Steering head with non-rotating near-bit stabilizer at core of new RSS set for field trial in North American unconventionals

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By Katie Mazerov, Contributing Editor

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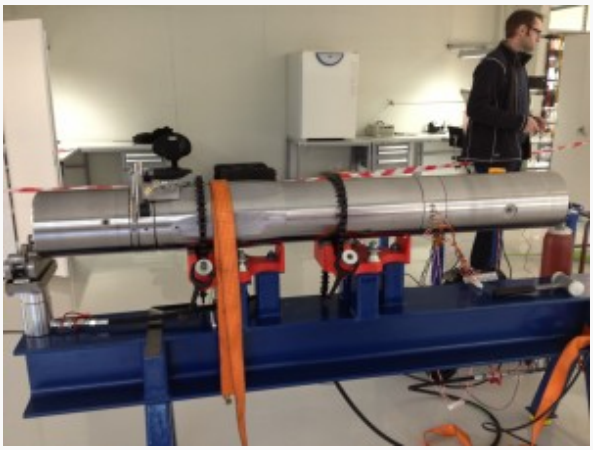
he unconventional boom that has swept across North America over the past decade has made an indelible mark on the oil and gas industry, ushering in a wave of new tools and methodologies to expand the operational envelope. The sector has also opened the door for new applications of commonly used offshore techniques, among them rotary steerable systems (RSS). Long deployed in offshore and high-value directionally drilled wells, RSS are becoming more widely used to drill unconventional shale wells that are targeting increasingly high build-up rates (BUR) and longer laterals.



2TD Drilling and a major operator undertook a comprehensive design-test-verification process, including four prototypes, to develop the OrientXpress RSS, which will begin field trials in the US this year. Prototype B verified that the steering head could deliver adequate forces to create a steering response and survive the loads in a downhole drilling environment. This model led to the development of the first full-system prototype.

A new electromechanical RSS, developed under a collaborative effort between Norway-based **2TD Drilling** and a major oil and gas company, is designed for wells targeting high BURs or steep dogleg severity (DLS). The new RSS, the OrientXpress, was developed through a comprehensive and iterative design-test-verification process using various prototypes, culminating with the current version that will soon undergo field trials. The field trials are expected to happen in Q2 this year in an unconventional shale play in the continental US.

The RSS is expected to launch commercially later this year, according to Dr **Shona Grant**, Managing Director of 2TD Drilling. The RSS is initially targeted at the North American unconventional shale market, but the company plans to take the technology offshore once a record is established on land.

In designing the RSS, the 2TD development team took into consideration the expressed needs from operators in the shale plays for a reliable and cost-effective tool that can drill a smooth borehole, achieve a high BUR and deliver long laterals. “The need to drill longer and smoother laterals to boost productivity and increase margins is driving the uptake of RSS tools in the onshore market,” Dr Grant said. “Given the relatively small license/lease areas, the RSS needs to be able to build from a vertical to a horizontal well trajectory in as short a radius of curvature as possible.

“Most conventional directional drilling methodologies, such as slick bent motor assemblies, are typically slow to build a curve section and often do not deliver the wellbore quality for getting casing to bottom trouble-free,” she continued. “These systems are less flexible than an RSS and must be preset to specific BUR capabilities prior to going downhole. Typically, any directional change in the wellbore is created by ‘sliding’ the BHA followed by a period of rotary drilling. This is repeated until the desired wellbore profile is achieved. This, in turn, means that each directionally drilled section is relatively slow to complete, while the technique itself tends to generate steps in the wellbore between each sliding and

rotary drilling section."

The OrientXpress is a short RSS – 3.5 m (11.5 ft) that is designed to provide BURs of up to 15°/100 ft, the top end of the industry's capability. "The shorter length makes a difference in terms of maneuverability downhole and enables operators to put MWD tools, including measurements such as gamma ray or resistivity, closer to the bit – approximately 30 ft closer to the bit than when drilling with a motor – to ensure the well is being drilled in the desired location," Dr Grant noted. "The tool also takes its own direction and inclination measurements from sensors located some 2 m behind the bit. This data is integrated into the tool's directional response, enabling precise well placement without the need to continually project and correct from similar sensors in the MWD tool that are located far behind the drill bit."

