Better bit performance will continue to cut costs

DRAMATIC ADVANCES have been made in bit design and cutting materials and much has been learned about how bits react to different forces.

But the ever-present pressure to reduce the cost of drilling continues to fuel advances in hardware and technique.

Papers prepared for the "Bits and Drilling Dynamics" session at the 2001 SPE/IADC Drilling Conference, to be chaired by **Dan Scott**, **Hughes Christensen** and **Pat Neal**, **Reed-Hycalog**, explore improvements made possible by new bit designs and enhance understanding of the drilling process.

SHORT RADIUS DRILLING

In SPE/IADC paper 67694 prepared for the Conference, "Short-Radius Drilling Performance Improvement in Algeria," the authors highlight cost savings achievable through close cooperation between the operator and service companies. The paper was prepared by P A Neal, Reed-Hycalog; **A El-Demerdash**, **Schlumberger Reservoir Development Services (Anadrill)**; and **B Benamor** and **R Zeghouani**, **Sonatrach**.

Short radius re-entry drilling began in Hassi Messaoud in 1995. The build and horizontal drain section's Cambrian formation is extremely hard and abrasive. Accelerated bit wear complicated well trajectory and increased drilling cost.

Specifically, note the authors:

• Up to 25 bits were used requiring 50 days to drill 350 m on the first well;

• Missing the sidetrack required re-setting the cement plug;

• Difficulties in controlling well trajectories resulted in multiple correction runs;

• Uncontrolled well trajectories led to nonuniform and excessive dogleg severity and undulating horizontal drains that affected the life, maintenance and production cost of the wells.

A team of engineers and geologists from the operator, bit manufacturer, directional drilling, and MWD contractors reduced overall drilling cost by over 30%.

Bit performance was identified as a major contributor to increased drilling cost and time delays. Prolonging bit life by optimizing bit selection and reinforcing the gauge, shirttail and cutting structure with diamond-coated tungsten-carbide inserts reduced the number of bits required to drill the well from the 24-27 used on the first wells to 8 on the last well reported.

Improvements in bit performance led to reconfiguring the MWD system, moving directional control and inclination measurements closer to the bit. As a result, well trajectories were consistently landed on target and on the right azimuth and a uniform dogleg was obtained.

In addition, the horizontal drains were drilled with fewer undulations, resulting in longer well life. And production improved and problems declined for the well logging and intervention operations.

The following technical contributions are attributed to this project by the authors:

• Development of near-bit inclination measurement tools for slimhole applications;

• Advanced diamond-coating technologies for shaped inserts;

• Development of on-bit stabilization with reduced torque for use with low-torque motors;

• Directional accuracy improvements through proper bit selection with regard to offset and cutting-structure modifications.

COMPLEX GEOLOGY

Drilling through the complex overthrust geology found in the Andes foothills of Northern Argentina and Bolivia presents a number of distinctive challenges.

SPE/IADC paper 67695, "Combination of Straight Hole Drilling Device, Team Philosophy and Novel Commercial Arrangement Improves Drilling Performance in Tectonically Active Region," describes the drilling of a well in this area.

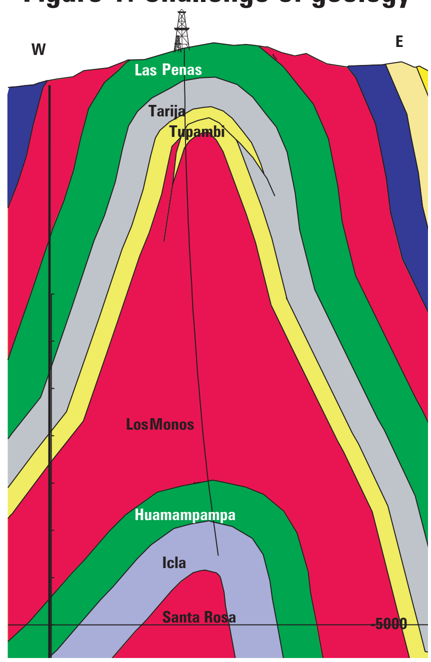
Authors **J M Garoby**, **Baker Hughes Oasis**, **A Huppertz**, **Baker Hughes INTEQ**, **M Barnes**, **C Vargas** and **F Rueda**, **Pan American Energy**, and **M D Pacione**, Baker Hughes Oasis also describe the advantages of the technology and practices used and highlight some opportunities for future improvement.

In this overthrust region, formations that are hard, abrasive, and at the same time prone to bit balling have to be penetrated in large hole sizes (22 in. and 16 in. typically). Historically, these intervals have given major problems of low penetration rates, hole deviation and frequent drill-string failures.

The strategy adopted to address expected problems had three main components. A recently developed straight hole drilling device was used.

The contract for its use was a novel combination of lump sum and incentive payment that effectively aligned the commercial objectives of service company and operator.

Figure 1: Challenge of geology



And the operator challenged all personnel to identify the best drilling performance achievable with current technology and then to deliver that performance.

