Rotary steerable systems prove value offshore Indonesia, offshore Libya, in Gulf of Mexico

By Simon Peach, Weatherford International

ROTARY STEERABLE SYSTEMS have proven their value over conventional mud-motor steerable systems in three ways: by cutting drilling time and expense; extending the reach of horizontal wells; and succeeding at temperatures and pressures where mud motors cannot operate. This article provides a brief overview of the technology, followed by three case histories that illustrate the value of these systems.

TECHNOLOGY OVERVIEW

Weatherford's Revolution rotary steerable system (RSS) uses point-the-bit drilling technology and includes in the design both a non-rotating sleeve stabilizer and a rotating near-bit "pivot stabilizer" to orient the drill bit axis with the axis of the intended hole trajectory. A rotating drive shaft runs through the center of the non-rotating sleeve to transmit torque and weight through the tool to the drill bit.

The bit is steered through the formation by deflecting the drive shaft within the non-rotating sleeve stabilizer, as illustrated in the two cross-sections of Figure 1. The drive shaft is deflected in a direction opposite to the required trajectory, and the pivot stabilizer acts as a fulcrum to point the bit in the required direction. The hydraulic force for deflection is provided by a pump driven by relative rotation between the center shaft and the non-rotating outer sleeve. Both the non-rotating sleeve of the steering unit and the rotating pivot stabilizer are close to the gauge of the hole to maximize the directional performance of the RSS.

The offset of the drive shaft – the degree of steering – is controlled by the onboard navigation and control electronics of the RSS. Tool face and deviation rates are programmed from the surface using drillstring rotation, while mud pulse LWD provides uplink telemetry. The entire system offers a very compact design to facilitate logistics and deployment.

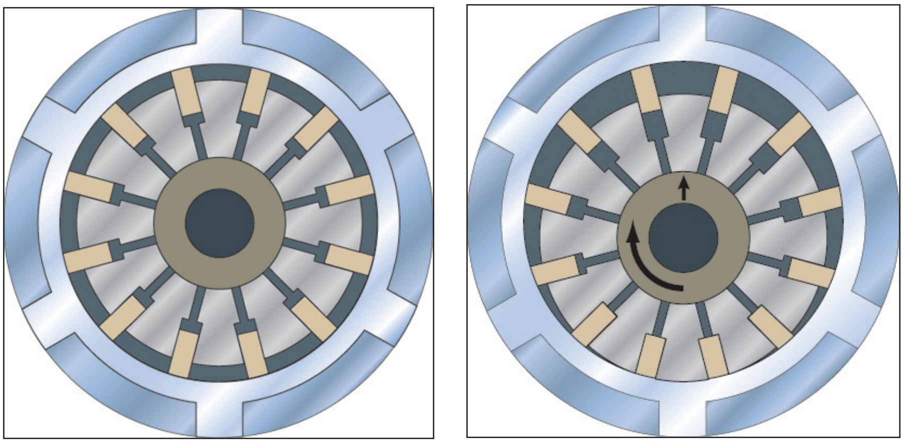


Figure 1: Neutral position (above left): Drive shaft concentric with non-rotating sleeve. Steering position (above right): Drive shaft deflected from center line of hole.

The efficacy of this approach is illustrated by the following case histories.

