Drilling riser monitoring for improved offshore drilling operations

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During riser operations in deep water and harsh environments, it may be a challenge to maintain operability and riser integrity. The Riser Management System (RMS) delivered by Kongsberg Oil & Gas Technologies is developed to gather relevant measurements in real time during operations and combine the available information in a way that gives the operator continuous advice on where to position the vessel together with the current operational margins for all parameters associated with the riser. In complex and strong seas, the ability of the RMS system to predict the optimum vessel position, as well as to monitor the full state of the riser has made it a standard system for most new drill vessel builds. Kongsberg has delivered Riser Management Systems since 1995 and is currently the market leader with more than one hundred installations worldwide.

This article gives an introduction to offshore drilling with a marine riser, the loads that the riser is subject to, and the potential failures that may occur. The flex-joint joints that are part of the riser are among the most significant operational parameters that determine if a drilling operation can be performed or continued safely. Knowing the risk and failure modes, mitigation actions to avoid or reduce risk as well as extending the operational window using monitoring and decision support features of RMS are described.

Offshore drilling vessels

Offshore drilling is performed from floating drillships and drillrigs, commonly termed as a mobile offshore drilling unit (MODU). These drilling vessels are custom build vessels specially designed and equipped for drilling and completing subsea wells. When a new exploration or production well is required, the vessel will arrive at the location, drill the well and then leave for the next assignment. Once the well is prepared, other units designed and equipped for production, such as e.g. a FPSO will be connected to the well. Most of these drilling vessels use dynamic positioning (DP) to keep position during the drilling operation. That means that they use their thrusters to stay on location instead of anchors. This is an advantage since the time to prepare for the operation is minimized and since anchors are not applicable in deep water. The drillships have a ship shaped hull, and the rigs are platforms with legs standing on pontoons under the waterline. The advantage of the ships is that they can sail faster than a rig between locations, whereas the advantage of the rigs is that they are more stable in heavy seas. In Norwegian waters the rigs dominate, however the majority of new builds are drillships.

The obvious challenge of offshore drilling is the water, where the drilling equipment is on board the vessel, and the wellhead, which is where the subsea well starts, is on the seabed. The drilling riser is a temporary extension of the subsea wellbore from the stack at the wellhead on the seafloor to the drilling vessel on the surface where the drilling operation is performed. The drillstring, as well as casing and tools, are operated through the riser, and it also serves as a conduit for the circulating drilling fluid during the drilling operation. During the drilling operation, the riser is subject to large loads from the environment in the form of wave and current loads, and from vessel motions.

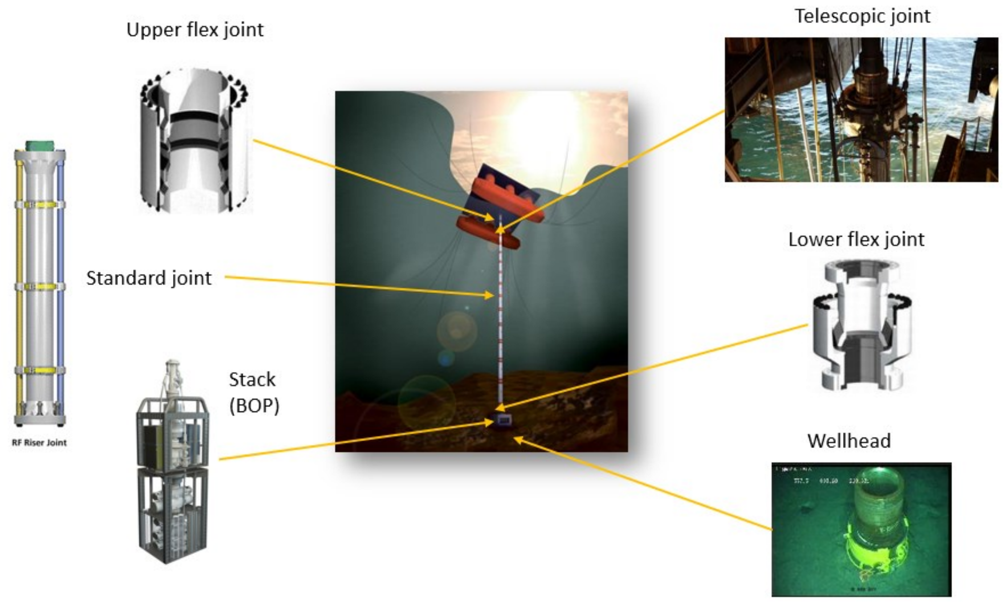

Fig.1 The drilling riser is made up of many joints, some with special purposes

The riser is tensioned at the top to prevent it from collapsing due to its own weight.

