Slider: new level of efficiency to directional drilling

AUTOMATED TECHNOLOGY FOR optimizing directional drilling with a downhole motor and measurement while drilling (MWD) system was developed by assimilating surface torque with downhole bit and drillpipe behavior.

The technology, developed without introducing new or additional equipment downhole, allows drillers to maximize drilling efficiency and improve wellbore quality due to less trajectory tortuosity during the sliding operation of the drilling process.

The new technology integrates surface and MWD data to provide the following benefits in the sliding mode:

Improved ROP and horizontal reach capability;

Improved tool-face correction while drilling, without coming off bottom;

• Improved well trajectory;

• Improved motor life due to less stalling;

• Quick and accurate tool-face orientation;

• No lost-in-hole exposure;

• Time savings when switching from rotating to sliding without coming off bottom;

• Overall performance optimization;

• Less stress on the directional driller due to the automation of rocking and sliding techniques that were previously performed manually.

The technology is owned by **Noble Corporation**. **Slider LLC** has the exclusive worldwide commercial rights to market the technology, for which there are three patents pending.

COMMERCIAL APPLICATION

Slider technology was recently utilized by a major operator on a barge rig in the Gulf of Mexico with directional drilling company **Integrated Directional Resources** (IDR). **Scott Jones** with IDR learned about Slider LLC, contacted them and was impressed enough with the simplicity and potential time savings

Slider built a laboratory model to test the automation system that was comprised of three basic components for simulating the surface controls, wellbore events and downhole conditions.

that he in turn contacted the operator, suggesting that it be used in the development well being drilled with the barge rig.

"Everything worked as advertised," Mr Jones said. "We're pretty happy with it.

"I've been waiting for something like this for a long time," he added. "Probably 75% of the wells being drilled with mud motors can see improved efficiency with the Slider technology."

Mr Jones also said that the robotics of the Slider technology is fairly straight forward. "What makes this technology work or not work is that the logic that drives the robotics is well thought out."

Mr Jones said he has already recommended it to other operators and has several candidate wells.Slide Drilling

A motor and MWD system is designed with a downhole motor and a bent housing. The entire drillstring rotates to drill a tangent section, but only the bit rotates to produce a curve or bend.

Drilling with only the mud motor is commonly called slide drilling because the drillpipe slides along the wellbore without rotating; the bent housing (and thus, the tool face) is oriented for trajectory control.

With the motor and MWD system, sliding drilling efficiency is largely dependent upon the driller's ability to transfer the proper amount of weight to the bit without stalling the motor, and to reduce longitudinal drag sufficiently to achieve and maintain a desired tool-face angle.

Several techniques are available for reducing longitudinal drag. They include lubrication, rollers, downhole vibrators within the bottom hole assembly (BHA), and the use of a "rocking" procedure that consists of turning the pipe to the right and then to the left by an amount that avoids interference with the tool face.

The effectiveness of each technique varies with well conditions but each technique also has They. Limitations can include cost, rig downtime, permanent installation requirements and increased risk for downhole failure or loss due to introduced equipment, vibrations and fishing restrictions.

By defining the relationships between torque, drag and downhole pipe movement, Slider LLC established the foundation for a control system for automating the slide drilling process, helping to ensure optimum performance.

BENEFITS OF TORQUE CONTROL

By sensing the amount of surface torque needed to transfer the proper amount of weight to the bit, and eliminating the need to come off bottom to make tool-face corrections, automated slide drilling allows substantial increases in both the daily footage drilled and the length of horizontal departures that can be achieved.

To commence slide drilling from the rotary drilling mode, the driller simply initiates an automatic rocking action by applying sufficient torque to the left and then to the right to allow appropriate weight transfer to the bit.

The transfer of weight is controlled through the adjustment of rocking depth, which is automatically adjusted to compensate for changes in reactive torque.

Consequently, downhole back-offs due to sudden major motor stalls are avoided, and no time is lost in orienting the tool face.

Corrections in tool-face angle are easily achieved through additional torque pulses (bumping) during the rocking cycles.