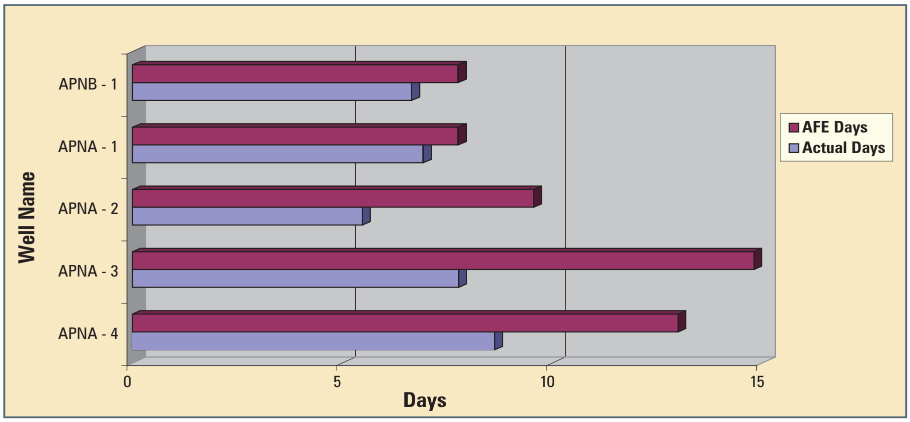
1. BP INDONESIA

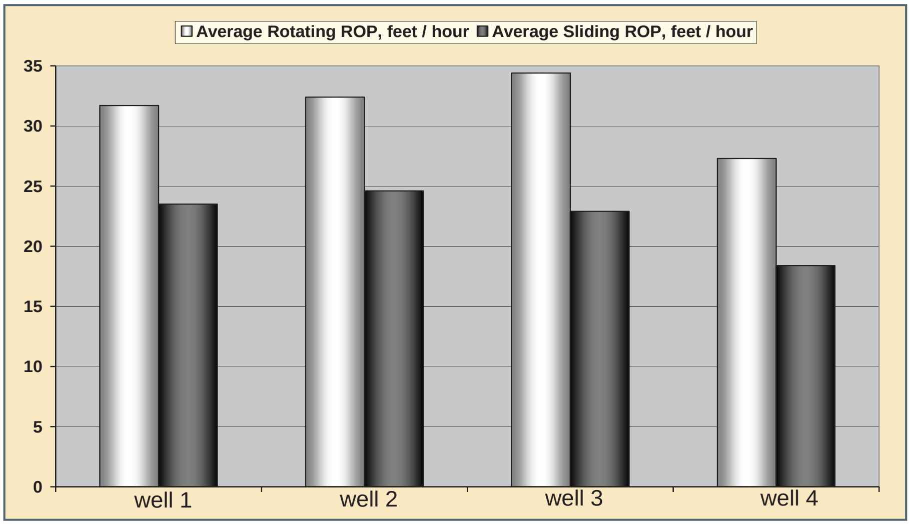
The challenge that BP faced in the Java Sea offshore Indonesia was to drill very shallow, extended-reach gas wells in an extremely weak, "Vuggy" limestone reservoir known for fractures and voids. With lost circulation always possible, the potential for differential sticking was high. The use of mud-motor steerable systems would have exacerbated the problem because of the large amount of non-rotating time during steering operations, when the string would have to be slid through the formation rather than rotated. Even in straight tangent sections, rotation would have to be stopped a significant percentage of the time to fine-tune the steering. With prior experience of lost circulation, differential sticking and lost assemblies in this field, BP decided that the best way to avoid risk would be use of a rotary steerable system.

A 6 ¾-in. RSS was used in conjunction with a triple combo LWD string to drill the horizontal reservoir sections from a jack-up rig in the Java Sea. The near-bit inclination system in the RSS provided directional information to the driller, and the resistivity and density tool close to the bit facilitated geosteering. Starting depth for the horizontal sections varied from 2,000 ft to about 5,000 ft; the goal for horizontal sections was 1,000 ft, which was reached in nearly every case. In most cases, the inclination remained remarkably constant through this difficult formation, with the final TVD within 1 ft or less of the starting depth of the horizontal section, well within the 3-4 ft TVD window.

Each well took about a day to drill. In one of the deeper wells, a hard limestone stringer was encountered that slowed the rate of penetration from 150-270 ft/hr to 15 ft/hr. This was followed by very soft formation that sent the ROP as high as 620 ft/hr. In this soft formation, the BHA started to drop; this was overcome by changing the deflection setting of the tool from 29 % of maximum to 79 % of

Figure 2 (top right) shows the wells drilled in the Java Sea offshore Indonesia were drilled 25% faster than planned using RSS. Figure 3 (bottom right) shows that in 4 wells drilled offshore Libya using conventional downhole mud motor assemblies, ROP while steering (sliding ROP) decreased significantly with depth.





maximum. The well was landed successfully, although drilling of the horizontal section stopped at 907 ft because of excessive fluid losses.

Figure 2 shows that all wells were drilled and completed with excellent results – with smooth, constant inclinations; 25 % faster than planned; 16 % less than AFE; and without accidents or HSE incidents. BP saved more than US$1.25 million.

2. LIBYA

When Shell developed the Brent Field in the North Sea in the late '70s and early '80s, it took four platforms to exploit the field. With rotary steerable systems, that same reservoir – all lying within less than a 10-km radius – could potentially be developed from a single platform.