In the early part of the project, the 12¼-in. section was being drilled at 4,406 m (190 m from casing point) in only 100 days, 28 days less than the best offset performance. This was also 52 days less than the AFE and 65 days less than the regional average.

At 16-in. TD the vertical displacement from the surface location was 49 m, compared with the 120 m at the equivalent point in the closest offset. Casing point was reached without any twistoffs or washouts.

Together these achievements set a new benchmark for drilling operations in this area, according to the authors.

MEASURING VIBRATIONS

Downhole vibrations can shorten the life of drilling equipment and reduce efficiency. Although vibrations can be controlled by changing parameters at the surface, the challenge is to know which parameter to alter.

SPE/IADC paper 67696, prepared for the Drilling Conference by **K Ashley**, **Texaco Exploration and Production** and **X McNary** and **C Tomlinson**, **Schlumberger RDS**, suggest that measuring downhole vibrations along multiple axes can be a solution.

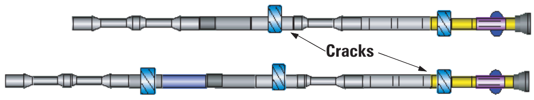
In "Extending BHA Life With Multi-Axis Vibration Measurements" the authors note that extending motor, bit, MWD, and BHA component life is of primary importance in the drilling process. Downhole vibrations can cause anything from minor damage to catastrophic failure in any of the components of a typical BHA.

Most vibrations can be controlled with the alteration of surface parameters such as weight-on-bit and rotary speed in conjunction with downhole measurement tools such as downhole weight-on-bit and downhole torque as well as BHA alteration. The problem is knowing which parameters to alter without adversely affecting total drilling performance.

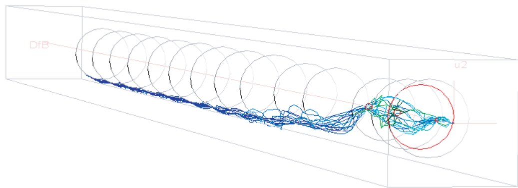
Recent advances in MWD technology have provided a means of measuring downhole vibration in multiple axes.

This information—provided in real

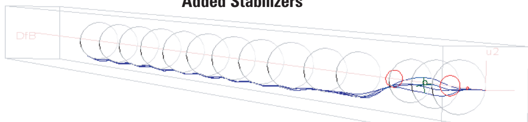
Figure 2: Modified BHA reduces fatigue



The rotary steerable BHA designs used early in the Norwegian North Sea application were prone to rapid fatigue in the locations indicated.



The drillstring dynamics program was used to evaluate dynamic displacements during periods of unstable behavior. A time lapse image of the results is shown. The dynamic bending stresses where cracks were observed were up to 5 times higher than static values.



The modified BHA (top) decreased the range of dynamic displacements and bending stresses (bottom time lapse image). The modifications have contributed to significant improvements in system reliability.

time—allows the driller to control the proper parameters to minimize specific vibration effects. The result is maximum BHA life and total drilling performance.

Multi-axis vibrations are classified as torsional, lateral and axial. These readings are transmitted from the multi-axis vibration chassis in the MWD to the surface by way of the MWD transmission system. At the surface these parameters are monitored by the MWD crew and made available by display anywhere around the rig.

The authors use a case history to detail how the use of this information has resulted in a change in drilling methodology and dramatically increased the success ratio in one area of application.

Attempts to drill vertical holes with 30/60 pendulum assemblies (MWD and straight hole mud motors) or 60/90 pendulums (in rotary mode with only MWD) had met with catastrophic failures in the past year. Mud motors had been twisting off and several MWD failures resulted in junked electronics.

On the first well, using a 30/60 pendulum assembly, the mud motor was twisted off at the AKO sub and the MWD failed. The MWD collar was even torn open. The MWD dump revealed very high shocks.

After this run, two rotary runs were made with only MWD and 60/90 pendulum assemblies. Both MWD tools failed.

It was decided to use the multi-axis vibration chassis to get a picture of what was happening downhole. The MVC data revealed violent episodes of mostly torsional and lateral vibrations characteristic of BHA whirl. These episodes occurred in hard, wet sands prevalent in this area.

This MWD run failed as well.

On run five, the MWD was stabilized top and bottom. Using the MVC, the drillers were able to "see" the sands and adjust their weight-on-bit and rotary speeds to reduce vibrations to acceptable levels and prevent the BHA from going into a whirling state.

Parameters were returned to normal in shales. All failures ceased. A record BHA run was recorded.

On two subsequent wells the assemblies were modified using straight hole motors with sleeve stabilizers. Both wells were drilled without failure.

The combination of a multi-axis vibration measurement in real-time, proper stabilization, and downhole weight and torque measurements has now become standard practice for this operator.

ADVANCED MODELS

Drilling models continue to offer the potential for steady advance in drilling performance. In SPE/IADC paper 67697, "Improving Drilling Performance by Applying Advanced Models," the authors describe lessons learned during efforts to develop advanced models.

