Management of Riser System and Areas of Attention

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Abstract- **This article aims to provide a general overview from operational side with regards to riser mechanics. It is utmost important to understand the movement of the riser string in the view of taking the right decision in case of losing platform's position and therefore the decision for emergency disconnect. Any company operating in deep and ultra-deep waters needs to set up the decision tree in order to safely disconnect and secure the well. Once the riser is deployed, it is essential that its behavior is monitored closely in order to be able to face any possible critical situations. In this respect, understanding of riser mechanics and capability of recognizing potential problems before their development into distress situations is extremely important. This article is simulating the operation of riser system for a drilling installation with dual rig and N-Line tensioned system.**

Keywords: Riser, impact, stress, API

1. DEFINITIONS

ARA	Acoustic Riser Angle System		MDO	Marine Diesel Oil
BOP	Blow Out Preventer		MW	Mud Weight
CCW	Counterclockwise		MRU	Motion Reference Unit
Cd	Drag Coefficient		MSB	Main Switchboard
CG	Center of Gravity		mT	Metric Tonnes
CRA	Corrosion resistant Alloy		OD	Outside Diameter
CW	Clockwise		OS	Operator Station
DARPS	Differential Absolute & Relative Positioning System		PLMR	Platform Manager
DGPS	Differential Global Positioning System		PMS	Power Management System
Dhyd	Hydrodynamic Diameter		POM	Program Operation Manual
DP	Dynamic Positioning		PS	Process Station
DPO	Dynamic Positioning System Operator		RAO	Response Amplitude Operator
DSL	Drilling Section Leader		RFID	Radio frequency Identification
ECR	Engine Control Room		RKB	Rotary Kelly Bushing
EQD	Emergency Quick Disconnect		RMS	Riser Management System
ER	Engine Room		ROV	Remote Operated Vehicle
ERA	Electrical Riser Angle system		RPM	Revolution Per Minute
ESD	Emergency Shutdown System		SJ	Slip Joint (TJ Telescopic Joint)
F&G	Fire and Gas detection system		SMYS	Minimum Yield Strength of Steel

FMEA	Failure Modes & Effect Analysis		SR	Support Ring (TR Tension Ring)
FMECA	Failure Modes Effect & Consequence Analysis		SSBL	Super Short Base Line
GPS	Global Positioning System		STD	Standard Deviation
HFO	Heavy Fuel Oil		TOE	Tension Offset Envelope
HiPAP	High Precision Acoustic Positioning		TR	Tension Ring (SR Support Ring)
HT	High Temperature (Cooling)		TJ	Telescopic Joint (SJ Slip Joint)
HV	High Voltage (11.0kv)		UF	Usage Factor
IAS	Integrated Automation System		UFJ	Upper Flex Joint
ID	Inside Diameter		UFJA	Upper Flex Joint Angle
IRJ	Instrumented Riser Joint		UPS	Uninterruptible Power Supply
LBL	Long Base Line		UR	Utilization Ratio
LFJ	Lower Flex Joint		URA	Upper Riser Angle
LFJA	Lower Flex Joint Angle		URJ	Upper Riser Joint
LMRP	Lower Marine Riser Package		WCSF	Worst Case Single Failure
LRA	Lower Riser Angle		WT	Wall Thickness

[11],[13],[16]

2. FOREWORD

Once the riser is deployed, it is essential that its behavior is monitored closely in order to be able to face any possible critical situations.

In this respect, understanding of riser mechanics and capability of recognizing potential problems before their development into distress situations is extremely important.

During operations, the RMS should be used in accordance with the current operating conditions, by selecting the proper mode of operation in the area in the top right hand side of the screen. In addition, the RMS may be used for planning actions to face changing environmental or operating conditions.

The following sections will deal with specific subjects that require combined knowledge concerning riser mechanics and RMS related skills [1],[2], [6].

