optimised. In addition, it is not sufficient to consider the riser in isolation as interaction with the wellhead and conductor becomes more important. Conventional practices of riser configuration and operation must therefore be enhanced to maximise productive rig time.

DRILLING RISER DESIGN REQUIREMENTS AND DEEP WATER CHALLENGES

The operational requirements of the drilling riser system that must be considered to determine the optimum design arrangement cover all stages of well development.

Installation and Retrieval – the riser configuration at all stages of deployment must be able to resist environmental loading without interference with the vessel or overstressing;

Drilling – small flex-joint angles are needed to minimise downtime and minimise wear from drill string rotation;

Completion Operations – small flex-joint angles are needed to ensure safe passage of equipment for running the completion and maintaining satisfactory operating envelopes for subsequent well operations;

Survival Conditions - loading from the riser must be such that connectors in the BOP stack and the conductor are not overloaded;

Disconnect and Hang-Off – riser recoil must be controlled such that the riser lifts away from the BOP but does not top-out at high speed. During hang-off, the riser must not be overstressed and interference with the vessel should be avoided;

In deep water, achieving the required objectives is more difficult. The key challenges are as follows:

- Riser curvature and wear are increased
- Buoyancy effectiveness is reduced
- Mud pressures are increased
- Collapse pressures are increased
- Base/disconnect tension applied at the BOP is increased
- Hang-off deflections are increased
- Running and retrieval takes longer

Current design guidance for configuration of drilling risers does not address deep water issues in sufficient detail. As a result, additional design guidelines have been developed by the Atlantic Margin Joint Industry Group (AMJIG), which consists of 22 operators with interests in the Atlantic Margin.

DEEP WATER DRILLING RISER INTEGRITY MANAGEMENT GUIDELINES

Development of the AMJIG Deep Water Drilling Riser Integrity Management Guidelines was initiated by BP and Shell and championed by Elf. All three operators closely involved with the development, carried out by 2H Offshore Engineering Limited, specifying the areas to be addressed and reviewing each draft. The draft guidelines were also issued for review to the AMJIG participants, drilling contractors and analysis consultants and their comments incorporated.

The guidelines are intended as a supplement to existing codes of practice NOT a replacement for them. Emphasis is placed on the need to adopt a system approach for assessing drilling riser operation in deep water, covering all stages of riser operation from installation through the retrieval and considering all components of the system including the riser, BOP, wellhead and conductor. The guidelines are in three main parts:

Riser Analysis – defines analysis methods, modelling considerations, design criteria to be achieved and methods of improving response;

Riser Operations – provides example operating guidance that should result from riser analysis including requirements for top tension and tension variation, drilling, survival and installation envelopes and methods by which riser usage can be monitored;

Inspection – defines methods for assessing riser inspection requirements based on fatigue life predictions and riser usage history, components to be inspected, inspection frequency and inspection acceptance criteria.

Guidance on procedures for conducting riser inspection is also given as an attachment

GUIDELINE APPLICATIONS AND FINDINGS

The main uses of the AMJIG guidelines are as follows:

- Assessing fitness-for-purpose of the riser and vessel
- Optimising the riser arrangement
- Predicting downtime
- Predicting fatigue life and hence inspection requirements
- Providing input to operating procedures

Elements of the guidelines have been used to assess the response of a number of drilling risers intended for use in deep and ultra deep waters in West of Shetland, Gulf of Mexico, Brazil and West Africa. This work has produced the following findings:

Joint thickness – greater wall thicknesses are needed to accommodate increased top tension, internal pressures due to mud weight and external collapse pressures in the event of fluid loss downhole;

Buoyancy – the lower part of deep water risers should use slick joints to maximise effective use of buoyancy and maintain satisfactory levels of tension during disconnect, hang-off and to a lesser extent installation and retrieval;

Soil Conditions – the soft soils found in many deep water areas assist riser behaviour through allowing movement of the conductor. This results in lower relative rotations across the lower flex-joint and reduced bending moments in the LMRP and BOP connectors and conductor;

Retainer Valves – the large mud pressures generated at the base of the riser in very deep water can greatly exceed the weight of the LMRP. If emergency disconnect is conducted with heavy mud in the riser, compressive forces are generated in the lower riser that may be result in buckling. Retainer valves are therefore needed to prevent uncontrolled response;

VIV Fatigue – high rates of fatigue damage are produced by vortex induced vibration which requires more frequent inspection of the riser or use of suppression devices.

ANALYSIS LIMITATIONS

The results produced from riser analysis that are used to develop operating windows and determine inspection requirements can only be as good as the input assumptions. Uncertainties in environmental loading and drag coefficients can produce conservative operating envelopes. Drill string tension can be beneficial to riser response, reducing curvature and VIV's. However, analytical assumptions tend to err on the side of conservatism, in order to ensure a safe design, and beneficial effects that may be difficult to quantify are often ignored.

