New technology can change deep well economics

Offshore deep drilling has marginal economics. One reason for this is the slow rate of penetration (ROP) that follows the need for heavy mud weights. To explain the significance of the problem, the same rock will drill at 1/10 of the speed when the mud weight is brought up by a couple of points.
With a big semisubmersible rig or ship, the slow speed becomes a big cost element. Many medium and more smaller fields are abandoned for this reason. In deep offshore regions like Brazil, even fields with larger reserves are put on the backburner for the same reason.

The heavy overbalance effect on ROP is well known to drillers and is also thoroughly debated and discussed in academia. New computer tools have recently given further details and insight to the cause of the problem. SPE paper 105885-PA from May 2009 gives a description of the problem and potential solutions by group of authors from both Schlumberger and Baker Hughes covering fluid, drilling and bit technologies. Leroy Ledgerwood III, Baker Hughes and Stefan Mizka, University of Tulsa has quantified the same effects in single cutter tests. The results were presented in paper SPE-119302-PA, March, 2010. Legerwood have later summarized the research in the 2018 SPE Distinguished Lecturer program.

THE AFTERBURNER PROJECT

In 2012 Tomax started a project to reduce the hydraulic jetting forces and reducing the impact pressure on the bottom. A reliable solution was found by applying the suction principle from a sewage pump for bottom hole cleaning. The pump would by design eliminate the flow pressing cuttings down to the bottom to be re-ground. It would also remove the risk from reactive pressures charging natural fractures. This meant more stable near bore rock. The solution was realized for drilling by five ejector pumps, also known as jet pumps, arranged to replace the waterways in a stabilizer located close to the bit. The system was set up for standard pump rates from surface. In addition to keeping the bottom clean, the jet pumps also produced a significant extra thrust or tractor force. This gave the project its name. Figure 2 shows a sketch of one of the five Afterburner ejector pumps.

Figure 1. The Afterburner project has demonstrated how a fluid-driven jet ejector can clean the well by suction and stop the bottom-hole balling at deep depths.

PREDICTABLE PERFORMANCE

In its first well, the Afterburner was used to drill hard rock at 1,094m MD (3,200 feet). The photo in Figure 1 is from this test. Before tripping in to the hole, the ability to clean the bottom by suction was verified. The verification also included a check of the pressure intrusions in to an artificial fracture 6 feet deep. The pressure at the end of the fracture was measured to peak 34 bar with a conventional bit while the reading was 0.5 bar with the Afterburner. This was quantitative evidence of the Afterburner advantage in unstable layers.

As drilling commenced in the test well, the reactive torque and the return of cuttings over the shakers confirmed the bottom was kept clean.

The hole cleaning capacity was stress-tested by using fresh water to lift the heavy cuttings from basement rock. The circulation rate was 1,800 liters per minute, or 480 GPM in imperial units. Key performance data was obtained from a downhole quartz gauge with readings taken at the face of the bit.

CFD ANALYSIS

An advanced, Computational Fluid Dynamics (CFD) analysis was needed for a detailed characterization of the Afterburner. The specialist engineers at Flow Design Bureau AS and EnginSoft took on the task. Their more advanced EngineSoft™ computer tools proved to be very useful for predicting and optimizing the solution for a wider variety of applications. The first analysis was run on the same drilling test that had already been completed. The CFD results came within decimals of both the previous MATLAB results and the pressure gauge recordings.

DEEP OFFSHORE TESTING

With the updated CFD models that also included predictions for sand erosion, operator VNG Norge AS sent an Afterburner unit to a deep offshore well. VNG had seen the rates of penetration (ROP) drop with increasing mud weight on this location and wanted to check out if the Afterburner could indeed help reducing the problem. Measuring the thrust force was a secondary objective but would serve to confirm if the suction effect was enough to evacuate the cuttings rather have them ball-up on bottom. Downhole data was obtained from a dedicated MWD drilling dynamics sub (Co-Pilot). The Afterburner, RSS and PDC bit were