The drilling riser by parts

The drilling riser is made up of many parts called joints, which are deployed from the vessel for each new well and modified to the water depth at the present location, see Fig.1. Several of the joints deployed in the riser are designed for special purposes. The wellhead is at the bottom fixed to the seabed. It is the termination of the subsea well and is not a part of the riser itself. The lower stack, made up of the blow-out preventer (BOP) and lower marine riser package (LMRP), is latched onto the wellhead and serves as a well control system preventing uncontrolled blowout from the well. At the top of the stack there is a flexible joint, or ball joint, termed the lower flex-joint. If the riser is bent due to environmental loads, this joint will bend to take up the bending moment and protect the BOP and wellhead. Continuing from the lower flex-joint are standard joints with and without buoyancy modules. The riser is fixed to the seabed, but the vessel is moving up and down with the waves. To compensate for this heave motion, a telescopic joint is placed at the top of the riser. This is two moving pipes inside each other where one is fixed to the riser and one is fixed to the vessel, allows the rig to move up and down without damaging the riser. Finally, an upper flex-joint compensates for the vessel roll and pitch motions.

Riser operation window and failure modes

These special purpose joints ensure the structural integrity of the riser. The telescopic joint prevents excessive stresses and the flex-joints prevent failure due to excessive bending moments. However, the flex-joint introduces an angled section, a discontinuity, on the riser which it is not possible to drill through if the angle typically exceeds three degrees.

The weather offshore can be very rough with large waves and strong and rapidly changing Fig.2 which is borrowed from YouTube and shows the telescopic joint. From this is easy to imagine that the drilling riser can suffer great wear and tear and is subject to failures. Some

Fig.2 The riser may be subject to great loads in bad weather conditions Offsore, sea waves

Fig.3 Buckling is the result of insufficient top tension

Fig.4 Key seating is the result of excessive riser angles. Here contact with the drill string has worn down the walls

