Claire Kennedy Platt, Jeff Clausen, and Rohan D'Souza, NOV, USA, explain how a new development in drilling motor technology is increasing operational efficiency.

AHEAD OF THE CURVE

As drilling in shale plays has become more prevalent throughout the last decade, operators have relied upon rotary steerable systems (RSS) as a common top-tier solution to drill as efficiently as possible. With high complexity and lost-in-hole (LIH) costs, RSS can lead to expensive operations, increasing industry demand for a low-cost, low-risk mechanical tool for drilling curve and lateral sections. Drilling motor technology has evolved in recent years, but it has lacked the operational flexibility to change the bend setting downhole. In response to industry demand, National Oilwell Varco (NOV) developed the Vector™ Series 50 SelectShift™ downhole adjustable motor, which allows for enhanced directional performance and the ability to drill a curve and lateral in a single run. Adjustment of the motor bend setting eliminates extra trips and enables faster correction, increasing ROP throughout all sections of the well.

The downhole adjustable motor features two configurations, which include a straight-to-bent assembly and a bent-to-bent assembly, each with two position options. The straight-to-bent assembly offers bend setting positions between a 0˚ angle and high bend settings between 1.5˚ and 2.3˚. In the bent-to-bent assembly, the motor achieves up to a 2.8˚ maximum bend. Anticipated popular bend settings will include 1.5˚, 1.83˚, and 2.12˚. The straight setting of the adjustable motor limits hole tortuosity and aids in hole cleaning. By allowing higher rotary RPM and less side loading of the bit, the straight setting aids ROP and drills a more in-gauge hole. The motor significantly lowers rotary torque and weight on bit (WOB) requirements when rotating in the straight mode compared to the bent mode, thereby extending well reach.

NOV engineers built upon existing Vector Series 50 motor technology to provide high torque output capability, 100% flow to the bit, and reduced bit-to-bend length. Compared to previous technology, the downhole adjustable motor features increased seal longevity and bearing loads, handling up to a 50% increase in off-bottom bearing capacity. Engineered to withstand 35% more torque than previous generations of motor technology, the

downhole adjustable motor can be run on the strongest ERT™ power sections from NOV. Capable of handling flow rates ranging up to 700 - 750 gpm, the motor may be run on the highest flow power sections on the market. The universal joint design features torque-transferring faces and a driveshaft that is up to 25% larger in diameter, enabling higher torque capability and reliability.

The all-mechanical design offers bend setting options similar to directional motors. Operators adjust the bend angle to a high or low bend setting via RPM and flow changes in less than 2 minutes. A permanent pressure signal difference ranging from 150 - 250 psi on surface indicates the positions for bend setting confirmation. The MWD scribe stays the same for all bend adjustments. Combined with 100% flow-through-the-bit technology, this allows for maximum drilling efficiency. The downhole adjustable motor may be used for sidetracking, multilateral, lateral, and most directional applications. The current available tool size is 7 ⅛ in. for hole sizes ranging from 8 ½ to 8 ¾ in.

Case studies

Currently in the customer field trial stage, the SelectShift enables operators to increase efficiency and cost savings by reducing the number of trips required while also optimising critical drilling parameters and increasing operational flexibility. Engineers have tested the technology at the NOV Research and Development Test Center (RDTC) in Navasota, Texas, and Catoosa, Oklahoma. The downhole adjustable motor has completed more than 150 downhole shifts, drilling a total of 16 100 ft in five wells. With a maximum build rate of 18˚ per 100 ft, the motor has achieved higher rotary RPM in the range of 150 RPM in the straight mode in comparison to 40 - 80 rotary RPM, which is typically used with a bent motor.

During a Navasota test in December 2017, the operator used the downhole adjustable motor in a curve-to-lateral application, testing the straight-to-bend configuration. The motor drilled an 8 ¾ in. curve-to-lateral wellbore, hitting both positions and providing better build rates than expected. It dropped 0.5˚ in 800 ft in the lateral with no sliding. In total, it drilled 2750 ft in 75 hrs with an instantaneous ROP of 60 - 200 ft/hr. The motor kicked off the curve at 3300 ft and landed at 4900 ft and at 800 ft of lateral, completing 28 shifts during the run.