3. OPERATIONAL ACTIVITIES

Pre-Deployment Check

Besides the normal activities, the following activity shall be carried out prior to riser deployment:

a) Verify that the bolt torque for all buoyancy and centralizer thrust collars

b) Verify that all instrumentation is installed or ready to be installed when needed

c) Verify that all instrumentation is installed properly

d) Pay special attention to the electrical inclinometers on the IRJ and the LMRP. The flat on their mounting flange should be facing forward

e) Pay special attention to the acoustic inclinometers on the IRJ and LMRP. Verify the orientation of the mini pods at the IRJ

Deployment sequence

The typical sequence for riser string deployment is as follows (from bottom to top), [10]:

– Horizontal X-mas Tree (if any)
– BOP
– LMRP + Riser Adapter/IRJ
– A certain quantity of 75 ft joints (buoyant and/or with guards) (note 1)
– Fill-up valve joint (note 2)
– A certain quantity of 75 ft joints (buoyant and/or with guards)
– A certain quantity of pup joints
– Telescopic joint
– Spacer spool

The above sequence shall be prepared in accordance with the rules for riser storage, as well as the string make-up rules.

Note 1: If available, the 75 ft joint immediately above the Riser Adapter should always be of a thicker main tube wall (0.813”). This is to improve the bending strength of the lower string during the deployment of the BOP stack through the splash zone.

Note 2: Normally, the Fill-up Joint should be operating at a water depth between 200 and 500 ft, [3].

General rules for riser deployment

A typical riser string for deep water is configured in such a way to have a certain number of joints dressed with Riser Guards, [9] at its lower section and other joints dressed with Riser Guards at its upper section. The reasons are as follows:

a) The lower joints with Riser Guards will increase the weight of the bottom of the string. In case of emergency hang-off, such arrangement will prevent the string from buckling or entering into vertical axial resonance.

b) The upper joints with Riser Guards will decrease the side force on the riser due to waves and surface currents.

c) In addition, the joints with Riser Guards may have a thicker wall (depending on the total quantity of joints available) if compared to the buoyancy dressed joints, to withstand higher tensile stresses (at the top) and higher hoop stresses due to internal pressure (at the bottom).

d) The location of the joints within their storage area was determined to allow maximum flexibility for any water depth.

Riser deployment/retrieval interruption

In the event of forthcoming bad weather, such to cause the vessel to be beyond its operational limits for running/retrieving riser, a decision shall be made (depending also on the time available) as to what configuration leave the hanging riser in. This is more important in deep water, if a considerable part of the string is already hanging in the water, [13].

An evaluation of the hanging string in the expected weather conditions should be made.Depending on the time available, it may be possible to retrieve some joints to shorten the string to change its natural frequency, or to make it longer and more stable by adding heavy slick joints.

During riser deployment/retrieval, the hook and the gimbal are subject to a load composed of two factors:

- The static load (caused by the weight in water of the riser string);
- The dynamic load (caused by the inertia of the riser string mass subject to the heave action of the vessel)

For mild sea states and short strings, the dynamic component is typically negligible.

At worsening sea states (that is, roughly speaking, higher waves), the dynamic component may become relevant.

However, another factor that makes the dynamic component increase is the length of the hanging string. A sea state that may be harmless for deployed length of, for instance, 1,000 m may become critical (from the point of view of the dynamic load) for string lengths in the order of 2,500 m and beyond, [12].

The RMS, when coupled with the RFID system, is able to provide advance warnings to prevent the static plus dynamic load combination to exceed the rating of the deployment equipment.

Should the warning be given by the RMS during deployment, the operation should be interrupted as long as the sea state does not improve. It is important not to add any further joint (actually, if at all possible, the deployed string should be shortened by 3-4 joints).

Should the warning be given by the RMS during retrieval, the best solution is to move to a soft hang-off configuration (that is, deploy the TJ and hang the string at the tensioners as opposed to the spider).

The reason is that, because of the different stiffness of the tensioner cylinders with respect to the spider assembly, the dynamic characteristic of the riser string is changed dramatically when shifting from hard to soft hang-off.

Monitoring of significant parameters during operations

When the RMS sensors are properly working, and the initial settings have been established, the system will issue alarms in case of exceeding of one or more critical parameters.

