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Drilling Optimization Service Solutions for Overcoming Difficult Dynamic Conditions in a Deepwater Drilling Campaign: A Case Study

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Abstract

Deepwater exploration is essential because of the scarcity of hydrocarbons, increasing demand and depleting reservoirs. Many countries like India started extensive operations in deep water, looking for oil or gas to fulfill local demand. The commercial production is possible when the initial investment is minimal and returns on investment must be as early as possible. Fundamental to the successful delivery of any well is to identify a well's unique challenges and understand the drilling risks and performance barriers that can result in non-productive time. Gaining knowledge culminates in the development of drilling solutions that deliver customized technologies, optimized drilling parameters and operating procedures. The resulting what? provides the means to effectively reduce wellbore delivery costs and operational risk, improving operational performance safely, reliably and efficiently.

Worldwide deepwater activities increased significantly, making effective service solutions essential. Real-time remote drilling advisory services provide 24/7 surveillance and interpretation of the drilling information via real-time monitoring, enabling appropriate recommendations to optimize drilling parameters to avoid known non-productive time. These remote drilling advisory services ensure collaboration with the drilling team to mitigate drilling performance barriers. In this paper, case studies are presented that are related to efficient drilling, reducing the risk of stuck BHA, recommendations and lessons learned from a few deepwater wells drilled in areas with water depths of more than 500m. The effectiveness of the process is described in brief: BHA design, torque and drag analysis, real-time ECD management, vibration analysis, proper utilization of available LWD data, optimizing drilling parameters to ensure maximum mechanical specific energy is delivered at the bit, bit selection for maximizing ROP and documenting best practices. The pie chart of timing of all the operations from spud to rig move gives a clear picture of time utilization and room for improvement.

Introduction

Well complexity and drilling data have increased substantially in the last decade. There is a shortage of drilling specialists available to manage and analyze the real-time drilling performance process. Taking the data to the drilling specialists at real-time monitoring centers is more cost effective than utilizing one specialist per well per rig. Drilling optimization solutions comprises the integration of real-time well information such as gamma ray, resistivity, acoustic, neutron/density, real-time image data, mud logging data, drilling events, pore pressure and fracture gradients, with historical data from offset wells, geophysical logs, litho-facies and correlated well events. The information enables the operating window to be adjusted with more certainty, maximizing the operational parameters and applying the best technologies available. The result is valuable engineering deliverables including alerts, recommendations, proposals and programs issued in a pre-emptive fashion, thus optimizing the real-time decision-making process, which is essential in deepwater environments to minimize the cost.

Real-Time Drilling Optimization

The ideal drilling optimization must provide solutions in the following areas:

- Rig time analysis
- Pore Pressure and fracture pressure, including safe mud window, geomechanics, stresses, LOT and FIT
- Monitor and adjust drilling parameters for efficient drilling
- Analysis of hydraulics, torque and drag, swab and surge, fluid rheology and ECD management
- BHA vibrations, stick slip analysis and mitigation
- Maximum MSE delivered at bit, ROP and bit selection
- Casing design, casing point determination and cementing operations

Rig Time Analysis

The first step is to monitor and analyze total rig time, which is the time from the spudding of the well to the rig move. This time analysis gives data about where the extra time is spent, where there is room for improvement and what are the possible alternate options to save rig time. **Fig**.**1** shows a pie-chart of the total rig time, the actual hours and percentage with total rig time.

The data in Fig.1 presents rig timing data from spudding to rig move. This data is only for illustration. In this particular example, it shows maximum time about 30% is utilized for drilling, which is considered as a good average. Fig. 1 also shows that about 4% of the time is lost for well control, 18% of the time is used for tripping, 17% of the time is used for wireline logging and about 2% of the time is used for rig repair. The DO Engineer can check and analyze individual data and suggest recommendations because he/she knows the best practices followed on other rigs.

The aforementioned example comprises the data of just one well. It is helpful to pinpoint individual well-related issues and find possible root causes and remedial actions. Similarly, if a comparison is performed between a number of wells in the same field, area and rig, the comparison gives more in-depth knowledge for finding a solution for optimizing and reducing delivery time.