A recent example of the extended reach that rotary systems offers is the Al Jurf platform 62 miles offshore Libya in the Mediterranean. In a paper to be presented at the Offshore Mediterranean Conference and Exhibition in March 2007, authors **H. Vigor** of **TOTAL** and **Simon Peach** and **John Niven** of **Weatherford** compare mud motors with the slimhole Revolution RSS system in seven wells drilled between April 2003 and June 2005 from that platform.

All of the wells were drilled with 6 ½-in. horizontal sections through a fractured carbonate reservoir. Four of the lateral sections were drilled using conventional downhole mud motor assemblies, and three were drilled using the slimhole point-the-bit RSS, which allowed a direct comparison of the performance of the two approaches.

Conventional steerable downhole motor assemblies and a tapered string of 5-in. and 3 ½-in. drillpipe were used to drill the 6 ½-in. build and lateral hole sections on four wells. During the course of drilling these four reservoir sections, a total of 15,310 ft was drilled in a total of 542 drilling hours, for an overall average ROP of 28 ft/hr. All of the laterals were drilled using a biopolymer, calcium-carbonate-based drilling fluid with a mud weight of 9.2 ppg.

In general, the ROP of the steerable motor assemblies was acceptable, as illustrated in Figure 3; however, the penetration rate while steering (when the drill string was sliding rather than rotating) decreased significantly with depth due to increasing drag on the drillstring. Analysis of sliding ROP versus hole depth is shown in Figure 4. Between measured depths of 9,000 ft to 12,750 ft, the average sliding ROP decreased by 66%.

The three other wells were drilled using the point-the-bit RSS, in addition to the use of rotary steerable assemblies. As in the conventional wells, the 6 ½-in. hole RSS sections were drilled using a biopolymer, calcium-carbonate water-based drilling fluid with a mud weight of 9.2 ppg.

The use of the RSS provided significant improvements in drilling efficiencies. These wells were drilled 38.6 % faster than the conventionally drilled wells (Figure 5). In addition, the use of RSS enabled longer-reach wells to be drilled; the increased stepout allowed access to parts of the reservoir that had not been reachable with conventional assemblies. The longest 6 ½-in. hole section drilled using conventional directional techniques was 4,826 ft, whereas the longest drilled using RSS techniques was 6,283 ft — a 30.2 % increase and the longest section drilled to date in the Al Jurf field. Similarly, the maximum MD achieved with conventional techniques was 12,750 ft compared with 15,569 ft for the RSS assemblies, an increase of more than 2,800 ft.

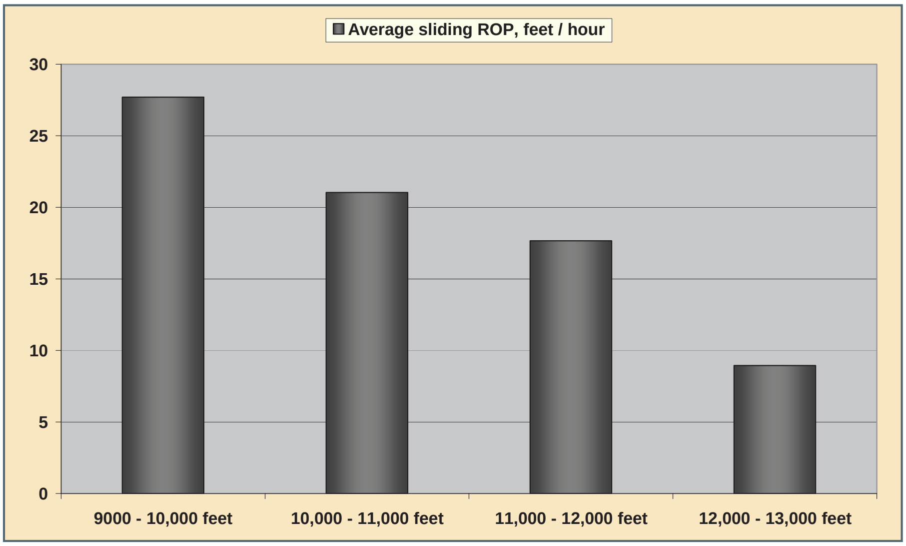


Figure 4 shows that in the conventionally drilled wells offshore Libya, ROP while steering — when the drill string was sliding rather than rotating — decreased significantly with depth due to increasing drag on the drill string.

