Simulation can help optimize drilling and cut costs

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THE CONSTANT NEED to reduce exploration and development costs has resulted in the development of the new phase drilling optimization simulator. Drilling can now be simulated during planning and pre-execution phases.

Simulator technology has been used in reservoir and completion optimization for decades. The use of simulation technology in design, testing, and training has grown rapidly.

Simulation should be a must in drilling planning, during drilling, and in making a post well drilling analysis.

EVALUATION TOOL NEEDED

In the past, drilling optimization has been complex and uncertain. There was a heavy reliance on "on the fly" decision making, which requires highly experienced personnel.

Recently, several service companies have tried to improve the drilling process by organizing groups of experienced personnel to be involved in the planning and execution of the drilling operation.

But because experience gained in one location is difficult to apply to new locations, it is not easy to quantitatively evaluate operating conditions and parameters before they are changed.

A scientifically-based evaluation tool has been needed to permit improvement in the drilling operation.

This article shows that use of a drilling simulator can optimize the drilling process and quantify the degree of improvement possible. Also demonstrated here is the expanded use of rock property data to enhance tool selection and operation.

The drilling optimization process can be separated into five identifiable phases:

- Data gathering and study;
- Apparent rock strength generation;
- Simulation;
- Real-time analysis;
- Post analysis.

The last four phases involve the use of the drilling simulator.

The data gathering and study phase builds a knowledge base of the facts and experiences gained while drilling in a particular area.

All offset well data are studied to identify potential problems. The goal is to minimize or eliminate these problems and establish limits based on information acquired from the study and equipment used while drilling.

APPARENT ROCK STRENGTH

The next phase involves selecting a reference well which closely matches the planned well.

Using the data from the reference well, an Apparent Rock Strength Log (ARSL) is generated by the inversion of the "bit specific" rate-of-penetration model. The effects of drilling hydraulics, mud rheology, and pore pressure are integral to the model.

The inverted rate of penetration provides a calibrated measure of rock strength under actual drilling conditions and simultaneously determines the wear characteristics of the bits used in drilling each section.

This wear characteristic is a statistical evaluation of the bits' performance while drilling different formation types under a variety of operating conditions and includes detailed bit geometry and resistance to wear.

Where detailed section data are available, for example in logged sections, these data and neighboring well data are included when generating the ARSL.

Figure 1 shows that there is credence to the application of rock strength data from an offset well as if it were similar to the rock strength profile of the proposed well. The offset well data provide reasonably accurate results in correlating data from neighboring wells to planned wells.

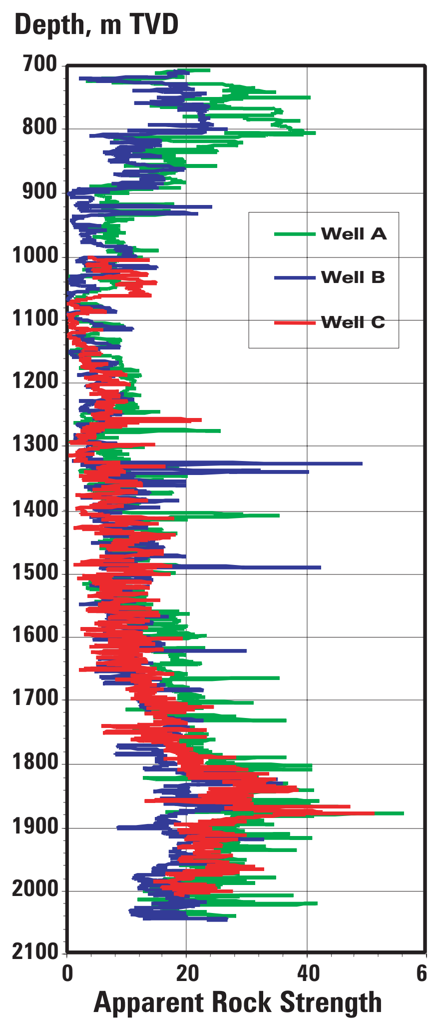
Three wells drilled in the Norwegian sector of the North Sea were used to conduct this comparison. The ARSL was independently generated for all three wells and the result overlain on a true vertical depth basis. No data were available for the upper part of Well C.

While there are local variations in the ARSL values generated and some uncertainty in predicting the occurrence of geological structure, there is a remarkable correlation.

This may not always be the case. Thus, given better geological descriptions this log can be modified to provide a true representation of the formation to be drilled.

ARSL also has some associated applica-

Figure 1: Apparent rock strength



tions. This log provides an enormous application base and provides the basis for several related analyses that can be conducted to assist in a variety of common engineering problems encountered in drilling.