The time varies according to the depth drilled, but, it gives good base for individual time analysis and also gives idea about where more focus should be put. It should not be the comparison between rig performance, but, concentrating on NPT and actions need to be taken to reduce it. The drilling optimization engineer concentrates on low drilling time and high circulation time. In most cases, large amounts of rig time were utilized for well control operations, circulation for adjusting the mud weights or clearing the cuttings.

Pore Pressure Prediction and Mud Weight

The workflow for performing a conventional 1D pore pressure analysis comprises calculating the overburden gradient and determining the pore pressure, fracture and shear failure gradient.

The ultimate goal is finding the theoretical or ideal mud weight for drilling, which does not cause wellbore stabilization problems. It is difficult to achieve an ideal situation; therefore, it is generally given in the range of mud weights, which is called drilling mud window. If the mud weight is too low, the lack of wellbore support can induce rock compressive (shear) failure. However, if the mud weight is excessive, it can induce hydraulic fracturing (tensile failure) of the rock. The sigma(**σ**) 1, 2 and 3 are the principal stresses and are perpendicular.

Borehole Breakouts from Image Logs

Depending on the mud weight during drilling, the real-time density image logs give the indication of breakouts or local fractures. If breakouts are observed during drilling, mud weight can be adjusted to reduce or eliminate borehole stability problems. **Fig.4** shows the breakouts observed that indicated the mud weight was not enough and must be increased.

Mechanical Specific Energy and Bit Selection

For efficient drilling, other parameters monitored include torque, preferably downhole torque, surface RPM, WOB, mud rheology and drillstring vibrations. Another important parameter is the Mechanical Specific Energy values in real time. The general MSE formula is:

MSE = [((4*WOB)/(3.14*BS*BS*1000))+((480*RPM*TRQ)/(BS*BS*ROP*1000))]

The MSE must remain as low as possible and the rate of penetration (ROP) must remain as high as possible by varying weight on bit (WOB), rotary speed (RPM)/ torque (TQA) and mud flow within normal operating limits.

Fig. **5** is from a deepwater well**.** The change in formation (harder) contributed to the increase in torque, and hence, the increase in average MSE from X100m to X500m.

MSE values are used as a trend that the crew monitors and gets used to its behavior. Normal MSE behavior later in the well and on succeeding wells provides confirmation of consistent performance and warnings of deviations from expected performance, up to and including earlier detection of drilling problems. It is a good plan to adjust drilling parameters to minimize the value of MSE.

Drilling Dynamics and Vibration Analysis

Movement of the drill string within the wellbore and the drill bit interaction with the formation generate potentially harmful downhole vibrations. Vibrations are inevitable because drilling a well is a dynamic process. Low-level vibrations can be tolerated. However, severe downhole vibrations can affect log quality and may also result in tool damage or failure. Most of the RSS tools and some instruments incorporate vibration stick-slip (VSS) sensors to monitor downhole dynamics so corrective action can be taken in real-time. Three modes of vibration are possible: axial, lateral or torsional (one, two or all three may be present depending on prevailing conditions)

An example of a downhole axial vibration is bit bounce, which can be observed at the surface as “Kelly bounce”. An example of a downhole torsional vibration is rotational stick-slip, which is seen at the surface as periodic fluctuations in drilling torque. Downhole lateral vibrations (also called bending vibrations) are strongly attenuated in the drill string and rarely reach the surface, but can be the most damaging vibration in the least amount of time. An example of real time vibration data monitoring screen shot is shown in Fig. 6.

Case Study 1:

In well XX, the rig used a practice of back reaming with a low flow rate of about 105 GPM. There was an increase in torque, hook load and pump pressure that indicated the hole getting packed off. It was also compared with torque and drag analysis done before the start of hole section. The drilling team was recommended by the drilling optimization engineer to back ream with optimum parameters of at least 70% of drilling parameters. The recommendations were implemented, possibly avoiding future hole pack problems, which could have arised.