Figure 1. *SelectShift rotary drilling comparison (ROP fixed).*

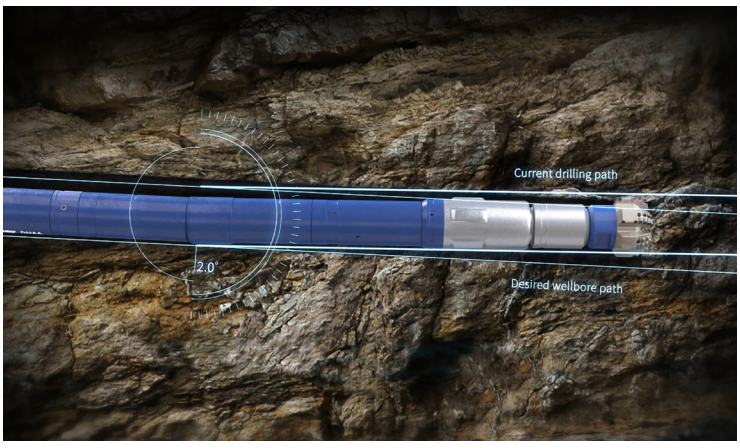

Figure 2. *Vector Series 50 SelectShift downhole adjustable motor.*

During another Navasota test run in January 2018, the operator used the same BHA configuration, drilling an 8 ¾ in. curve-to-lateral wellbore. The downhole adjustable motor drilled 2550 ft in 65 hrs. In this run, the motor kicked off the curve at 3300 ft, landed at 4400 ft at 80˚, and reached 600 ft of the 80˚ tangent. The motor achieved average ROPs of between 60 - 200 ft/hr, drilling the lateral and tangent at 150 - 200 ft/hr. Rotary drilling in the straight setting achieved 100 - 150 rotary RPM for 50% of the lateral. The straight setting demonstrated significant benefits when compared to bent motor rotary drilling at 50 RPM, showing less stick slip with lower WOB and torque values while achieving the same ROP. The motor achieved 16˚ per 100 ft and completed 35 shifts during the run.

NOV completed additional tests in Catoosa during March and June 2018, testing the straight-to-bent configuration for customer demonstrations. In several 8 ¾ in. dedicated curves and a vertical tangent wellbore in a hard limestone formation, the motor drilled a total of 4700 ft, confirming a build rate of 14 - 18˚ per 100 ft and basic function in hard rock with torques as high as 15 000 ft-lb applied to the motor. The motor demonstrated higher RPM capabilities in the straight mode. The testing provided a comparison of the effects on torque and drag when switching from rotary drilling at high RPM in the straight mode with the downhole adjustable motor versus rotary drilling at lower RPMs with a bent setting, as would be experienced with a conventional fixed bent motor.

The downhole adjustable motor further demonstrated ROP gains possible in straight mode at high RPM in the vertical-tangent wellbore, increasing ROP 50 - 70% at the same WOB when drill-off testing was completed in both modes in the same formation. The tool remained in the straight mode for most of the vertical-tangent run, and the bent mode corrected back to the proposed well plan as needed. ROP for this test held at an average 150 ROP throughout the run with sustained average ROP set as high as 380 ft/hr in the straight mode, finishing in less than 18 hrs. The performance validated for the tool's build rate, sliding performance, and new upgrades to longevity in harder formations. Longer duration field trials will follow.

Conclusion

As the downhole adjustable motor undergoes field trials, NOV will continue running the motor in different well profiles and applications. With a focus on increasing ROP, reducing non-productive time, and reducing downhole vibrations while optimising critical drilling parameters such as torque and WOB, NOV will phase the Vector Series 50 SelectShift downhole adjustable motor's commercialisation based on well profiles and applications.

The proven record of field trials of the downhole adjustable motor opens new opportunities for drilling curve and lateral sections in a single run. Less torque and WOB requirements in the straight mode and lower bend settings can aid drilling in shale plays and extend lateral length by helping drillers avoid obstacles such as hole tortuosity, excessive sliding, and poor hole cleaning.

Increased flexibility to change the bend setting downhole meets a long-standing demand within the industry and has the potential to change drilling practices. By reducing the number of trips, increasing operational flexibility, improving hole quality, and optimising critical drilling parameters, this downhole adjustable motor can help operators increase cost savings and achieve more efficient drilling operations.