# Directional technology, steerable systems advance

**DIRECTIONAL DRILLING** technology and steerable systems have steadily improved the ability to optimize recovery, improve project return and lower the impact of exploration and development operations on the environment.

At the 2002 IADC/SPE Drilling Conference in Dallas, a key session focuses on advances in directional drilling and rotary steerable systems. Session chairmen are **J H Moss**, **ExxonMobil Development Corp**, and **S D Gomersall**, **Schlumberger**.

## NEW PDM TECHNOLOGY

IADC/SPE paper 74455 describes how the application of new positive displacement motor technology on 2 wells led to a step improvement in performance when compared to conventional drilling methods.

Gross section rate of penetration was improved by up to 300%, and the operator achieved its longest horizontal section to date through the Rotliegendes formation in the North Sea.

Future developments to realize the full potential of this technology are also discussed in “The Introduction of New Generation Positive Displacement Motor Technology in Combination with Application Specific PDC Bits: A Step Improvement in Drilling Performance on Horizontal Rotliegendes Sandstone Sections.”

The paper was prepared for the Conference by **C D Rayton**, **Baker Hughes Inteq**; **P Taylor**, **Conoco UK Ltd**; **J Grindrod** and **C Sim**, **Baker Hughes Inteq**; and **N Biggs**, **Hughes Christensen**.

Wells on the Jupiter and Phoenix fields in the UK Southern North Sea require relatively long (1,000-5,372 ft) horizontal hole sections to be drilled through the Permian age Rotliegendes sandstone reservoir.

Tight target tolerances on true vertical depth necessitate good directional control over the entire section length.

Historically, these sections were drilled with high-speed turbines run in conjunction with polycrystalline diamond compact (PDC) drill bits or diamond impregnated bits; and conventional low speed positive displacement motors (PDMs) coupled with both roller cone bits and PDC bits.

Drilling with turbines resulted in heavy drill bit wear due to high rotational speeds and required significant periods of orientation to combat the assemblies’ inherent left-hand walk tendencies, according to the authors.

Conventional PDM and roller cone assemblies gave rise to multiple trips due to bit bearing life limitations on run length.

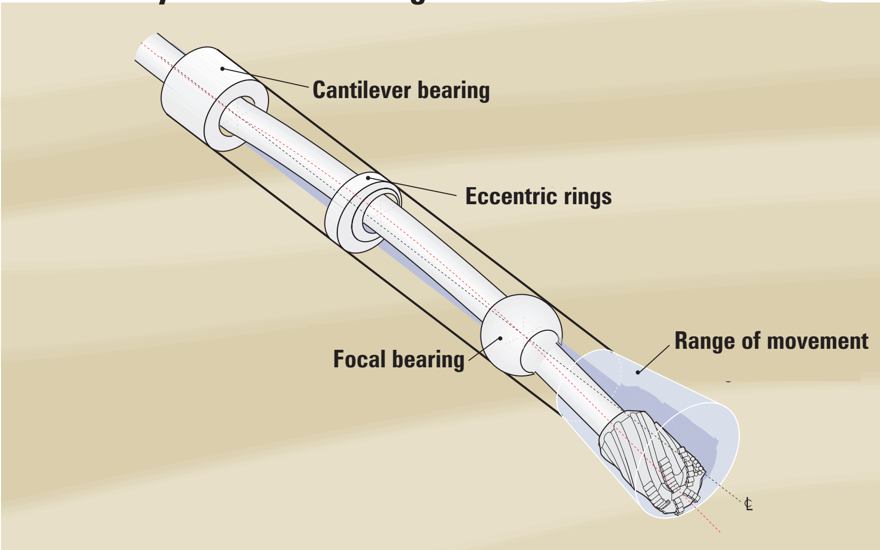
The problems of erratic PDC bit torque and stalling of conventional motors due to variable weight transfer coupled with motor torque output limitations, made attempts to use this combination unsuccessful.

The new generation PDM is able to produce significantly more power and torque than conventional motors at comparable bit speeds.

Compared with turbines, the new generation PDMs are easier to control, monitor and optimise because both RPM and power output are directly proportional to drilling fluid flow rate and motor differential pressure, respectively.

Application-specific PDC bits featured a unique tandem gauge, designed to maximise hole quality and therefore provide more even weight transfer to the bit. This combined with an optimised PDC cutting structure facilitated smooth torque output at the bit/rock interface and so supported the use of the new motor technology, report the authors.

## New rotary steerable drilling tool




## ROBOTIC CONTROL

IADC/SPE paper 74458 reviews the development of a second-generation rotary steerable drilling tool.

“Robotic Controlled Drilling: A New Rotary Steerable Drilling Tool for the Oil and Gas Industry,” was prepared for the Drilling Conference by **R T Hay**, **E J Cargill**, **T M Gaylor**, and **J R Hardin**, **Sperry-Sun Drilling Services**; **A Ikeda**, **MIN Consultant Inc**; **Y Kyosawa**, **Harmonic Drive Systems Inc**; and **T Yonezawa**, **Japan National Oil Corp**.

Important to the tool development was to base the design on lessons learned. Proven technology from outside the drilling industry was also used.

Core elements such as a strain wave gearing transmission and electrically operated clutches were developed initially for use in industrial robots.

Other significant elements are the shaft design, advanced rotary seal systems and anti-rotation devices.

The principle of operation is a bendable shaft coupled to the drillstring situated inside a rotation resistant housing. When the need arises to change the borehole trajectory, two eccentric rings are turned to bend the internal rotating shaft allowing the bit box to pivot about spherical roller bearings near the bottom of the tool.