Triggering of many alarms will depend, in particular, from the exceeding of the pre-set values entered in the RMS Operational Limits window, [5].

It is a good practice, however, to monitor the relevant parameters and look for potential problems even if the values shown are within yellow and red operational limits.

Some of the most significant parameters are as follows.

LFJ mean and predicted extreme values.

If, without any change in the operating conditions (such as vessel offset or mud weight), an increasing or decreasing trend is observed

It may be possible that some significant changes in the environment (e.g., currents) are occurring, and special attention should be given to how the situation develops

It is advisable to switch to alternate primary or backup sensors to see if they provide the same information.

UFJ mean and predicted extreme values

If, without any change in the operating conditions (such as vessel offset or mud weight), an increasing or decreasing trend is observed

It may be possible that some significant changes in the environment (e.g., currents) are occurring, and special attention should be given to how the situation develops

It is advisable to switch to backup sensors to see if they provide the same information also, visual inspection is possible in this case:

a) TJ stroke mean and predicted extreme values

If, without any change in the operating conditions (such as vessel offset or mud weight), an increasing or decreasing trend is observed

It may be possible that some significant changes in the environment (e.g., currents) are occurring, and special attention should be given to how the situation develops (note, however, that periodical increasing or decreasing trends in the mean TJ stroke are normal because of tide variations)

It is advisable to check if the stroke sensors, taken one by one, are showing values that are consistent between each other

b) Pipe and coupling utilization factors in the Riser Loads Table/IRJ Loads Table windows.
The utilization factor at a certain location of a structure is defined as the ratio between the stress at that location and the maximum acceptable material stress
If the utilization factor at a certain location is changing, it means that the stress at that location is changing
If the change takes place without any variation in the operating conditions, then it may be that some changes in the environment are occurring, and special attention should be given to how the situation develops
It is also advisable to change the sensors being used by the system, to see if the information provided is consistent (remember that the utilization factors are calculated values, and are deduced from the measured parameters)

c) Onset of axial instability
Advance warnings about this possible occurrence in deep water will be provided to the DPO by the RMS. It will be the DPO's responsibility to inform the personnel responsible for riser running and retrieval operations.

d) Radio Frequency Joint Identification (RFID)
Each 75 ft riser joint and all pups joints are equipped with four RF tags embedded within the lateral surface of the pin and box flanges. Two diametrically opposite tags are installed within each flange.

A database has been created where each tag is associated with a specific joint (it may also be said that each joint is associated with four tags).

Each time a joint is run or retrieved through the rotary, the antennas installed within the gimbal structure report the information about the joint being run to the acquisition PC.

In this way, the acquisition PC is basically running a tally of the riser string.

The RFID data are used by the RMS for two main purposes:

- Warn the DPO of the potential for axial instability of the riser string
- Calculate the accumulated fatigue damage of each joint on the basis of its time in operation and its position along the string. This information may be used by the rig management to schedule for inspections.

Tension ring operations

Monitoring the Tension Ring is a critical task that requires tight cooperation between personnel in the wheelhouse and in the moon pool area.

An incorrect assessment of the Tension Ring rotation status may lead to severe damage to the Tension Ring itself and/or the riser system.

Even though the string may withstand a certain amount of torque, it is to be clear that the riser is not designed to be continuously subject to torsion.

The hub of the Telescopic Joint, [4] is resting into the Tension Ring with no locking mechanism with respect to relative rotation. In other words, relative rotation between rig and riser may be composed by any combination of the two following occurrences:

- Relative rotation between the Tension Ring and the TJ hub.
- Rotation of the TJ hub roller bearing.