The discrepancies between predicted and real drilling and survival limits can be overcome in practice by relating riser response to parameters that are readily measured offshore, namely riser tension, mud-weight and the lower flex-joint and upper flex-joint or ball-joint angles. By monitoring these parameters and ensuring they are kept within predefined limits the uncertainties associated with environmental conditions and analysis assumptions can be obviated.

Overcoming the uncertainties associated with VIV fatigue predictions is more difficult to achieve. However, the prize for achieving this goal is significant. Over-conservatism in predictions of fatigue damage can lead to the following:

- Changes in riser tension (if possible) and buoyancy
- More frequent inspection
- Use of suppression devices

Methods by which VIV fatigue damage are predicted and ways in which fatigue accumulation can be monitored are described below.

VORTEX INDUCED VIBRATIONS

One of the main concerns with deep water drilling risers is the effect of currents on riser response. Large currents speeds typical of those observed in many deep water developments give rise to vortex induced vibrations, whereby the drilling riser vibrates normal to the predominant direction of current flow. High levels of fatigue damage can be generated in this way, along the entire riser length. Reliable predictions of VIV response are needed to ensure that premature failures do not occur and that undue expense in specification of suppression devices is not incurred.

VIV Suppression

If the methods of riser and wellhead system optimisation described above cannot provide adequate operating envelopes or fatigue life requirements, consideration may be given to the use of VIV suppression devices. Many systems have been proposed [3]. Two systems that provide high levels of suppression and have been used in previous operations are helical strakes and fairings [4-6]. Both strakes and fairings can reduce VIV fatigue damage by over 80%, but both systems also introduce handling difficulties. Strakes have the added disadvantage of increasing riser drag and hence flex-joint angles, whereas fairings can reduce drag loading.

VIV ANALYSIS

A detailed review of current VIV analysis methods is given in reference [1]. Of these methods, only a few are commercially available to the riser designer, including the DnV Rules [2] and the analysis programs SHEAR7 [3] and VIVA both developed at MIT under separate JIP's. The guidance provided by DnV enables prediction of the response of uniform risers in uniform current flows. This approach is unsuitable for many developments where highly sheared current profiles are experienced. The program SHEAR7 accounts for variation in current speed through the depth and enables prediction of multi-mode VIV response of a uniform riser in sheared or uniform current and has been extensively validated using model tests. The most recent technique to become commercially available is the programme VIVA, also developed at MIT. This can account for the effects of varying riser section along the length, drilling riser choke and kill lines and is currently being validated using tank test data.

In order to obtain estimates of long term VIV fatigue damage, analysis must be conducted with a number of current profiles of varying severity, typically based on exceedence level. The fatigue damage obtained assuming continuous application of each profile is then factored according to the assumed duration of the profile, and the total long term damage is given by the sum of the factored damage from each profile. As the more severe current profiles generally produce greater rates of fatigue damage, a more refined selection of profiles is required amongst the low exceedence levels.

VIV UNCERTAINTIES

Sensitivity analyses must be conducted to evaluate the influence of changes in such parameters on predicted fatigue life and provide lower bound estimates of fatigue life for design purposes.

The environments in which risers are to be used have widely differing current profiles. The ultra-deep water Gulf of Mexico has the submerged eddies to contend with, not found in the current deep water developments in the same location. West Africa and West of Shetland have large through depth current speeds which place a high degree of importance on excitation velocity bandwidths in the determination of VIV fatigue damage. Variation in current flow direction though the water depth, particularly significant in Brazil, adds further difficulty to reliable prediction of VIV fatigue damage.

The drag diameter used for VIV analysis should take account of choke and kill lines and buoyancy modules. For a slick drilling riser, the effective drag diameter varies according to current direction. To account for uncertainties in flow direction sensitivity analysis should be conducted using drag diameters that account for flow both normal to and in the plane of the choke and kill lines. A further difficulty arises when selecting the drag diameter to model a riser arrangement that uses a combination of buoyant and slick joints. It may not be satisfactory to simply average the diameter over the whole riser length as the extent and degree of VIV excitation and damping may not be satisfactorily determined. Until more rigorous analysis methods are developed, sensitivity analysis, accounting for the change in drag diameter along the riser length need to be conducted.

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In each of the above areas, the riser designer must make simplifying assumptions in order to produce estimates of VIV response. Out of necessity, such assumptions must err on the side of conservatism. However, due to the lack of available data the levels of conservatism may not be understood even when parametric analysis is conducted, and enhancements to analytical tools are needed in order that these uncertainties can be quantified and undue conservatism avoided.