This action points the bit in the direction opposite the shaft bending direction.

This tilting action mimics the behavior of a PDM steerable assembly by pointing the bit and is a departure from other rotary steerable device concepts that push the bit sideways to change the wellbore trajectory.

Combining this tilting action with a long gage bit technology allows for maximum effectiveness in torque and drag reduction while reducing vibration and eliminating hole spiraling.

The design requirements also forced the drilling system to integrate with an existing MWD system to allow for automated or manual control from surface using a bi-directional communication system.

**Results obtained from recent tests demonstrate that the drill bit profile, the gage cutters and the gage length have a significant effect on the walking tendency and on the steerability of PDC bits.**

## HIGH TORQUE TURBODRILLS

Direct drive turbodrills operating at relatively high nominal speeds are an industry standard for niche applications in vertical, deviated and horizontal wells.

The majority of footage drilled, however—and drill bit types used—require much lower speeds and higher torque delivery than can be achieved with direct drive turbines.

IADC/SPE paper 74456 reports on a lower-speed, high-torque machine that maintains the turbodrill's characteristic high-reliability, steerability and performance benefits over a wide range of drilling applications.

The paper, "Advances in High-Torque Turbodrilling Technology," was prepared for the Conference by **A M Downie** and **G J Burckitt**, **Neyrfor-Weir**.

Turbodrills can deliver high power, excellent steerability and are inherently very reliable. But their speed and torque characteristics, particularly in high torque or abrasive applications, are not compatible with PDC or roller cone bits designed for rotary drilling speeds, according to the authors.

The nominal speed of direct drive turbodrills can be reduced, within limits, by the use of appropriate blade designs, but is achieved at the expense of torque per stage. Nominal torque levels can be restored, but the resultant tool length and blade stage numbers makes this uneconomic and too long for steerable applications.

However, relatively short turbine sections that deliver high power at high speeds can be coupled with a gear reducer to allow lower output speeds to be achieved within a short overall tool length.

The gear-reducing device also acts as a torque multiplier, increasing the torque by the same factor as the speed reduction ratio. The inherent diametral limitation on downhole tools, and their coaxial design, makes the epicyclic or planetary gear reducer a natural choice for this application, according to the authors.

## BIT PROFILE AND GAGE

The importance of wellbore deviation control is well recognized by the drilling industry.

A comprehensive analysis of the directional behaviour of PDC bits is presented in IADC/SPE alternate paper 74459, including the effect of bit profile, gage cutters and gage length.

"How the Bit Profile and Gages Affect the Well Trajectory" was prepared for the Conference by **S Menand** and **H Sellami**, **Paris School of Mines**; **C Simon**, **Drillscan**; **A Besson**, **TotalFinaElf**; and **N Da Silva**, **Security DBS**.

A full-scale directional drilling bench was built to measure the walking tendency and the steerability of PDC bits. The results obtained demonstrate that the bit profile, the gage cutters and the gage length have a significant effect on the walking tendency and on the steerability of the PDC bits.

A rotary steerable system has been designed for use in areas with extreme environments, poor infrastructure and difficult logistics.

A 3D theoretical rock-bit interaction model was developed to reproduce the drilling test results, the authors report.

Whatever the directional system used to deviate the wellbore (rotary steerable systems, BHA or bent sub) the analysis described by the authors is integrated in a user's guide set of recommendations with reference to the directional behavior of the drilling system.

## TARGET DESIGN

Target design is an important element in planning extended reach and advanced three-dimensional wells.

IADC/SPE alternate paper 74460, "Target, Risk-Based Target Planning And Real-Time Update Based Upon Multidisciplinary Information," describes a method and a tool for target analysis. The paper was prepared by **I Haarstad** and **O Lotsberg**, **Statoil**; and **S Evans**, **Landmark Graphics Corp**.

To design a meaningful driller's target, there must be several well defined inputs. The traditional inputs are total geological target area, seismic interpretation uncertainty and 3D survey positioning uncertainty.

Obvious additional inputs should be 3D geophysical and geological uncertainties, and well inclination relative to the target plane. With these inputs, in addition to acceptable risk tolerances, one is able to design a driller's target and to calculate geological target hit probability at given intersection points.

To take full advantage of a thorough analysis there should also be 2 additional inputs: geological and well positioning uncertainty correlation. In this way, geological markers, updated with MWD/LWD while drilling, could be used to reduce the relative geophysical uncertainty at the target, and thereby increase the driller's target or correspondingly increase hit probability.

These ideas are integrated and visualized in 3D geological software. The methodology has been used successfully on the Heidrun and Åsgard assets where results show that designing an optimal driller's target helps avoid unnecessary and complicated steering.

In other cases, the thorough target analysis can justify more expensive and time-consuming drilling to ensure the well meets the objectives.

## ROTARY STEERABLE

Rotary steerable systems are revolutionizing the way in which oil and gas wells are drilled. Over the past 5 years the technology has emerged from prototype status to a standard application in locations with good infrastructures like the North Sea or the Gulf of Mexico.

In more remote areas with more challenging logistics like West Africa, Asia Pacific, and South America, the use of rotary steerable technology has been very limited.

IADC/SPE paper 74457, "Application Of New Generation Rotary Steerable System for Reservoir Drilling in Remote Areas," describes a rotary steerable system designed for these areas. The paper was prepared by **H Gruenhagen**, **Baker Hughes Inteq GmbH**.

The new generation rotary steerable system is designed specifically for remote areas with sometimes extreme environments, poor infrastructures and difficult logistics.

Technological challenges had to be overcome for the standard application of rotary steerable systems in these areas, but case histories illustrate the advantages of the systems.