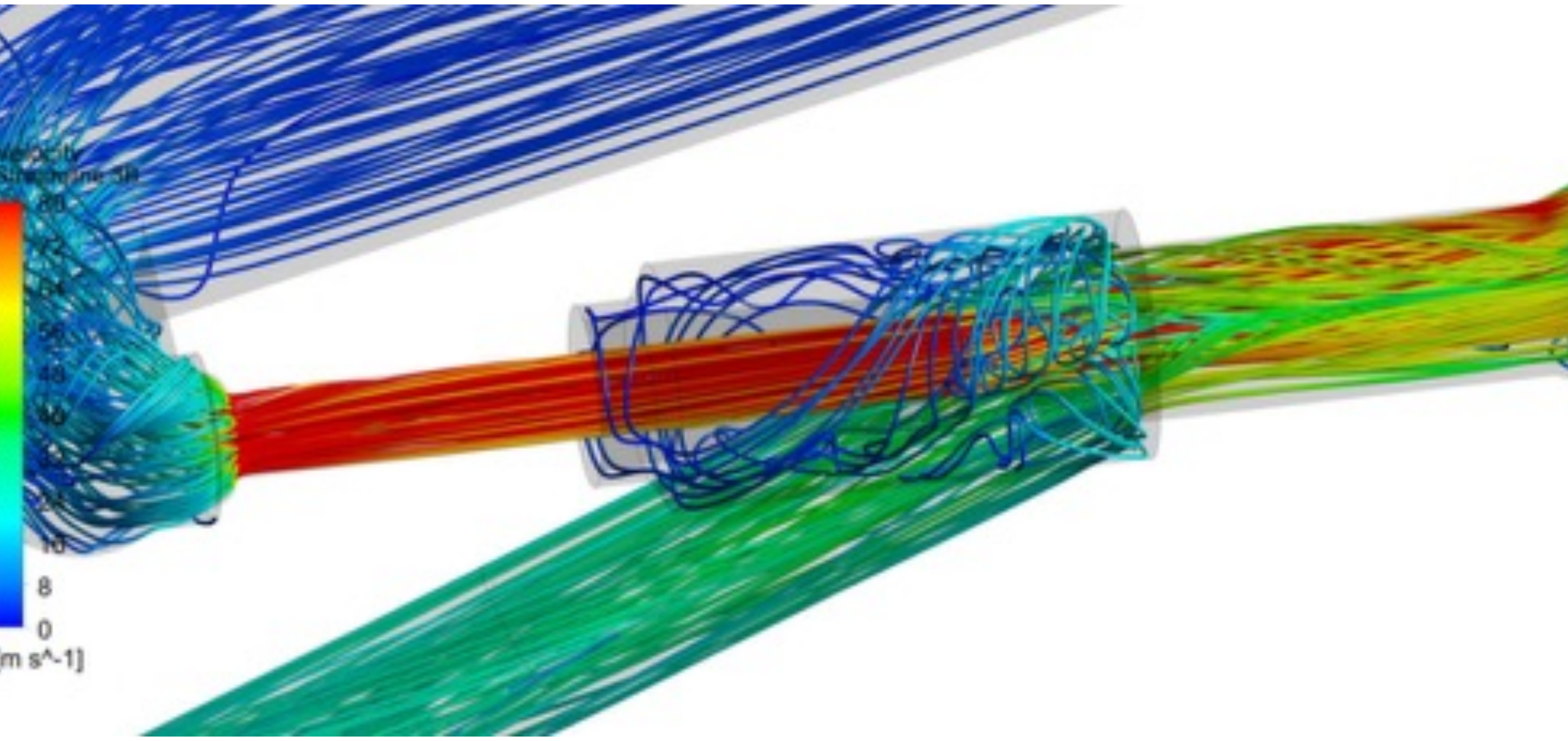

Figure 2. The Afterburner ejector pump principle: The flow from surface makes a fast (red) jet of fluid with low pressure in its core. The low pressure draws in mud and cuttings from the suction channel that keeps the bit on bottom clean.

tripped in to 4,100m MD (13,400 feet). When drilling commenced, double ROP at less than half the WOB from the previous run confirmed clearly no re-grinding was taking place. The Co-Pilot data showed the WOB contribution from gravity was between 2 and 3 kdaN. The driller simultaneously reported WOB readings between 7 and 9 kdaN from the hook. The bit size was 8½" and the mud was 1.55 SG. The flow was 1,630 lpm (430 GPM).

CLEAN CUT

The bottom hole cleaning by the Afterburner is done by suction. An important aspect in preventing re-grinding and bottom-hole balling is the fact that suction simply works better than jetting: This can be appreciated by observing how the household vacuum cleaner works best in tight corners. The CFD modeling of the Afterburner dynamics showed the same. A 3D velocity plot from the CFD model is presented in Figure 3. The plot shows how the sweep is at its best in the corners of the cylinder. This was what triggered VNG Norge AS to try out this principle for eliminating the infamous chip hold-down phenomena.