M W Dykstra, **Hughes Christensen**, **M Neubert**, **Baker Hughes INTEQ**, **J M Hanson**, **Consultant** and **M J Meiners**, Hughes Christensen, prepared the paper for the Drilling Conference.

Drilling dynamics models fall into two general categories: engineering tools and research tools.

Engineering tools are designed for everyday use; they provide estimates of important parameters for planning purposes, such as natural frequencies and buckling loads. Research tools are much more powerful. They allow complex phenomena to be studied in great detail, but require a significant time investment.

To be of value, both types of models require validation.

In some cases this can be done through lab testing, in others controlled field tests are necessary, according to the authors.

Once fidelity is established the models can be used in a number of ways, including component design, bottom hole assembly (BHA) design, and investigation of component contributions to overall drilling system performance. The authors report that efforts to develop, verify and apply advanced dynamics models within one major service company have provided some valuable lessons. Examples include:

- Roller cone cutting structure can be adjusted to reduce off-center running tendencies;
- Polycrystalline diamond compact (PDC) bit designs can be adjusted to prevent impact damage;
- Bits that are dynamically unstable can feed BHA vibration;
- BHA designs that are unstable can cause rapid bit destruction;
- Operating parameters can be adjusted to improve performance of sub-optimal drilling systems;
- Intelligent stabilization can protect sensitive downhole equipment.

The authors present case histories where drilling performance has been improved through application of lessons learned from dynamics models.

For operators, the improvements have resulted in significant savings in rig time stemming from reduced tool failure frequency and increased drilling efficiency. For the service company, greater tool longevity and reduced maintenance costs have been documented.

PDC BITS IN HARD ROCK

Advancements in PDC bit technology, selection and bottom hole assemblies (BHA) design have contributed to the current enhanced performance levels of PDC bits.

However, in an alternate paper prepared for the Conference, "The Effects of Formation Hardness, Abrasiveness, Heterogeneity and Hole Size on PDC Bit Performance," the authors note that PDC bit performance in harsh environments—hard, abrasive and heterogeneous formations—continues to be inconsistent.

And, according to the authors of alternate paper SPE/IADC 67698, **G Mensa-Wilmot** and **M Fear**, **Smith International-GeoDiamond**, the problems associated with these applications get amplified when large hole sizes have to be drilled.

Footage per bit and rate of penetration (ROP) tend to be substantially low in such applications.

The authors establish the effects formation hardness, abrasiveness and heterogeneity have on the definition and optimization of BHAs, energy levels needed for efficient drilling, vibrations behavior and analysis.

A methodology that quantifies the effect of hole size on PDC bit performance is also described.

It will establish a process that ensures greater PDC bit efficiency, especially when large hole sizes are drilled in harsh environments.

The authors suggest that the lack of proper understanding of PDC bit dull grades, and the inability to effectively assign the "true" causes of their dull grades have contributed greatly to the ineffectiveness of PDC bits in harsh environments.

In addition, the inefficient interpretation of the effects of WOB, RPM, flow rate, HSI etc as functions of formation hardness, abrasiveness, heterogeneity and hole size has also limited PDC bit performance in harsh environments.

Recent research activities have established differences in the BHA and operational mediums needed to effectively tackle harsh environment applications, according to the authors.

In addition, this work has established the actual causes of PDC bit failure—static and dynamic wear. The severities of these failure modes have now been defined as functions of these harsh environments, and the BHA types needed to optimize performance in the different applications.

Hole size effects have also been defined and quantified as functions of formation/lithology and vibrational behavior.

Elaborate dull bit analysis has revealed remarkable differences in the dull characteristics of PDC bits in hard and in abrasive formation drilling. Differences have also been identified in the BHA design, conditions needed to optimize bit performance, and the induced vibrational modes and behavior in such situations.

These new findings and interpretations have re-defined PDC bit efficiency in harsh environments and large hole size drilling, according to the authors. The technologies and processes described can be applied to any PDC bit.

MULTIPLE SENSOR TOOLS

The early generation MWD tools were designed to provide inclination, azimuth and gamma measurements. As the formation evaluation sensor technology migrated from the wireline industry to the drilling industry, service companies adopted a modular design concept where new sensors/support electronics were packaged in discrete subs or modules.

The modular concept offers advantages: the measurements which are not required for a specific application may be excluded and selective placement of independent sensors relative to the bit is possible.

But according to the authors of alternate SPE/IADC paper 67699 prepared for the Drilling Conference, the consequences of additional formation sensors, drilling sensors and new applications has resulted in complex bottomhole assemblies which create trade-offs regarding sensor placement, real-time information selection and MWD system reliability.

In "Multi-Sensor MWD Tools Integrate Information and Reduce BHA Complexity," **R Randall** and **G D Folks**, Baker Hughes INTEQ, discuss a new generation of MWD tools that will integrate multiple sensors into one sub, optimizing space and reducing drillstring length.

This will allow drilling engineers more flexibility to design bottom hole assemblies capable of drilling increasingly complex well profiles. The combination of these sensors is also the first step in developing intelligent systems capable of data integration and analysis downhole. ■