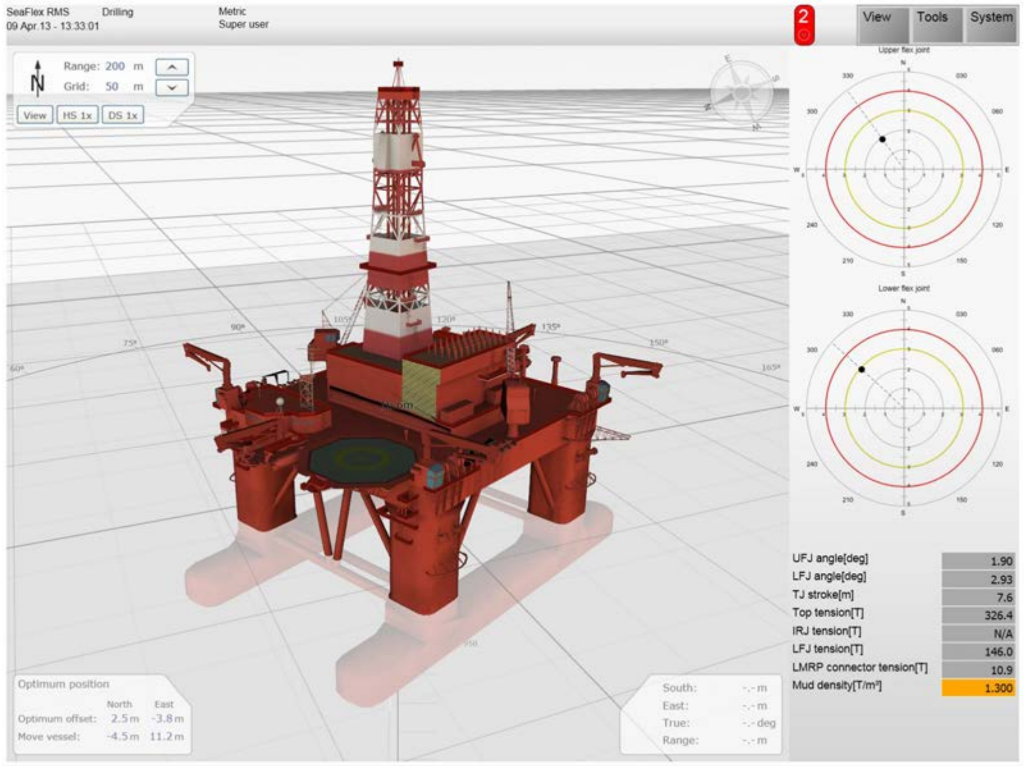

Fig.5 The user interface is important to ensure that the operator has the best possible situational awareness as basis for decision making

examples are buckling, which is due to insufficient top tension, see Fig.3, key seating resulting from excessive riser flex-joint angles causing contact between the drill string and riser wall that can wear down the riser walls, see Fig.4, and rupture which is due to excessive loads or fatigue. Assuming a day rate for a drilling vessel exceeding USD 500.000 the delays caused by such damage is significant, not to mention the cost to replace the equipment and the risk of potential environmental damage from an uncontrolled blow out.

It is important to avoid damage on the riser and the wellhead, and a key purpose of operational riser monitoring is to identify the risk for such damage so that corrective action can be performed.

Operational monitoring

The Riser Management System (RMS) is a software based solution that combines an advanced numerical model with real-time sensor measurements collected from sensors and systems onboard that affects the riser, such as e.g. the DP system, the drilling control system, the tensioner system, the BOP control system and the acoustic position reference system.

To supports the operator in understanding the situation and make the right decisions RMS has introduced a situation view in 3D that allows the operator to navigate in a virtual space to inspect different aspects of the current operational situation, either by taking a step back for overview, or by zooming in to examine the details. The advantage of this technology is the improved operator perception of the actual situation that contributes to enhanced situation awareness. Examples of the situation view are shown in Fig. 5,6, and 7.

Reducing nonproductive time

But RMS can do better than just presenting data and monitoring with alarms on critical operational parameters. When the collected real-time data is combined with the embedded engineering know-how, the system can provide the operator with something more valuable, decision support. In this way the system can contribute to eliminating guesswork and sub optimal solutions. The advantage is reduced risk, reduced down-time and reduced wear and tear of the equipment.

Recall that the most critical operational parameters are the flex-joint angles and the telescopic joint stroke. Neither of which can be directly manipulated by the operator. There is a linear relationship between the flex joint angles and the vessel offset that RMS exploits to transfer the operational limits to vessel positions on the surface. The system can then determine the surface vessel positions that will keep the upper and lower flex-joints within the operation limits respectively, and also the optimum position that will minimize the angles. By following this advice and tracking the optimum position, the operation window for the vessel can be extended, even when the environ-