WELLBORE STABILITY

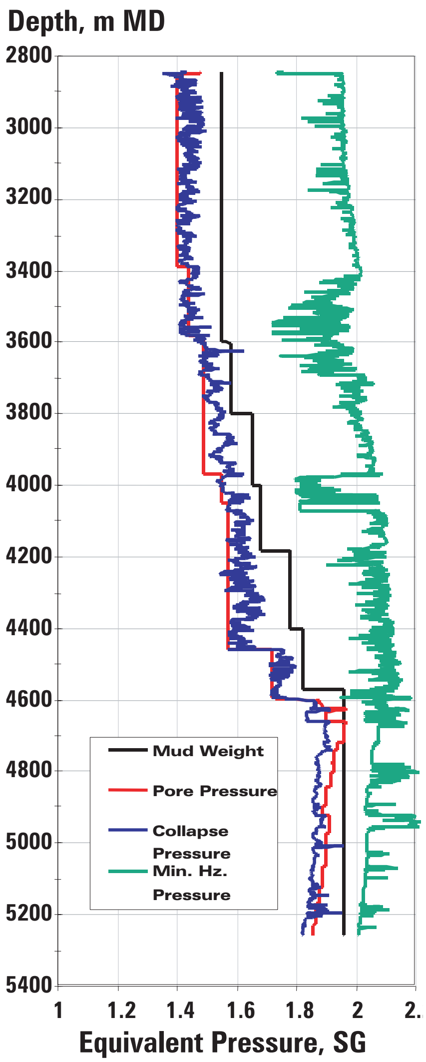
A wellbore stability profile is important to minimize the risk of wellbore collapse, pipe sticking, lost circulation, and other problems.

Knowledge of the operating limits on mud density, based on an established stable profile, minimizes the occurrence of these problems.

The ARSL represents the compressive strength of the rock in the same plane as the bit's trajectory.

In conjunction with pore pressure and well direction, this in situ stress is translated into three principal stresses around the borehole wall.

Figure 2: Stability profile



The principal stress can then be used with established failure criteria to determine the wellbore stability mud weight window with depth. A safe mud weight and casing program can then be determined.

Figure 2 is an example of the results obtained from conducting such an analysis using the ARSL.

The collapse pressure and fracture pressure curves define the lower and upper limit of the stability envelope.

Mud weights lower than the collapse pressure will lead to wellbore collapse and mud weights in excess of the fracture pressure will lead to wellbore fracture.

Care must be taken in mud weight selection to account for the equivalent circulating density (ECD). Optimum mud weight should therefore be higher than the collapse pressure to ensure that the hole is stable when circulation is stopped.

By the same token the mud weight should be lower than the fracture pressure by an amount equivalent or greater than the expected ECD.

STEERABILITY

Another application of the ARSL is in determining the ability of 3D rotary assemblies to steer effectively.

The relationship between the behavior of a rotary steerable bottomhole assembly and changes in apparent rock strengths can be determined by correlating tool behavior with data obtained from the ARSL.

This has been established from analysis conducted on several wells. By correlating the apparent rock strength with drilling and survey data, it has been possible to isolate relationships between dogleg severity of the steerable rotary assembly and formation strengths.

When the formations are very soft, the response of the steering tool is limited and the gravitational force plays a major role when modeling the total bottom hole assembly behavior.

As the formation gets firmer, the response increases up to a certain level on the drillability curve before the formation's internal resistance against directional changes overtakes the added response of the "push-off" action from the 3D steering tool.

The exact correlation for modeling this behavior is a relation established by using the ARSL and varies from location to location.

The end result can then be used to establish power settings for these steering tools, given hole inclination and operating data, to achieve a desired build and/or turn rate.

SIMULATION STUDIES

The third phase of the optimization process uses the ARSL in the drilling simulator.

It is used in combination with established casing points, well paths, drilling mode (rotary or steerable system), mud types, bit types, pull depths, operating conditions, and mud rheology and hydraulics to perform simulations.

The ARSL, with information from simulator modules, known limitations to operating parameters and rig equipment constraints, dictates parameter boundaries to be used.

These added simulator modules are the Wellbore Stability Analysis, Well Path, and Hydraulics optimization modules.

The effect of any number of drilling parameters and operating conditions within the prescribed limitations can then be evaluated.

The performances of several bits can be evaluated and the best bit, and the corresponding optimal set of parameters to use while running the bit, can be selected.

As part of the optimization process, multiple scenarios are evaluated, including:

- WOB/RPM combinations;
- Changes in operating parameters as a function of GDL variations;
- BHA configurations;
- Bit types including impregnated, NDBs, PDCs, and roller cone.