Case Study 2:

In well YY, a drilling break was observed from 4m/hr to 70 m/hr. A flow check was performed that showed a gain of 2.6 Bbl in 20 min. The well was shut; SIDPP (Shut in Drill Pipe Pressure and SICP(Shut in Casing Pressure) were both 0 psi. This was giving indication that the well is stable. Then started circulation of one cycle upto BOP and then through choke. No gas or change in mud properties were observed. The mud weight was increased by 0.3 ppg. A flow check was performed to know the gain and then the well was shut in to monitor any pressure changes. There was no pressure indication on SIDPP or SICP.

Actually, after shut in check, the well should have been flowed for a longer period.. Since there was no pressure while shut in, there was no need to increase the mud weight.

Increasing mud weight increases overbalance and reduces ROP. Unwanted increase in mud weight also increases the chances of losses and reduces the possibility of reaching TD.

Results and Discussion

The drilling operations and parameters must be monitored remotely by dedicated and experienced drilling optimization engineers. The process of real time monitoring, interventions, comparison with available data from same field, enables the circumstance to be examined by a third party with a different perspective. In the first case, the decision was taken proactively at a right time and possible stuck up situation was avoided. Any more delay in circulating with higher GPM, could have made the hole conditions severe. In the second case, even though there was no need, the mud weight was increased, resulting in losses. It took a couple of extra days to control the losses and resume drilling.

Conclusion

BHA design optimization, proper selection of drill bits, rig time analysis, proper pre-drill modeling for optimizing mud weight during drilling, operational limitations and real-time monitoring/recommendations can deliver significant savings in drilling time and, ultimately, rig cost. The aforementioned causes are especially important in deepwater environments because of the difficult dynamic conditions starting from top hole section to deeper 8-1/2” sections. Real time drilling optimization through real time data monitoring centers is proved very effective and cost saving. The database and lessons learned are beneficial for planning the next well and reducing NPT. A good understanding between the operator, drilling contractor and service company personnel from real-time centers is the key to success for an efficient drilling campaign in deep water.

References

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Figures and Tables:

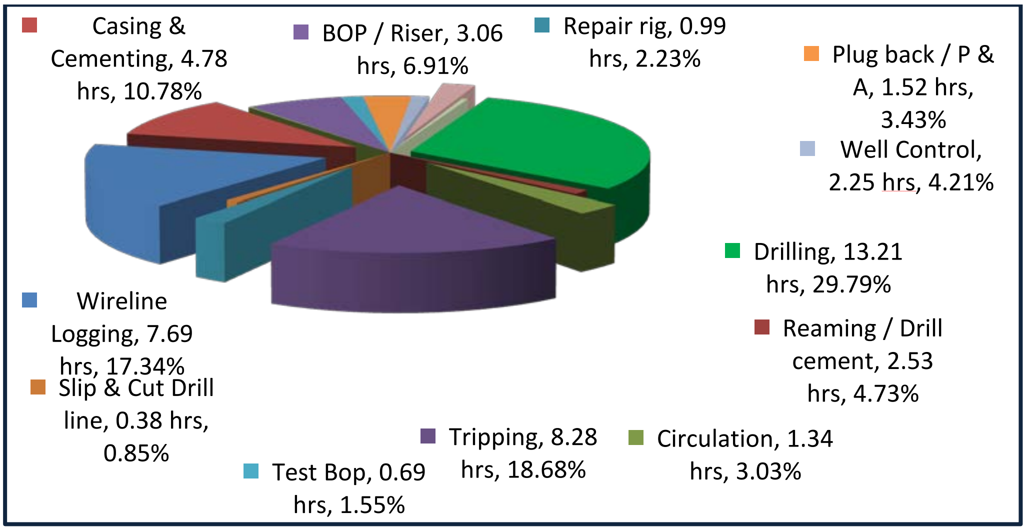

Fig. **1**: Pie chart of rig timing from rig spud to rig move

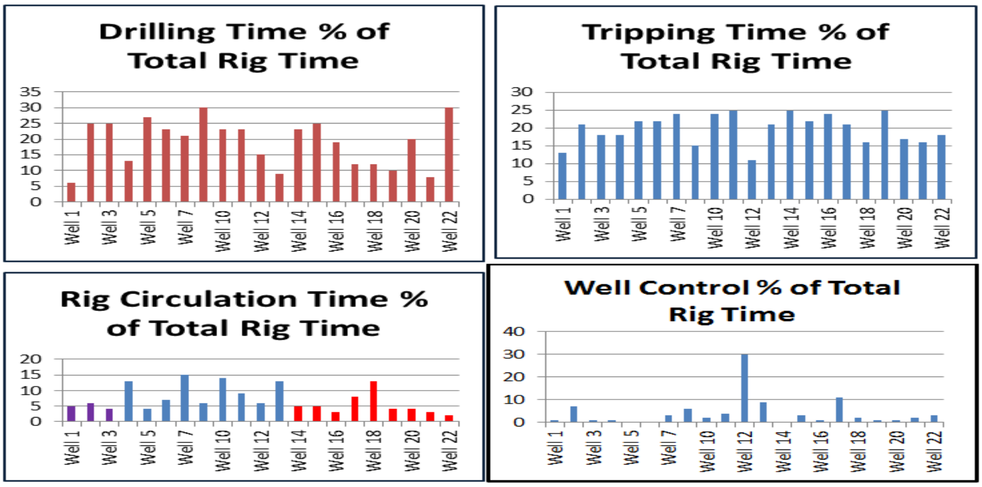

Fig. **2**: Charts show the data from various deepwater wells drilled with various rigs.

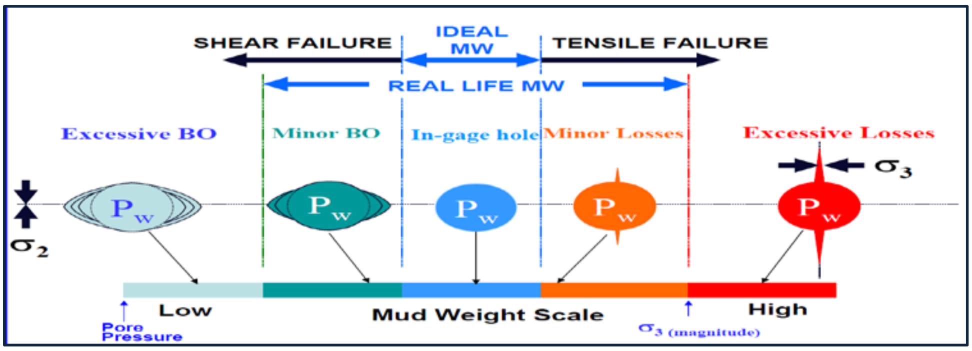

Fig. **3**: Mud window shows the effects of various mud weights on the formation failures.

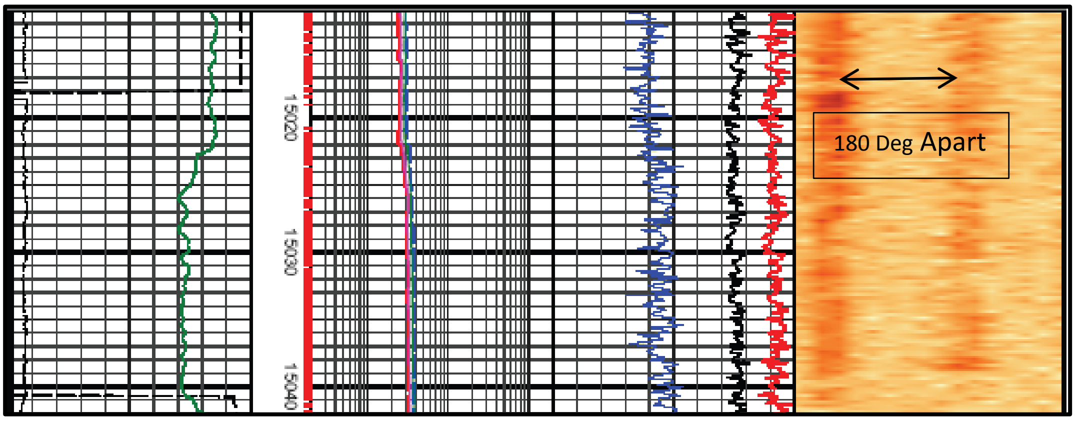

Fig. **4***:* Oriented breakout associated with changing mud weight (16 sector ‘raw’ density image). Breakout is observed on opposite side of the borehole. The non-image tracks contain standard gamma, resistivity, density and neutron curves.