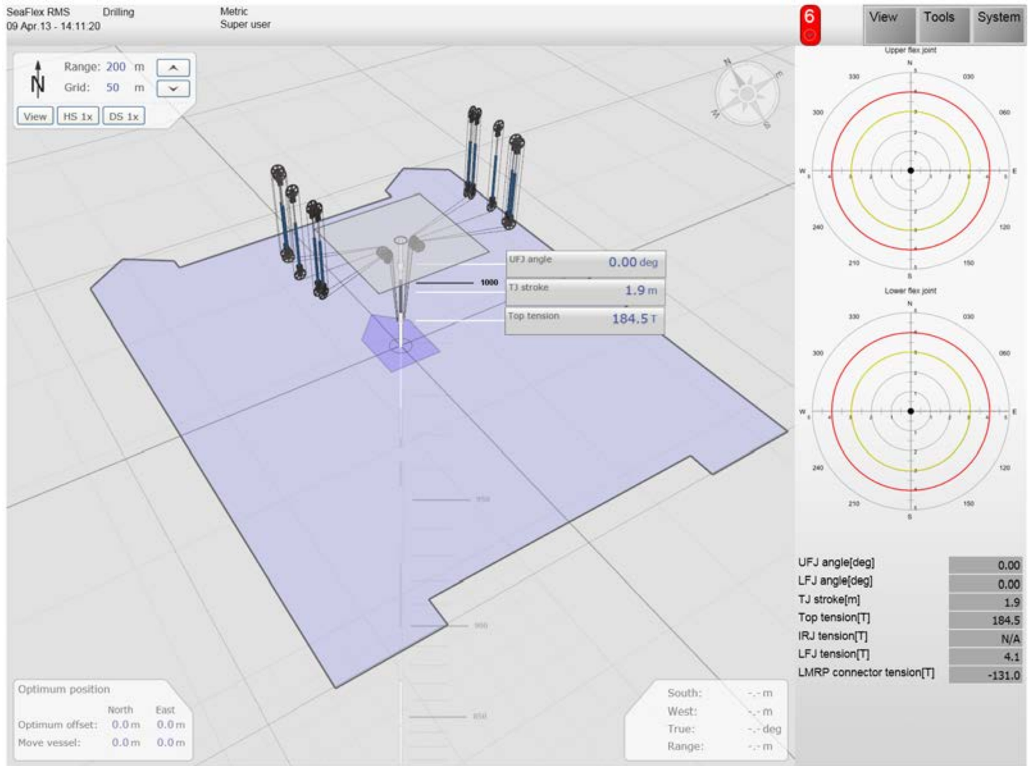

Fig.6 The tension system is one of many subsystems that can be investigated through the RMS user interface

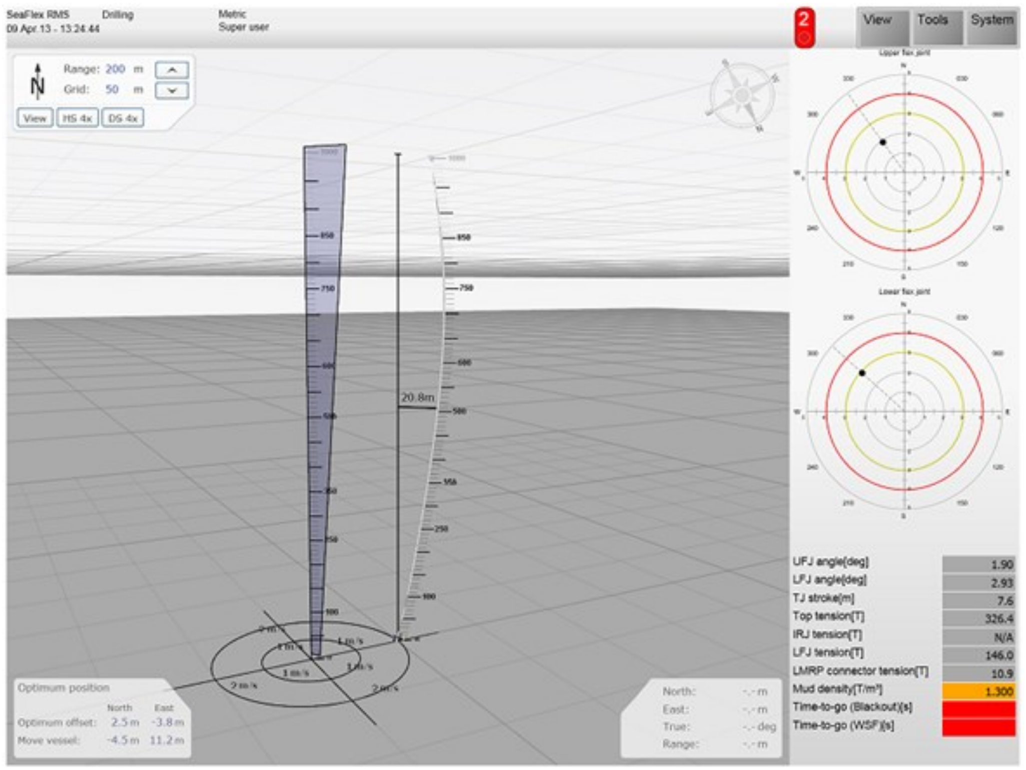

Fig.7 Riser shape and ocean current profile visualized in RMS allows the operator to take a step back and view the full riser shape

mental loads are significant. The optimum position and the dynamically computed operational limits used for position advice are shown in Fig.8.

