First Field Results for Extended-Reach CT-Drilling Tool
V. Dagestad, SPE, Statoil ASA; M. Mykkeltvedt, Weatherford Norge A/S; K. Eide, SPE, PI Intervention A/S; and N. Reimers, Tomax A/S

Abstract
Coiled tubing conveyed drilling and milling operations have over the last years been improved by several new inventions. One such invention is the Anti Stall Tool (AST). The Anti Stall Tool controls the force applied to the bit relative to torsion and prevents the bit from stalling under load. This way the AST technology provides improved operational flexibility and tolerance for abrupt weight transfer typical for operations in extended reach and high angle wells.

Statoil has conducted a qualification program involving the new invention and has found it to meet the objective of significantly reduced stall-outs. Additional advantages are improved bit and motor life and fast penetration. The AST is now in the early commercial stage with 8 field operations on the record and sizes ranging from 3” up to 4 ¾” OD. This document summarises the findings from the qualification program and the first field operations.

Introduction
Long and deviated wells have for long been the best and most viable route to good field economy on the Norwegian Continental Shelf. For the major operator in this area, Statoil ASA these wells have shown to be a challenge in terms of maintenance using coiled tubing technology. The challenge is mainly arising form friction levels making the interventions unpredictable with delays, failed campaigns.

A new, promising tool to meet the challenge is a patented concept named the “Anti Stall Tool” (AST). The AST invention is aimed to reduce and even eliminate stall-out problems related to drilling and milling.

The concept claims the ability to:

• Actively balance the drilling forces downhole to prevent bit stall-out
• Reduce damages from shock loads through an improved transfer of energy

Technical background
The AST concept is based on providing a continuous balance between drilling torque and the force applied to the bit. This ability to balance and consequently stabilize the drilling torque is beneficial for extended life of downhole equipment and is assumed to be effective for preventing destructive forces working in three different directions; Torsional, axial and lateral.

Although not seen as very difficult loads to deal with, most of the damages to threaded connections come from torsional peaks likely to origin from stick-slip motions. The AST works actively to limit stall-out and the associated stick-slip motion as follows:

• When the bit approaches stall, the torsion accumulating in the string will eventually activate the AST causing a contraction of the tool. This contraction will off-load and free the bit
• Following a contraction, the unit will release the excessive string torsion gradually

In cases where the forces do not exceed normal drilling levels, the AST tool will not provide any motion or other action. Axial overload is typically occurring from weight transfer problems associated with deviated wells and floating vessels. The string is usually mechanically resistant to this kind of loading but in combination with drilling operations the axial shocks can place excess weight on the cutters and initiate motor stall-outs. The AST works directly to counteract axial overload by allowing for 6” of contraction. Lateral shocks are very destructive and difficult to absorb once they occur. A good strategy is to stabilise the BHA and monitor the status by MWD sensors where available. Stabilising the BHA is becoming increasingly difficult because of the fixed cutters tendency to enter into a stick-slip mode. The AST will reduce damages from lateral forces by counteracting stick-slip as described under torsion forces above.
**AST principle of operation**

Reference is made to Figure 1. The principle of the AST tool is that torsion with magnitude to overcome the compressed spring (a) will make the upper part (b) with external helical spline screw into the lower part (c). The relative motion between the upper (b) and lower (c) part leads to a contraction (f) and the drill bit is pulled off bottom causing an immediate reversal of the accumulative stalling process. As the torsion is reduced, the spring (a) will extend the unit and hence put the bit back to drilling. The bit is never pulled off bottom in the process. It is only retracted sufficiently to reach a new equilibrium between the torque and the spring force. The bottom shoulder (e) will allow for direct transfer of pull through the system and thereby allow for unaffected fishing and upward jarring.