Near-bit stabilizer

The crux of the RSS is a steering head that comprises a rigid, non-rotating, near-bit stabilizer supported on two off-center, oppositely positioned drill sleeves. When the sleeves are rotated relative to one another, the bit is offset. The tool face and degree of offset can be adjusted when required to enable continuous control of direction and BUR downhole, explained **Andrew Gorrara**, Engineering Manager, 2TD Drilling.

Testing equipment for the new RSS included the Iron Man, a custom-designed horizontal drilling rig, to simulate actual drilling conditions. The rig, coupled with a 900-hp mud pump and a conventional mud motor, was designed to control weight on bit and achieve a representative rate of penetration. The rig's control system monitored performance and recorded data for later analysis. A second test rig has since been manufactured to further simulate the expected shock and vibrations in a real downhole drilling environment.

Unlike other RSS, this tool has a steering mechanism that does not use external hydraulic actuation or external moving parts, such as pads or pistons that push against the wall of the borehole to put a side force on the bit.

"In effect, the near-bit stabilizer is pushed off-center from the drill string," he said. "We are essentially changing the geometry of the BHA by adjusting the near-bit stabilizer so it continuously orients the bit in the direction we want it to go. We believe this is a more robust solution than hydraulically activated pads, which are dependent on the mud flow characteristics and come into contact with different rock types that vary dramatically in formation strength."

The directional sensor package in the RSS is positioned close to the bit, just behind the near-bit stabilizer. "Obtaining high-quality measurements this close to the bit means the operator is more likely to steer the wellbore to the optimal position," Mr Gorrara noted. The tool also contains its own turbine generator and its own independent communications system that does not interfere with other MWD devices, enabling this to run as a standalone tool.

The system's extensive and staged development and testing program began in 2011 with the development of a prototype of the steering head for 8½-in. hole size applications. Since then, three further prototypes have been built. This step-wise approach allowed the development team to resolve technical issues in an incremental way from one prototype to the next, Mr Gorrara noted.

"The first two prototypes were focused on proving the steering head concept, the first being a 'proof of concept' for the steering theory, while the second, completed in 2012, verified that the steering head could deliver both the forces required to create a steering response and also survive the loads in a downhole drilling environment."

Design process

“After verifying the steering head could generate sufficient force to orient the bit in the desired direction, we moved ahead with the first full-system prototype, Prototype C, under the project. Early in this process, a decision was made to develop the RSS for 7 7/8-in. hole size applications, as this slimming down of the final hole size can reduce the overall well costs, including casing and cementing costs.

Prototype C of the RSS was slimmed down for 7 7/8-in. hole size applications. The prototype was a complete RSS built to demonstrate that the steering concept could function in a predictable and controlled manner while drilling at surface conditions. Key design elements and learning from the testing of this model have been used to modify the RSS into its current configuration, which will be used in field trials in the US.

Generally, it is also easier to scale up a slim design rather than vice versa. The smaller bit size requirement resulted in a significant mechanical re-design of the RSS,” Mr Gorrara continued. The design was optimized and improved by dividing the motor/gear mechanism and near-bit stabilizer into two separate modules, making it possible to isolate most of the near-bit steering stabilizer’s drilling loads into a separate section, he explained. The development of a new coupling methodology also significantly reduced the manufacturing cost.

“Prototype C was a complete RSS built to demonstrate that the steering concept could function in a predictable and controlled manner while drilling at surface conditions,” he said. This phase of testing was completed in early 2014 and served to verify the overall integrity and directional drilling capability of the RSS. The design process for this phase was divided among several smaller teams, each responsible for delivering separate elements in the RSS – for example, the turbine generator, control system, power and data transfer, motors and motor control, the sensor assembly, steering head coupling and the steering head, including the near-bit stabilizer and sleeves with the anti-rotation mechanism.