Future applications of the Riser Management System

With the current trends in the industry, operations are becoming more and more challenging, introducing heavier equipment, deeper waters and harsher environments. At the same time the average level of experience of offshore operators is dropping. This emphasizes the need for operational tools for decision support in operations, such as the RMS, for ensuring save and optimal drilling operations in the future.

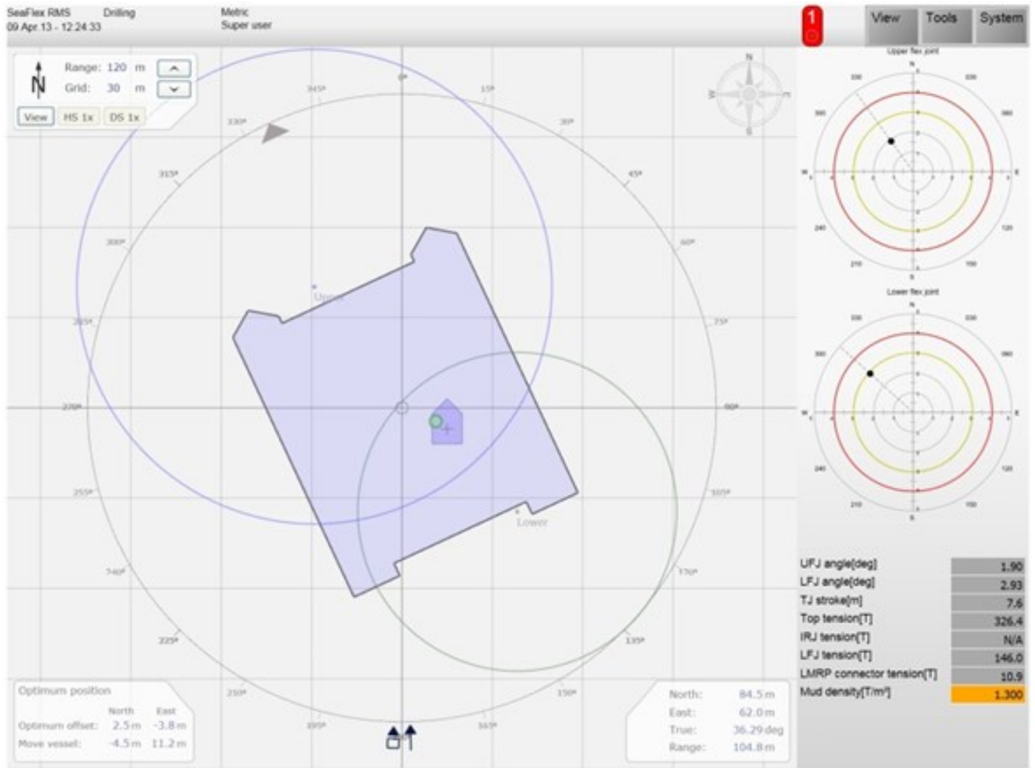

Fig.8 The optimum position advice is the most important system feature. Following the optimum position advice may increase the operation window

Insight into Upper Triassic depositional environments and stratigraphy from the Svalbard Archipelago, inferred from palynology, sedimentary organic matter and geochemistry

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Insight into Upper Triassic depositional environments and stratigraphy from the Svalbard Archipelago, inferred from palynology, sedimentary organic matter and geochemistry.

The Barents Sea and Svalbard Archipelago are increasingly the focus of academic research. This is primarily related to the regions hydrocarbon prospectivity and the UNIS CO_2 storage project in Spitsbergen.

Outcrop samples from Juvdalskampen and Botneheia sections from central Spitsbergen are used to reconstruct the depositional environment and to correlate the Triassic Kapp Toscana Group with the regional stratigraphic frame. This is approached by an integrated sedimentary organic matter and biostratigraphic study. The interval studied is the lateral equivalent of the Snadd Formation in the Barents Sea. These formations consist of alternating mudstone and sandstone sequences with an overall increase in sandstone from the base to the top.