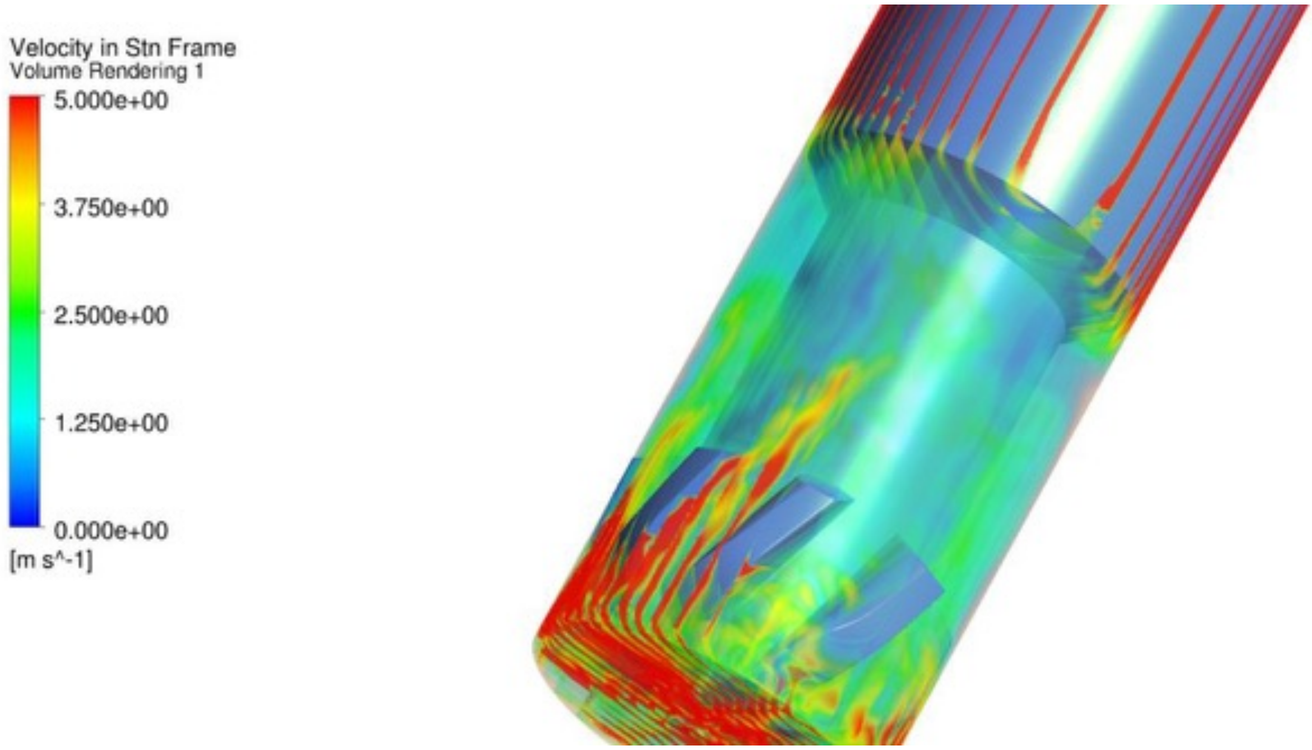

Figure 3. Computerized Flow Dynamics (CFD) model showing the bit.

SPECIAL CONSIDERATIONS

The Afterburner tested was based on a 40cm (1.2') long, spiral blade stabilizer. Instead of waterways, the 8 3/8" OD stabilizer had five ejector pumps. The unit is also characterized by five fluid channels leading from above the stabilizer and down to the bit nozzles. A sharp PDC cutter that is making hole needs practically no more cooling than the heat sink provided by the bit matrix and the rock. Hence the circulation of fluid sufficient for lifting out the cuttings is also sufficient for cooling. The drawdown pressure will by design level out below 100 psi. The cross-section of the Afterburner body with its large pumps and its borehole clearance makes the surge and swab pressures peak at about 20 psi. This is when tripping at 30 seconds/stand. The figures have been verified by both quartz gauges and comparison of drag readings in deep offshore testing.