THEORY OF TORQUE CONTROL

To understand the effect of surface torque and reactive torque on longitudinal drag, a velocity vector was derived from the combination of pipe rotation to the right and left, and drillpipe movement forward during drilling.

The velocity component is a function of the position of the pipe along the entire wellbore. The direction and magnitude of this vector will dictate the degree of reduction in longitudinal drag.

Left-and-right torque rocking initiated by the top drive reduces longitudinal drag in the wellbore, allowing the drillpipe to rotate from the surface down to a point where torque from rotational friction against the side of the hole stops the drillpipe from turning.

Meanwhile, reactive torque generated by the drill motor is transmitted up the pipe to a point where it is overcome by the bottom hole friction along the BHA/drillpipe system, referred to as the point of interference.

Between this point and the bit (described here as the zone of interference), the velocity component again dictates the degree of reduction in longitudinal drag and the change in tool-face orientation.

To prevent pipe rotation from the surface from penetrating the zone of interference, the system is tuned based upon on-bottom and off-bottom torque measurements in the field during each job.

The point of interference changes as the reactive torque changes. To keep the difference between the depth of the point of interference and the depth of rocking relatively constant, thus providing a known constant actual sliding distance, an automated control system must compensate for this change.

The actual sliding distance is the length of drillpipe that does not turn during the rocking cycle.

Ideally, an actual sliding distance of zero would appear to provide the fastest weight transfer to the bit.

However, eliminating the actual sliding distance is not only impossible to achieve without affecting the tool face, it is also not necessary to provide good control of pipe movement, as proven in laboratory and field experiments.

COMPONENTS AND OPERATION

Input parameters to the control system include surface torque, standpipe pressure and/or downhole tool-face angle. The automation technology package comprises a software and a hardware component.

Software. The software component collects torque and standpipe pressure data required to determine the need for adjustments during drilling.

Standpipe pressure provides an indication of reactive torque, which changes continually. In monitoring reactive torque via standpipe pressure, the system continuously adjusts the rocking depth (amount of surface torque applied to the right and left) to compensate for the effect of reactive torque.

Because factors unrelated to reactive torque such as cuttings buildup, partially plugged nozzles, etc. can affect changes in the standpipe pressure.

The downhole tool-face measurement is used to determine the amount of correction needed to restore the tool face to a predetermined target angle.

To correct the tool-face angle during a rocking cycle, the driller can “roll” or “bump” the tool face by initiating torque pulses. These corrections can be made to the right or left with ease.

Hardware. The hardware component features a universal robotics solution to fit any top drive. It is non-intrusive and requires no rig modifications for operation.

The robot actuates the control systems (e.g. buttons, switches, wheels, etc) as directed by the software.

Safety. Though the automated system’s robotics eliminates the need for most manual adjustments required in conventional slide drilling, the system is designed to allow manual intervention at any time, assuring the highest level of operational safety.

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Complete redundancy was built into the torque control system to avoid left-hand torque overshoot and potential back-off, including a software check in the control logic and a hardware system that assigns an operator-adjustable torque limit to the top drive.

The automated control system can be installed in less than 2 hours without interrupting the drilling process.

Installation of sensors and the panel control box is the primary task involved.

DEVELOPMENT METHODOLOGY

To maximize the potential for successful field tests, Slider LLC conceived a strategy comprising three basic steps:

- Build a laboratory physical simulator;
- Conduct field tests with a smaller horizontal well drilling rig equipped with a hydraulic power swivel to validate the prototype’s reliability and ease of installation and operation;
- Scale-up production to a universal product line.

The laboratory physical simulator used to test the automation system comprised three basic components for simulating surface controls, wellbore events and downhole conditions.

The surface system contained the driller’s console, drawworks, top drive, and instrumentation package.

The wellbore system included a specially designed pipe for simulating the same wraps that drillpipe would be subject to in the field (d-less analysis was used) and a borehole torque and drag producing device.

The bottomhole system included a downhole motor with rock/bit interaction and adjustable formation strength capabilities. The rock/bit device was used to generate reactive torque, and its output could be varied based on the aggressiveness of the bit being simulated.

The formation strength device allowed for axial advancement of the bit while drilling to simulate softer or harder rock.

