# Penetration rate and bit life can still be improved

**THE PACE OF DRILL BIT** technology development seems never to slacken. New materials and better application of new bit types have driven penetration rates and bit life steadily higher during virtually the entire life of rotary drilling.

Two sessions on Bit Technology and Applications at the 2002 IADC/SPE Drilling Conference in Dallas 26-28 Sept highlight the importance of continued bit development. **D E Scott**, **Hughes Christensen**, chairs both sessions.

## OPTIMIZING ROP

IADC/SPE paper 74512 shows how use of a personal computer (PC)-based sensing, calculation and display system allows drillers to take advantage of years of knowledge accumulated by their predecessors to accurately control weight on bit (WOB) and rate of penetration (ROP).

Use of the system in more than 100 wells over a 2-year period has resulted in approximately 20% improvement in ROP, the authors report. Significantly, the drillers achieving this record represented various drilling contractors, cultures, disciplines and experience levels.

"PC-Based System Optimizes and Increases Bit ROP," was prepared for the Conference by **M D Pinckard**, **Noble Engineering & Development Ltd** and **T Proehl**, **Triton Engineering Services Co**.

At the heart of the system is statistical process software that analyzes and optimizes WOB and ROP by showing the driller two graphical lines. One line shows what WOB should be (target WOB) and one line shows the actual WOB. The driller manipulates the rig brake to match the actual WOB with the target WOB (a process known as "stitching the line").

Traditional training methods required the driller to learn to "feel" the rig vibrations and sense other signals to attempt to optimize penetration.

A second set of displays available at the rig enables the company man to monitor WOB and ROP from the doghouse. The software samples data often enough to mathematically forecast optimum WOB in real time for any operating condition. Trends are easily recognized so that the company man and driller can anticipate coming events. Lessons learned from each job are archived for use as input to company training.

## BIT CHATTER

Field experience has shown that Polycrystalline Diamond Compact (PDC) bits survive a variety of drill string vibrations in soft to medium-hard formations. Yet impact-type failures are common when hard rock stringers are abruptly encountered.

The authors of IADC/SPE paper 74525, "PDC Bit Chatter in Hard Rock Drilling," report on research into the problem. The paper was prepared by **D W Raymond**, **Sandia National Laboratories** and **M A Elsayed**, **University of Louisiana**.

PDC bits have been used successfully in the laboratory to drill hard rock, such as Sierra White Granite (28,000 psi compressive strength). However, PDC bits are rarely used in these hard formations. Impact-related failures can be caused by the onset of instability in the drill string resulting in a variety of drill string vibrations (bit bounce and stick-slip). Some of these instabilities can be categorized as self-excited vibrations—"chatter"—and are avoidable given a proper understanding of the dynamics of the drill string and the rock-bit interaction.

Research at Sandia National Laboratories has shown that improper selection of operating conditions can result in the onset of chatter in the drill string.

Using the Hard-Rock Drilling Facility at Sandia, the authors simulated the axial and torsional compliance of a drill string equipped with a PDC bit. Test results indicate that bit vibration amplitude is highly dependent upon operating conditions.

Damping was also used as a means to suppress vibration.

Field experience and laboratory testing have shown that severe chatter in hard-rock formations results in cutter failure, whereas chatter is survivable in formations of low compressive strength. Reducing the vibration amplitude, whether by selection of proper operating conditions or the proper damping, is an effective means of mitigating chatter and its destructive effects, according to the authors.

## BETTER ROP IN SHALE

Although shales present much lower drillability challenges when analyzed from a mechanical or geologic standpoint, the performance of PDC bits in these formations does not always reflect this characterization.

Recent findings show that shale behavior, especially its drillability, is much more dependent on factors such as mineralogy, depositional depths, mud types and mud weights than it is on hardness and/or abrasiveness.

Compared with the other bit types, PDC bits experience much higher reductions in ROP (approximately 70-90%) when drilling shales that have been exposed to these factors.

IADC/SPE paper 74526 explores the effects of these conditions on shale drilling efficiency, especially the penetration rates of PDC bits.

"Innovative Technology Improves Penetration Rates of PDC Bits in Shales Drilled at Great Depths with Weighted Water Based Mud Systems," was prepared for the Conference by **G Mensa-Wilmot**, **Smith International-GeoDiamond** and **M J Fear**, **BP plc**.

In comparison to the other bit types, PDC bits establish the fastest ROP in shales.

However, PDC bits experience the highest ROP decays, when they are exposed to shales that are to be drilled at depths greater than 10,000 ft TVD with water based mud systems having high mud weights (greater than 14 ppg).

In such conditions, shale behavior and drillability change. This situation, when coupled with the "conventional" shearing rock removal action of PDC bits, drastically reduces shale-drilling efficiency, according to the authors.

Initial attempts at explaining the causes of the ROP decay depicted the shale as having turned "plastic," and thus not subjecting itself to effective shearing by PDC bits. Additionally, it was theorized that differential pressures caused by the difference in densities between the drilling and pore fluids caused the ROP decay.

Recent research and development have faulted these reasons. Hydrostatic pressure caused by the effects of depth and/or drilling fluid density plays a key role in the ROP decay.

It has also been established that drilling fluid qualities, characterized by their hydration or dispersive properties, affect the hardness and water content of shales, and thus their drillability. The shale does not turn plastic and can be effectively sheared by “specialized” PDC bits.

These bits must “scoop” the formation and create tensile stresses in the cuttings they generate. This forces the cuttings to brake into smaller “ribbon-like” pieces, so they can be easily lifted and transported into the annulus.

Cuttings from the bit must be discrete, with variable adjacent thicknesses, to minimize radial “inter-facial” attraction. The drilling fluid must flow between the cuttings generated by adjacent PDC cutters to reduce their sticking tendencies. These bits, when exposed to low WOB values, must exhibit high ROP responses at reduced torque levels. These characteristics establish “efficient” mechanical cleaning properties.

These specialized PDC bits must have high face volume and void volume ratios to maximize cleaning efficiency.

## TSP BITS

Thermally stable diamond product (TSP) drill bits can reduce overall system costs by increasing rates of penetration and bit life. IADC/SPE alternate paper 74515, “New High Strength and Faster Drilling Thermally Stable Diamond Cutter for Drill Bits,” focuses on the development of advanced drilling systems that use the bits. The paper was prepared by **R P Radtke**, **Technology International Inc**.

Thermally stable diamond cutters are able to withstand high frictional heat generated when drilling hard and abrasive rock.

In the past, TSP diamond cutters have not generally been economic for hard rock drilling due to insufficient size and strength.

A major accomplishment has been the development of a new high shear strength microwave brazing process developed in cooperation with the **US Department of Energy** and the **NASA Jet Propulsion Laboratory**.

Another advance is improvement in impact strength through materials research at the **Colorado School of Mines**. Unique 13-mm and 19-mm diameter diamond cutters have demonstrated the potential to double both rate of penetration and bit life.

Thermally stable diamond drag bits have the potential to reduce well costs by 15% and overall drilling project cost by 7.5%. ■