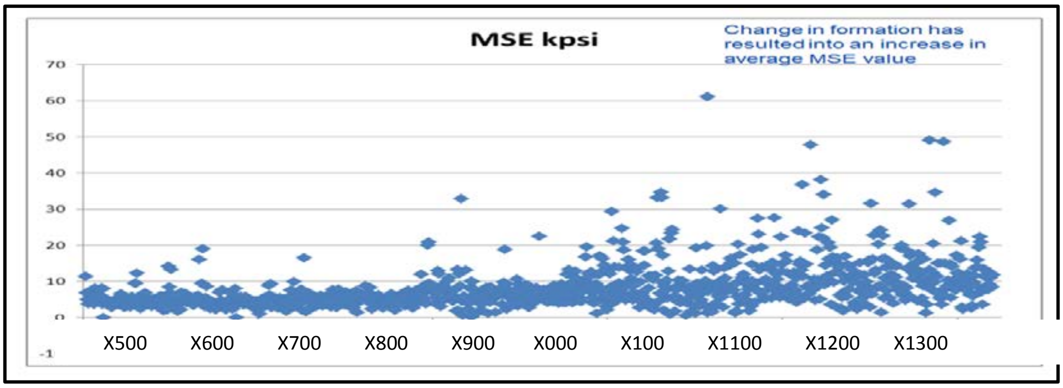

Fig. **5**: The figure shows MSE values in kpsi plotted on the Y axis and the measured depth on the X-axis. The average MSE is about 5 kpsi until about X100 m depth. After X100 m, there is an increase in the average MSE values because of formation changes

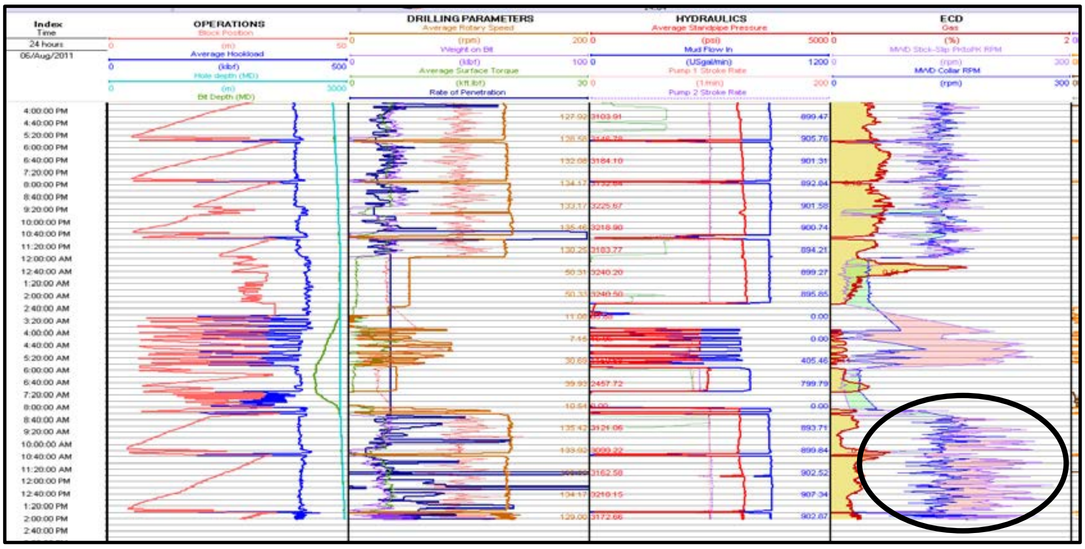

Fig. **6**: Real-time data monitoring screen shot. Every track has one group of drilling parameters. At the end of the log in track 4, lateral vibrations and stick slip increased and drilling stopped.