The following instructions should be carefully followed:

a) It is clarified one more time that the ring is connected to the tensioner cylinders. Any relative rotation of the ring with respect to the rig will cause the tensioner cylinders not to be radially oriented towards the center of the ring (as it should be).
b) The relative rotation between riser and rig may be remotely monitored by the DPO at the RMS console in the wheelhouse.
c) From now on, clockwise (CW) and counterclockwise (CCW) indicate the rotation of the ring relative to the TJ hub.
d) A reference line pointing forward should be painted on the riser Spacer Spool to indicate its front side. The most important rule to keep in mind during weathervanes operations is to make sure that, at the end of a maneuver, the two hinges of the tension ring are aligned in the port/stbd direction and, at the same time, the painted reference line on the Spacer Spool is pointing forward and parallel to the longitudinal axis of the rig.
e) When the rig weathervanes, the tensioner cylinders may rotate with respect to the riser, therefore inducing a certain torque on the string. In order to keep full control of the situation, the vessel should not be allowed to weathervane automatically.
f) The ring rotation measurement is given by the calculated difference between the vessel's rotation (measured by the DP system) and the riser string orientation. As a consequence, it is strongly recommended that a local visual verification of the ring position with respect to the Spacer Spool reference line (i.e., verify that the reference line on the Spacer Spool is parallel to the longitudinal axis of the vessel) is made in real time, to support the rotation measurement data provided at the RMS console.
g) In general, measurement errors at the RMS console may be considered cumulative.
h) It is recommended that the vessel weathervane is carried out in 5° or 10° steps. At the end of each step visual observation should be made to confirm the actual rotation.
i) The Tension Ring shall be operated according to relevant instructions in Cameron user manual. In addition, it is important to remember that the maximum relative rotation should not be in excess of +/-180° from the starting position. The angular rotation is limited by the length of the jumper hoses from the Tension Ring to the Telescopic Joint, as well as by the twist of the auxiliary lines hoses around the riser.
j) The theoretical torque needed to initiate the roller bearing rotation is as per the chart below.
k) The torque is applied by simply weathervanes the vessel and let the tensioner cylinders achieve enough out-of-radial direction to start dragging the ring. However, the following points must be taken into account/

The reason for having all TOE plots ready and available, is to replace the RMS in case of a system failure critical enough to impair the reliability of the RMS (e.g., loss of all sensors for the LRA, or damage to the RMS console). It is important to remember that a TOE plot is not as reliable as an on-line tool such as the RMS.

TOEs are generated on the basis of historical data and do not reflect the actual situation.
The main uncertainty when consulting a TOE is probably related to the asymmetries (with respect to the zero offset) of the lines representing the angle limits conditions.

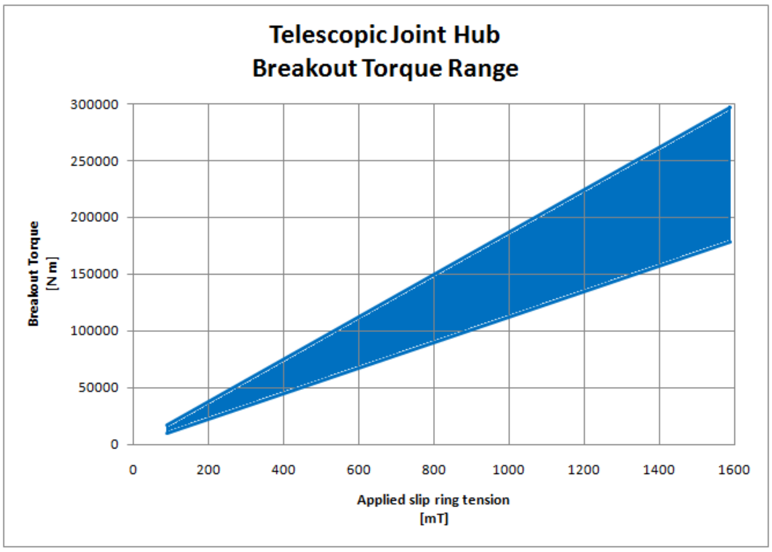

Figure 1 Tension Ring breakout torque range

The order of magnitude of the torque applied by the tensioner cylinders as a function of the tension at the Tension Ring may be summarized by the following table:

Table 1. Applied tension and torque

Applied tension (mt)	Torque applied by the tensioners (Nm) between 1° and 5° of relative rotation
400	9,000 ÷ 43,000
600	13,000 ÷ 65,000
800	17,000 ÷ 84,000
1000	22,000 ÷ 105,000
1200	26,000 ÷ 130,000
1400	30,000 ÷ 150,000

By comparing the table above with the breakout torque chart, it may be seen that 5 degrees of relative rotation between riser and vessel may not be enough to initiate the roller bearing movement.
To calculate the approximate torque applied to the Tension Ring, the following formulas should be used, [3]:

a) T = Applied Tension (mt)
b) α = relative rotation angle between rig and riser (degrees)
c) $T_1 = 0.03838 * T$
d) $\beta = \arctan((1.4 * \sin\alpha) / (2.4 - 1.4 * \cos\alpha))$
e) $L = 2.4 * \sin\beta$
f) Applied Torque expressed in Nm = $9{,}810 * L * T_1$

The above calculation has a 10% error margin (because of some approximations in modelling the geometry of the upper riser).

Note: The torque applied to the Tension Ring shall **never** exceed 275,000 Nm without authorization by the responsible engineer. Should such value be exceeded, the riser string may be subject to structural failure.

Use of toe plots

Tension-Offset Envelope (TOE) plots should have been generated by the RMS off-line module prior to beginning of operations, as previously described. A TOE (Tension-Offset Envelope) plot is a chart useful to display the so-called operating window for a certain riser string subject to a certain set of environmental and drilling conditions, [5], [14].

The horizontal axis shows the vessel offset, whilst the tension is shown on the vertical axis.

Such asymmetries are caused by the current profiles entered in the off-line module prior to generating the TOEs. In view of the above, it is recommended that TOEs are not used near their limits. In other words, the point representing current vessel offset and applied tension should be well within the operating area and not near the lines representing the limit angles.

When using a TOE because of the unreliability of the RMS, it is recommended to make reference, in any case, to all RMS sensors that are still reliable. In this way, the TOE plots may be backed up or corrected, by some of the measured riser system parameters.

Tensioner failure

The tensioning system is designed in such a way that a Worst Case Single Failure (WCSF) would disable one out of the six tensioning units.

If the applied tension settings should be in accordance with API 16Q (as it is the case when the RMS is used for string configuration), the safety factor used in the applied tension would ensure the stability of the riser string after the WCSF (in other words, the riser string would not be subject to structural failure).

The Tension Ring / Telescopic Joint assembly is designed to withstand the unbalanced load that would result from the failure of one (and not more than one) tensioner out of six (and not less than six).

Should a WCSF cause the loss of one tensioning unit, the well shall be immediately secured and the riser string shall be made as light as possible by displacing drilling mud with sea water, so that a controlled disconnect may be carried out, for the load to be removed from the tensioners.

In the event of WCSF of the tensioning system, under no circumstances the drilling operations should continue as before. The reason is that one further failure would result in an instantaneous load distribution that would cause permanent damage to the Tension Ring / Telescopic Joint assembly, with the potential of losing the riser string.

Under no circumstances the load should be re-distributed on four tensioners, even if this would result in a symmetrical load distribution. The reason is that one further failure would result in an instantaneous load distribution that would cause permanent damage to the Tension Ring / Telescopic Joint assembly, with the potential of losing the riser string.

The term “instantaneous” used in the two paragraphs above, means that there will be no time for corrective action. The damage would be unavoidable.

Emergency disconnect

The Emergency Quick Disconnect (EQD), also called Emergency Disconnect Sequence (EDS), is one of the most critical special operations to be performed by the riser system. It causes the separation of the stack at the LMRP connector, thus leaving the BOP secured and connected to the wellhead, [15]. The critical phenomena associated with this event have is part of riser mechanics.

The EQD should be initiated in every situation in which leaving the riser connected to the wellhead may cause a potentially catastrophic situation (i.e., riser components failure because of excess tension, casing failure because of excess tension or bending moment, excess UFJ angle, etc.).