VIV FATIGUE MANAGEMENT

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Measurements of riser response can be used for monitoring fatigue damage accumulation calibrating results of riser analysis. Measurements may be taken using strain gauges to give riser stresses directly or accelerometers to give displacements. Using the latter approach riser stress variations and accumulated fatigue damage may be inferred from comparisons between analysis results and field measurements. Such a system is currently being implemented West of Shetland and in the Voring Basin. By either approach the accuracy of response prediction methods can be determined and fatigue life predictions of riser and wellhead updated accordingly. This may have minimal benefit on the development on which the monitoring is conducted but may prove useful on subsequent developments in the same region.

Monitoring riser response provides a means of logging fatigue damage accumulation, which may be accelerated in deeper waters. This would account of seasonal variations of riser usage and actual rather than predicted field conditions. Records of accumulated fatigue damage would also assist in rationalising riser inspection schedules in terms of the severity of riser operating conditions rather than the more conventional time based approach.

ON-LINE V PASSIVE MONITORING

A major decision affecting the equipment required for riser stress and position monitoring is whether on-line or passive monitoring is required. The former provides output directly to the control room or bridge of the drilling vessel in real time, whereas the latter may consist of autonomous monitoring devices which are attached to the riser during running and removed following riser retrieval for subsequent analysis.

On-line devices must be hardwired to transmit signal back to the vessel. This may be achieved by way of telemetry, but the power needed for such an approach would require large batteries or limit the time over which data could be recorded. Hardwiring has been used for permanent riser systems (TLP production and export risers) but is not well suited to drilling risers that are regularly disassembled. Routing of power and signal cables can add to installation time and cables may be damaged. Consequently, consideration must be given to limiting the length of cable runs. To this end, monitoring devices mounted, near or on the base of the riser could be powered by way of the drilling riser umbilical, with those near the top powered by way of separate cables run to the surface.

Passive monitoring devices may be mounted on the riser joints either prior to or during running using straps or clamps. Processing of data can be conducted following riser retrieval either on or off the drilling vessel. A possible concern with this type of approach is that the devices cannot be checked to ensure they are operating correctly. Consequently, some redundancy of devices may be considered necessary. The passive approach has been successfully implemented for monitoring VIV response of drilling risers both West of Shetland and in the Voring Basin [47, 48].

FIELD MONITORING OF VIV

To complement the data provided by VIV laboratory experiments and further enhance VIV analysis tools, data is needed from riser arrangements which closely resemble real riser systems and conditions which simulate in-service environments. The extensive drilling activity in progress in many deep water locations provides an opportunity for providing valuable data at relatively little cost. Data has been provided from two such drilling programmes, as described below:

BP Schiehallion

- Paul B. Lloyd drilling riser in 375m water depth, accelerometers at 3 locations along the length monitoring over a period just longer than 1 month;

BP Nyk High [14]

- Ocean Alliance drilling riser in 1300m water depth, accelerometers at 5 locations along the length monitoring over a period of 74 days.

The data from both the above field experiments is currently being processed with the objective of calibrating analysis tools and required. The data from the Schiehallion work is also assisting in calibrating input assumptions for the riser tension contribution from drill string tension that is shown to have a significant influence on analysis results.

CONCLUSIONS

Assessing the adequacy of drilling equipment for deep water activity is a complex process involving many variables. Much can be done to optimise drilling riser response. A complete system approach must be taken, in which riser, wellhead and conductor system interaction and all stages of riser operation are considered. Increased use of weather forecasting and improved methods of monitoring can help in ensuring that operations are conducted safely and that productive rig time is maximised. The increased rates of wear and fatigue damage accumulation bring an added dimension to assessment of riser fitness-for-purpose that require more rigorous record keeping of riser usage and rationalisation of inspection procedures to reflect the severity of riser operations.

Improved confidence in VIV analysis methods to reliably predict the response of real risers in real environments requires the ongoing accumulation of experimental data with which theoretical algorithms can be validated. Current and planned test programmes will significantly assist in these objectives. In the meantime, the uncertainties in environmental conditions and analytical assumptions can be rationalised by monitoring of operating conditions and riser operating environments and response in order to satisfactorily manage riser fatigue and rationalise inspection requirements.

The extensive drilling activity being conducted in deep water high current environments provides an ideal opportunity for collecting data on riser VIV response and assessing the effectiveness of suppression devices at high Reynold's number. It is important that this opportunity is not lost, and that the data is processed in a timely manner in order that VIV design of future drilling, production and export risers can be rationalised.

Some evidence is available to suggest that current predictions of VIV fatigue damage are conservative. As the application of suppression devices can be costly, possibly affecting feasibility, alternative design approaches may need to be considered for some production and export riser applications where VIV fatigue lives are marginal. A typical approach may consist of installing bare risers and monitoring response in-service. Where fatigue life predictions are found to be conservative the use of suppression devices can be avoided. If predictions are unconservative, then suppression devices may need to be retrofitted or the riser replaced prior to expiry of the service life. Such approaches may prove extremely cost effective with the advent of low cost monitoring devices and recently developed suppression systems [8].

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