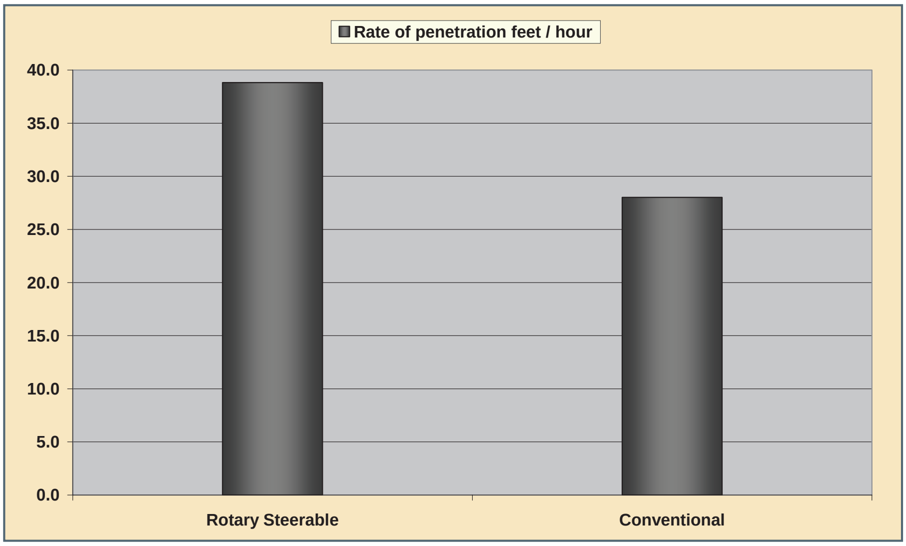


Figure 5 shows that 3 wells using rotary steerables drilled 38.6% faster than the 4 conventionally drilled wells offshore Libya in the Mediterranean.

3. GULF OF MEXICO

A major operator was drilling a vertical exploratory well in the Green Canyon section of the Gulf of Mexico from a drillship, where total daily costs were close to $500,000/day. At just under 29,000 ft, the 8 ½-in. hole started to drift in a way that would have meant missing the target. To solve the problem, Weatherford deployed the Revolution RSS with the HEL MWD and LWD systems, and within 24 hours drilling was once again on target.

The well ultimately reached TD at more than 34,000 ft (nearly 6.5 miles or 10.4 km), an achievement that broke the previous record depth of 32,727 ft (6.2 miles or 10.0 km) set earlier in 2005 by **Shell**, also using the HEL MWD and LWD systems. The RSS, MWD and LWD systems performed without incident, transmitting real-time and recording triple-combo log data in extremely hostile conditions where temperatures reached 280°F (138°C) and pressures exceeded 30,000 psi (206.8 MPa).

It was agreed that it would have been impossible to correct the drift problem with a conventional mud motor because the power sections in these motors are notoriously unreliable at high temperatures, and their physical construction is not generally rigid enough to withstand high pressure. Had the operator sidetracked at a shallower depth, there would have been no guarantee that the same drift problem would not re-occur in the sidetrack well. The entire exploration program could have been in jeopardy.

The expense implications of the RSS were also profound. In a drilling environment where each hour on the drillship cost the operator about $20,000, every minute saved was crucial.

The single successful rotary steerable run was terminated on reaching a coring point, after which the operator set casing and proceeded several thousand ft more to TD. The average rate of penetration for the RSS was 32 ft/hr.

CONCLUSION

In our experience, we have found that while rotary steerable systems may not be required for every job, there are many jobs where they offer profound advantages. Operators should consider RSS solutions in shallow directional wells where there may not be enough weight on bit to overcome drag on a non-rotating drillstring; in formations at risk of lost circulation and differential sticking; where they want to achieve high ROPs in wells over 8,000-9000 ft; where they want to drill the longest possible horizontal sections to extend the reach of a single drilling platform; and in deep wells with high temperatures and pressures. In many cases, the right choice can save millions.

Simon Peach is strategic business manager of Weatherford International Ltd. He holds a BSc in mining engineering from the University of Newcastle, Tyne, UK, and a MSc in rock mechanics and excavation engineering from the University of Newcastle, Tyne, UK. His previous positions with Weatherford/Precision include Eastern Hemisphere manager for UBD services and rotary steerable system product line manager.

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