The EQD may be initiated by either the DPO (at the RMS console) or the driller/asst. driller (at the BOP DCP), depending on the type of emergency.

Typically, the DPO will have a better understanding of the situation in case of drift off or drive off, whilst the driller would be more likely to make an intervention in case of drilling activity related emergencies.

It is of the essence to remark that, by definition, a situation where the EQD is necessary does not allow time for in-depth assessments or consultation.

The potential consequences of a delay in activating the EQD sequence could be catastrophic (see Macondo incident). Activating the EQD for reasons that later on may prove not fully justified is much more preferable than taking chances by delaying the EQD activation.

1) Normally ,there are three locations from which the EQD may be initiated:

- BOP Driller’s panel
- BOP Toolpusher’s panel
- RMS console

2) Once the decision to initiate the EQD has been made (based on the criteria described in the general section of the riser system), it is important to check the behavior of the riser system during and immediately after the EQD, in particular:

- Check the riser tensioning system and the draw works/top drive (as well as rotary table, diverter housing, etc.) to verify that no damage is sustained because of the stroke out.
- In particular, check the anti-recoil valves on all tensioners to verify whether they have been triggered (ref. is made to NOV user’s manual).

Note: the anti-recoil system is based, among other things, on the upwards velocity of the tensioner pistons. It may be possible that, for a certain riser disconnect, the upwards velocity of the pistons is not enough to actuate the anti-recoil valves. In other words, for certain disconnect, the valves may or may not actuate. After the event, to verify whether the system has been working properly, it is suggested to review the tensioner stroke records against what stated in user’s manual.

- Observe the final position of the TJ outer barrel after stroke out. The TJ should not be totally collapsed.
- If there were tubular (drill pipe, drill collars, casing, etc.) inside the riser at the time of disconnect, retrieve the drill string and verify its status. In particular, if any tubular are supposed to be sheared off at the BOP, check the sheared section. If the cut does not appear to be clean, take special care to check and access the wellbore

from the top of the BOP down, as some damage might have been caused by the drill string.

- Verify whether the riser Fill-up Valve has opened (the valve status is displayed at the driller's and at the tool pusher's panels). Note: once the LMRP is disconnected, the drilling mud should flow down the riser into the environment. This will decrease the internal pressure at the Fill-up Valve level. Depending on the mud weight, the Fill-up Valve may or may not open. If the mud is lightweight (or even water), the drop of mud level inside the riser may not be enough to have the Fill-up Valve open.
- On the basis of its setting prior to deployment, as well as the mud weight at the time of disconnect, verify if the Fill-up Valve behaved as expected.
- Check the bottom pressure sensor readings at the IRJ to verify that the pressure is equal to the environment pressure.

3) The riser hang-off configuration for Scarabeo 8 is achieved by leaving the TJ hanging from the tensioners. Unless there are special operational requirements, do not hang the riser at the spider gates (i.e. supported by one of the flanges).

4) During the hang-off mode (therefore including deployment and retrieval), do not close any of the BOP ram or annular preventers.

Acoustic doppler current profiler (ADCP)

The ADCP will be able to monitor subsea current speed and direction down to about 750 m water depth. ADCP operation shall be in accordance with manufacturer's user manual.

The real time data, [16] supplied by the ADCP may also be used by the drilling crew in order to evaluate whether a certain operation should be discontinued because of excess subsea currents (such as, for instance, transit with hanging riser). It is to be noted that the RMS does not use the data provided by the ADCP as part of its real time advisory capability.

The riser is normally designed to be able to cope with “reasonable” current profiles, without the need for the operation crew to be concerned about the onset of potentially harmful events such as Vortex Induced Vibration (VIV), or the need for additional special equipment to be installed on the riser joints (such as strakes or fairings).

The reference design current profile is shown in Figure 2.