These evaluations can be conducted for separate bit runs or entire wellbore sections.

REAL TIME EVALUATION

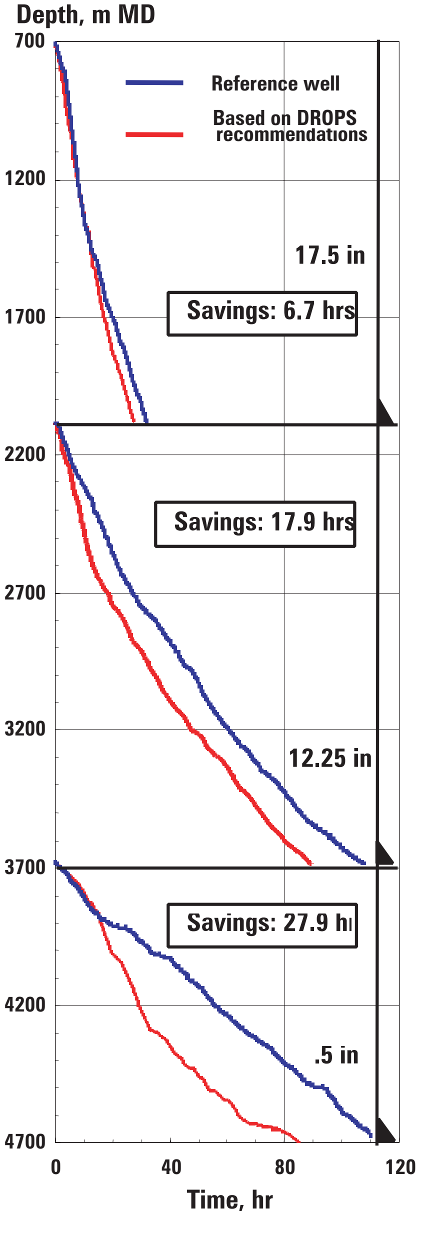
The follow-up phase involves a continuous evaluation of the drilling progress. During this phase updates are conducted to verify and, if needed, modify model predictions. Variations in operating parameters and lithology are continuously evaluated.

The resulting effects on predicted performance and bit wear condition are determined and relayed back to the drilling location.

Evaluation of stratigraphy to identify possible problem areas and variations in predicted stratigraphy are also conducted.

This process of re-evaluation has proved to be an asset since a real-time observed performance variation is usually an indicator of some anomaly.

Figure 3: Cost savings



POST WELL ANALYSIS

Finally, a comprehensive analysis of the operation is conducted to identify deviation from the predictions and possible reasons for the outcome. This is done to further improve performance in subsequent wells to be drilled in the field.

An important phase of the process is the refining of structural maps. Flaws in the history matching of the simulator should be identified and the simulator recalibrated for future use in that field. Post well analysis information is made available to all personnel involved.

Figure 3 demonstrates the saving potential that can be realized by judicious use of the new drilling simulator to perform well optimization.

In this well drilled in the Norwegian sector of the North Sea, there was a total time saving of 52.5 hours, compared with a previous well drilled in the field.

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Performance drilling is aim of the TMP approach

THEORETICAL MAXIMUM Performance (TMP) is a popular topic today. It is sometimes called by other names.

But whatever it is called, performance drilling is all about delivering a high quality well on time and under budget.

That is how the approach was described in an IADC World Drilling 2000 paper authored by **Govert Klop** and **Laas Elzenga**, **Deutag Europe** and **Bill Anderson**, **RLG Internationa**l.

"Technologically superior equipment is a requirement for performance drilling but the story does not end there," said the authors.

"To really achieve outstanding performance in the face of more sophisticated drilling challenges, a performance culture needs to be created in the drilling team."

THE CULTURE

By "culture" the authors refer to the demonstrated leadership and active involvement of the front line crew in applying their collective skills, experience, and commitment to the job.

The paper describes a system approach taken by Deutag Europe on a number of its advanced land rigs to create a performance culture.

The authors say the approach yielded tangible results in the form of shorter well delivery times, quicker rig moves, reduced surface equipment downtime, and shorter BOP test times.

There are two components of performance drilling, according to the authors: high technology systems and a proactive and positive work force focused on excellent performance.

A key element of the approach is the TMP meeting at which the well plan is thoroughly examined.

The authors recommend that a TMP meeting include 4 steps:

- Conduct a step by step well review;
- Establish Theoretical Maximum Performance times;
- Identify risks and opportunities;
- Create action plans.