Finite element (FE) modeling was used to identify ways to optimize tool stiffness and test the tool robustness to loads and bending stress, Mr Gorrara said. The FE model led to the modification of the bearing design, including the installation of an extra bearing on the main shaft to minimize bending and improve steering response.

Computational fluid dynamics (CFD) modeling optimized the turbine design and finalized the design of the stabilizers. The latter confirmed that flow areas within and around the tool would not cause undue erosion when pumping significant amounts of fluid through the system and were adequate for effective cuttings removal. The CFD modeling of the turbine confirmed that the power-generating capacity was adequate and that the blade geometry could be adjusted to meet the generator speed and power-generation requirements over a range of flow rates. Further testing was used to validate the FE and CFD analysis and to simulate actual drilling conditions to ensure overall system robustness.

Drilling into concrete

The test equipment used to simulate actual drilling conditions was based on a custom-designed horizontal drilling rig. The RSS was placed on the rig, which was paired with a 900-hp mud pump and conventional mud motor to drill directional holes through concrete. The rig was designed to be able to control weight on bit and achieve a representative ROP. The rig’s control system monitored performance and recorded data for later analysis.

A total of 10 concrete drilling tests were performed using Prototype C, with no tool failures. Initially six directional holes were drilled into the concrete block. In each hole, a different type of directional response was tested. A new hole was started in each case by adjusting the position of the horizontal drilling rig in front of the concrete block. The concrete mix was tailored to have a compressive strength

that was similar to the formations that the RSS would be expected to drill.

A second block of similar compressive strength but incorporating larger granite chips to create more variability and vibration was selected for the last four drill tests. Bit wear due to the granite chips reduced ROP for the last two holes.

This testing program confirmed both a predictable and repeatable steering response from the RSS, and the 15°/100 ft BUR. “We learned, however, that the drilling process went a little too smoothly and did not last long enough to really test the endurance of the RSS over several days,” Mr Gorrara said.

As a result, an additional test rig was designed and manufactured to further simulate the expected shock and vibrations in a real downhole drilling environment. The new rig can simultaneously rotate the RSS at up to 200 rotations/min, while fluid is circulating at up to 400 gal/min. It can continuously or intermittently apply weight on bit, lateral bending loads and side loads, along with the application of a drag force to the near-bit stabilizer. An axial shock of up to 50G can be generated twice in each revolution. This machine can be run continuously 24/7 to test system endurance.

Testing of the new RSS included drilling directional holes through concrete. A total of 10 concrete drilling tests were performed with Prototype C, with a different directional response tested for each hole. The concrete mix was designed with a compressive strength similar to formations in which the RSS would be expected to drill.

Field tests launching

Using the key design elements and learning from the testing of Prototype C, the 2TD team modified the RSS into its current configuration, which will be used in the field trials in the US, Mr Gorrara said. “Prototype D meets the requirements for a commercial production series run, designed to operate at up to 20,000 psi and 175°C, as well as being a modular design that simplifies assembly and maintenance.

Prototype D is undergoing environmental and verification testing in Norway. This will include further drill tests through concrete, followed by drill tests at a land rig facility. Four prototypes will be shipped to the US for field trials.

“We believe our testing capabilities will be a key differentiator in delivering a highly reliable RSS to the marketplace that can drill longer laterals accurately and efficiently,” Dr Grant noted. “For many years, the industry focused on getting wells drilled quickly,” she continued. “Now, operators are focused on margins where both cost efficiency and effective wellbore placement are key to improving field economics.”

OrientXpress is a trademarked term of 2TD Drilling.

2TD Drilling was recently acquired by Ryan Directional Services, a Nabors Company. It is wholly owned by Nabors Industries.