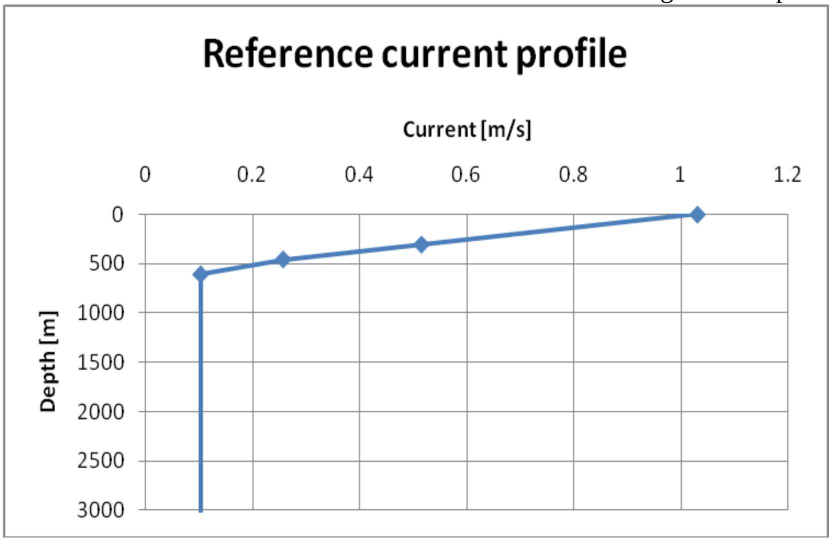

Figure 2. Riser design current profile.

Simultaneous activities

In this section, concerning subsea operations, simultaneous activity is defined as an activity that entails simultaneous deployment and/or operation of two strings, one for each well center (rig A and rig B). One of the most typical situations is when rig B is drilling riser less and rig A is deploying the marine riser [3],[17[,[5].

It is not possible to establish a set of detailed rules for such operations, as they are dependent on parameters such as water depth and well program requirements. However, some general rules should be followed in any simultaneous activity operation:

a) **Always** monitor by means of the ROV (and its sonar) the distance between the two strings. This applies especially to the bottom part of a string during deployment.

b) Keep in mind all the time that the behavior of the two strings with respect to each other may be strongly dependent on their attitude with respect to the current. In other words, a change in vessel heading may affect the relative distance between the two strings.

c) A rotating drill string (whose bit is already below the mud line) underwater will tend to bow if subject to a certain current profile. In general, stronger currents and high revolutions will cause larger sag on the string. Sagging of the drill string will disappear if the strings stop rotating.

Transit with hanging riser

In certain situations, when wells to be drilled are not too far away from each other, it may be worth considering not to retrieve the riser string but simply to drag the deployed string from one location to the next.

Even though some guidelines are provided in this section, it is to be clear that this type of operation is to be evaluated on a case by case basis [7],[18].

1) Clearly establish the environmental characteristics of the two locations where wells have to be drilled, as well as the transit details. In particular:

Water depth at both locations

- Environmental parameters at both locations (especially waves and currents)
- Course to be followed by the Rig from the first well to the second
- Seabed profile along the course between the two wells
- Any peculiar information about environment between the two wells (e.g., localized currents, wave direction, etc.)

2) By means of the RMS, perform an off-line dynamic analysis in the riser hanging mode, according to the guidelines already given in the previous sections. Make sure to take all differences from a normal hanging riser situation into account (e.g., during a transit the BOP is probably part of the string). The hanging riser evaluation shall take the following into account:

- The transit speed of the Rig shall be superimposed to the current profile
- Pay special attention to the correct definition of current direction at different depths, as well as vessel heading with respect to the wave direction
- If the information available about current profiles and/or wave direction is not deemed very reliable, then the most conservative assumptions shall be used.

3) Basic assumptions for the hanging riser analysis:

- The current profile is in the same direction of the current flowing against the string as a consequence of the vessel's velocity
- Increase the environmental current velocities by 20-30%

4) Assume that the waves are directed across the beam of the vessel.

5) If the extreme environmental conditions of the area appear to be too demanding for the operation, then limitations on the acceptable environmental conditions in which the operation can be carried out shall be given.

6) In any case, it is suggested that several current and wave simulations are run, in order to perform some kind of sensitivity analysis.