After initial manufacturing of the physical simulator, the system and its various components were calibrated against field rig data.

The same rig from which this data was gathered was later used for field-testing the automated system.

This assured the highest possible degree of accuracy during laboratory experiments and minimized the field trial duration.

The control system was developed for the laboratory simulator in such a way that the same software could be used in the laboratory and in the field.

Because the first field test was scheduled for a rig with a hydraulic power swivel, an industrial control panel for that system was modified so that the control panels could be swapped on the rig during the field test.

After the second field test, this adaptation was no longer necessary because robots (servo motors with appropriate software and hook-up capabilities) had been added to provide a universal solution for all types of top drives.

Component Testing. All components performed according to plan in the initial field test. The concepts learned in the laboratory were proven and all the discoveries were confirmed.

After five days of testing without any downtime, developers decided that it was safe to move from alpha testing to beta testing and remain on location, drilling the well up to the end of the lease boundary.

This was a rather unique and fortunate opportunity, considering that numerous field trials are normally required to prove new technology, even after thorough laboratory testing.

FIELD TEST RESULTS

On the first job, the average daily sliding ROP increased from 5-7 ft per hour to a range of 10-20 ft per hour. The ROP in the rotary drilling mode with the downhole motor was 40 ft per hr.

On the second job, the average daily sliding ROP increased from 3-4 ft per hour to a range of 5.6-7.2 ft per hour. Again, the ROP in the rotary drilling mode with the downhole motor was 40 ft/hr.

The field test well had a 4,000 ft+ horizontal departure and the directional driller experienced great difficulty in manually locking in the tool face to the desired value.

After a 45 minute attempt, the automatic torque control system was deployed. The tool face was easily obtained and maintained at the desired range of 140°-165°.

Thirty minutes after the automatic torque control system was put into use, the downhole motor stalled and the driller attempted to correct the tool face manually.

After five minutes without success, the automatic torque control system was again deployed and successfully corrected the tool face.

Extended Reach. When a motor and MWD system is used to drill a directional well, the sliding controls the wellbore trajectory. An inability to obtain the desired tool face or to achieve the rate of penetration necessary for sliding often results in increased drilling time and can be tolerated only for a short while.

The inability to slide can cause the target envelope to be missed or the lateral section to be cut short.

In one job, the driller encountered difficulty in trying to orient and control the tool face manually at higher step-outs. As a result, drilling economics limited the length of this lateral section.

This difficulty was not experienced with the automatic torque control system, although more data are necessary for determining limits of extended reach drilling.

Improving Motor Life. Stalling of downhole motors due to longitudinal drag and sudden transfers of weight to bit are known to cause premature motor failure due to excessive stresses exerted on the rubber component by the fluid blow-by.

During the first 45 minutes that tool-face orientation was attempted manually, the downhole motor stalled nine times.

Only one stall was observed during the use of the automatic torque control system.

Bumping. A "bumping" procedure is used to achieve a small tool-face correction (typically 10° to 40°). Such corrections are made after torque is increased during a rocking cycle.

If a right-hand correction is required, the right-hand torque will be increased by an amount determined by the directional driller.

A similar procedure is used for a left-hand tool-face correction.

This procedure is very simple and is commonly used with the automated torque control system to orient the tool face from its random landing position as the driller transitions from the rotary mode to the sliding mode.

This technique can also be used to correct the tool face if it begins to roll away from the target value while sliding.

Rolling. The automatic torque control system provides additional steering capabilities to a motor and MWD system through a procedure called rolling in which a continuous small torque bias is applied to the left or right to slowly build or drop the angle of trajectory.

The tool face is rolled to the right when the right-hand torque is increased and the left-hand torque remains constant.

Likewise, the tool face is rolled to the left when the left hand torque is increased while the left-hand torque remains constant.

At the end of a slide run, the directional driller decided to reduce the inclination by bringing the tool face closer to the low side.

This was accomplished by increasing the depth of the right-hand torque while holding the left-hand torque value constant.

A smooth roll of the tool face towards the right was observed over a 20-minute period and the tool-face angle changed from 155° to 200°. ■