Previous studies described that the Svalbard Archipelago was located at the northern rim of the supercontinent Pangaea in a shallow shelf setting at the time of deposition about 220 Ma ago. Over time progradation of deltas converted the shallow marine environment into a paralic setting with deposition of terrestrial sediments.

In this study a total of 60 samples were evaluated. The organic matter was mounted on microscope slides and carbon isotope values were measured for intersection correlation.

The top of the Botneheia Formation contains increased amorphous organic matter and palynomorphs indicative for a restricted environment. Above, the Tschermakfjellet Formation is dominated by terrestrial organic matter, with occasional marine forms therefore presumably deposited in a prodelta setting. The overlying De Geerdalen Formation is dominated by degraded plant debris and wood particles and towards the top of the formation the amount of freshwater forms increases. Together with superabundance of certain spores taxa and thin coal seams results in this being indicative of a terrestrial humid swamp setting. Finally, the Knorringfjellet Formation is characterized by an increase in marine palynomorphs. This indicates a transgression and shift back to shallow marine shelf conditions as part of a new depositional cycle.

The interval is subdivided into five biostratigraphic zones. Each zone is characterized by distinct assemblages of palynomorphs which can be used for correlation, plus integrated with regional palynomorph schemes. Bulk carbon isotope values then also allow independent correlation. The results indicate a Carnian age for the whole succession. In more detail, the Tschermakfjellet Formation is of Julian 1/I age and the De Geerdalen Formation of Julian 1/II to Julian 2 age.

Mueller, S., Hounslow, M.W. & Kürschner, W.M. (under review). Integrated palyno-, magneto- and carbon-isotope stratigraphy of the Upper Triassic Kapp Toscana Group in central Spitsbergen (Norway).

Mueller, S., Veld, H., Nagy, J. & Kürschner, W.M., 2014. Depositional history of the Upper Triassic Kapp Toscana Group on Svalbard, Norway, inferred from palynofacies analysis and organic geochemistry. Sedimentary Geology 310, 16-29. DOI: 10.1016/j.sedgeo.2014.06.003

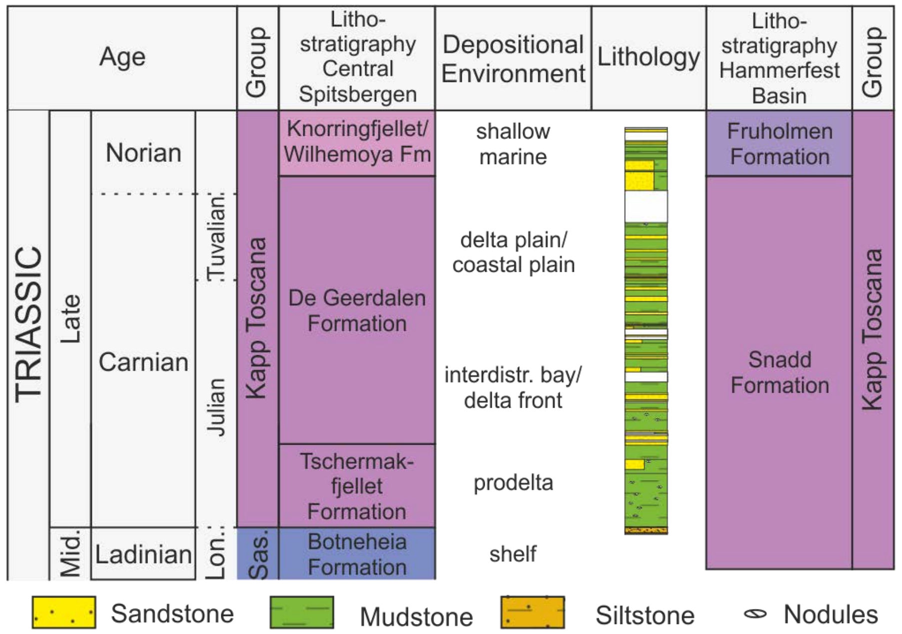

Fig.1: Summary of depositional environments and regional stratigraphy of the Kapp Toscana Group from central Spitsbergen