In operation, the following guidelines shall be followed:

- After riser disconnect, retrieve enough joints to make absolutely certain that there will be no interference of the seabed with the string.
- In any case, the riser shall be hung off by the tensioners connected to the TJ.
- It is recommended that the ROV is left attached to the BOP frame with the purpose of carrying out a survey during the transit.
- It is recommended that all active RMS sensors be monitored to detect unusual or degrading situations (for instance, increasing URA because of different current velocity against the string and/or worsening of vessel roll and pitch motions).

Post-retrieval checks

After the riser string is retrieved, the riser and BOP systems shall be checked to verify their general condition.

All recommendations included in the equipment relevant user's manuals shall be adhered to.

Over and above all normal maintenance procedures, the following actions shall be taken:

- Report of any unusual situations observed (e.g., corrosion, leaks, broken buoyancy or centralizer modules, loose clamps, damaged cables or hoses, etc.)

It is important to make clear that the checks of the systems after retrieval have two main purposes:

- Detect components that need to be repaired or replaced.
- Investigate the reason WHY the problem has occurred. It is not enough to know that something needs to be fixed or replaced. The main point is to prevent the problem from happening in the future.

Special attention shall be paid to check the following details:

- IRJ: clamping of strain sensor rings to main tube (check for straightness and loose items)
- IRJ: all instrumentation and cables
- All flex joints: check for wear on the internal surfaces. Excess wear at the lower or upper flex joints may indicate improper data from the RMS (or faulty inclinometers)
- Fill-up joint valve assembly
- LMRP: all cables and connectors

Fatigue analysis

Once the operation is completed and the riser retrieved, it is possible to proceed with additional analytical work intended to estimate accumulated fatigue damage and operating time for individual riser joints.

Fatigue analysis is a very useful tool to select the components of the riser system that have accumulated more fatigue damage and should therefore be inspected.

It is extremely important to make sure, during operations, that the sea state information is entered on a regular basis in the DP Operator Station.

Reliable information on sea states during operation is of the essence for obtaining usable fatigue analysis data.

Reference is made to the relevant sections in the RMS Program Operation Manual.

It is important to remember that fatigue damage is accumulated mainly because of alternating stresses due to bending moment variations along the string.

As a consequence, the time to be considered for accumulated fatigue damage is for connected riser only. Time spent in hang-off mode is not relevant for fatigue analysis.

Besides, it is to be kept in mind that the results provided by the RMS for the accumulated fatigue damage are not meaningful as an absolute indication of the remaining lifetime, but is to be regarded as a parameter to compare fatigue damage between different joints belonging to the same system but having different operating histories.

CONCLUSIONS

In order to be reasonably sure that the EQD sequence will succeed, the LRA is to be lower than 6 deg and a certain tension is required at the LMRP connector. The value of the applied top tension has to be higher than the weight of the string in the water plus the wet weight of the LMRP since a certain acceleration is to be imposed in order to free fast enough the area.

The moment in which the LMRP connector opens up constitutes a huge discontinuity point for the riser system that passes from a configuration of a beam tensioned at both the ends to a beam hanging on the top and free to move on the bottom.

The passage from one configuration to the other will happen after a certain time through axial oscillations of decreasing amplitude during which it is important to avoid compression in the riser joints.

A proper distribution of heavy slick joints in the bottom & top part of the string will take care of the elastic energy freed by the event so avoiding unwanted compression instability phenomena.

The riser anti recoiling system will accompany smoothly the string in its upward movement offering afterwards a reliable hanging off system for the disconnected string.

As already said, the string axial dynamic behavior can be schematically re-conducted to a system composed of masses interconnected by means of springs.

The action of the surrounding media (sea water externally and mud internally) will dampen the phenomenon with an action proportional to the square power of the relative velocity.

The down forces generated by the sea water are in any case "well" directed since they try to react in any case against the oscillation of the string (downwards if the string is going upwards and vice versa).

Environmental considerations are not applicable in this as in all the cases linked to emergency situations.

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