SELF CLEANING

The risk of blocking one or more of the ejector pumps was considered a risk factor in the design phase. The ejector pumps are therefore opened up to let through 14mm (11/16") ball shapes or marbles. This is far beyond any conceivable size and shape of cuttings from a PDC bit. Larger cuttings than 13mm can't enter the pumps anyway and will be trapped on the outside to be ground to pieces before entering. Continuous successes in cleaning up

“An advantage from the compact design is easy integration with existing technology.”

fill from the bottom of the hole in testing have indicated that the internals of the five pumps are self-cleaning. The mechanism behind this is believed to be the intensity of the vibrations created when rotating the bit and the BHA. The continuous impacts to the Afterburner body make it virtually impossible for cuttings of measurable mass to settle or bridge. With the cutters engaged in drilling, these vibrations will intensify further. The result is a very low risk of blockage.

BHA INTEGRATION

The Afterburner consists of a stabilizer converted into a jet pump.

An advantage from the compact design is easy integration with existing technology. In the latest field run, the unit was added to a 3-point push-the-bit RSS system. That made it a stiff, 4-point system that was acceptable for drilling straight ahead. Unfortunately, plans changed and called for maximum turn. This was not doable with such a stiff system in a deep well and the bit parted. The lesson learned was to either run the Afterburner in a plain rotary BHA or to fully integrate it as a stabilizer in a 3-point geometry. Figure 4 shows such an integrated Afterburner having the Tungsten Carbide pump installed.

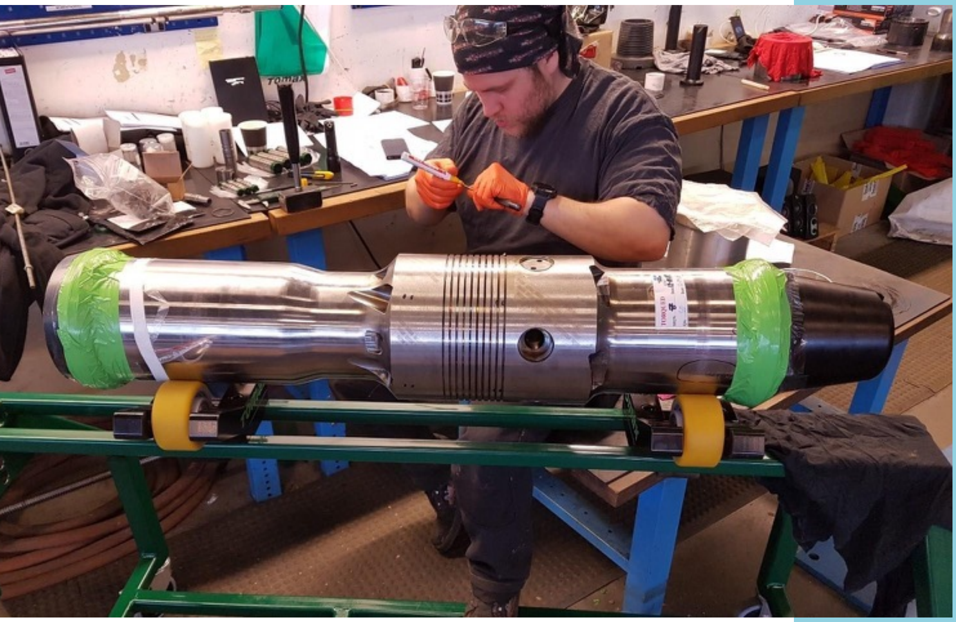

Figure 4. 2018 version Afterburner with wire-feed for integration in commercial RSS system.

Figure 5. The Afterburner aims to replace cuttings cleaning by jet impact. This picture shows the jet impact from a rate of 1600 lpm.

THE DRILLER'S PERSPECTIVE

One success criterion in the introduction of new technology is the driller's interface. The Afterburner makes no changes to the driller's practices. The WOB is read and understood as always and the brake is operated accordingly. There are no changes to barriers and well control procedures. A piece of good news for both the driller and the drilling engineers is the removal of the problematic blind zone in front of the bit: The blind spot is gone because the highest pressure in the system now moves up into the annulus where the MWD's pressure sensors are located. This mean ECD readings are accurate and less error margins are needed.

CONCLUSION

The Afterburner development has demonstrated how a fluid-driven jet pump can clean the bit, remove the crushed rock detritus by suction and thus eliminate the regrinding of cuttings that slows down the drilling, causes over-heat and limited bit life. The ability to speed up drilling in deep wells can bring back the potential and value of many offshore prospects.

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