**Tool layout**

The Anti Stall Tool comprises the following parts also identified in Figure 1:

- **a)** Pre-loaded spring
- **b)** Up-hole part with male helical spline
- **c)** Bottom-hole part with female helical spline
- **d)** Pressure seals
- **e)** Lower chamber and shoulder
- **f)** Telescopic section

**Figure 1: AST cross-section**

**Placement in the BHA**

The AST is placed as close to the bottom of the BHA as possible. Tests have been performed with the unit placed both over and under the motor section. To avoid excess stress on the motor driveshaft and bearing, the most beneficial placement in field applications has proved to be above the motor sections as illustrated in figure 2.

**Figure 2: Shows AST in a scale milling assembly for field operation in well # 8 in Table 3**
Prototype tool
Two identical prototype tools were produced for the qualification program. A tool dimension adapted to a 2 7/8” motor was chosen for economical reasons, ease of testing, and availability of a suitable test facility. The design of the AST is scalable, and hence starting with a small version was considered beneficial. The tool designer made the upper (stationary) body 3” OD to provide a 1/8” clearance for the moving, lower 2 7/8” sub. Table 1 shows the technical specifications for the prototype tools.

Table 1 – AST Prototype dimensions;

<table>
<thead>
<tr>
<th>Prototype dimensions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. OD</td>
</tr>
<tr>
<td>Min. ID</td>
</tr>
<tr>
<td>Connection</td>
</tr>
<tr>
<td>Length</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operating Range:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diff. press</td>
</tr>
<tr>
<td>WOB</td>
</tr>
<tr>
<td>Motor output</td>
</tr>
<tr>
<td>Flow</td>
</tr>
</tbody>
</table>

Test results
Three controlled tests were performed to find if the tool behaved according to the theoretical background.

Test #1
In the first test, the AST was run behind a 2 7/8” positive displacement motor (PDM) in the Weatherford-Bakke test center. A new mill was made up to drill out a hollow plug in a 5 ½” liner (see figure 3 and 5). The first run was a reference run without the AST to establish the maximum force (WOB) against the plug for the motor to stall. The AST was then included and the bit driven against the plug with increasing advancements and force. It was found that the AST worked as prescribed and it was impossible to stall the motor even with repeated forces (WOB) over two times the maximum reference load. Figure 4 shows the two runs without and with AST. Figure 5 is a picture from the actual test with motor and AST tool.

A discovery in this test was the fact that the prevention of motor stall-out made it possible to apply higher WOB and safely operate the motor close to maximum differential pressure. The higher load gave a clearly improved rate through the plug-dummy. Figure 6 shows the motor output graph with the improvement in torque range provided by raising the differential pressure from 30% to 80% of maximum as was done in this case.

Test #2
The second test consisted of a exit through 7” tubing with a one-run whipstock and mill system and a 3 ½” PDM. This configuration was beyond the initial design specification of the 3” AST but it was still found worthwhile for testing. It was found that the WOB required during window milling at times caused the AST to fully compress and consequently loose the antistall effect. The AST was however very important for starting the long taper-mill smoothly and without any stall-outs. The test also confirmed that the AST would not create a problem when operated in overload situations.

Test #3
The third test was a repetition of the second test but with coiled tubing unit and a 4 ¾” motor operating in a flow loop. The test gave the same results as test 2. The driller commented the ease of putting the mill on bottom with the AST tool. Based on test 2 and 3, a new AST tool was designed to provide a solution for 4 ¾” motors. The test summary is found in Table 2.

Table 2 – Test summary for 3” AST;

<table>
<thead>
<tr>
<th>Test Log</th>
<th>Location</th>
<th>BHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test #1</td>
<td>Bakke test bench</td>
<td>2 7/8” PDM and mill</td>
</tr>
<tr>
<td>Test #2</td>
<td>Bakke test bench</td>
<td>3 ½” PDM + whipstock</td>
</tr>
<tr>
<td>Test #3</td>
<td>Ullrigg</td>
<td>4 ¾” PDM + whipstock</td>
</tr>
</tbody>
</table>

Field Experience
The controlled tests confirmed the abilities of the Anti Stall Tool to prevent the bit from stalling. Furthermore, there was no evidence that the drilling efficiency would be compromised.

First field deployment
Shortly after the test program was completed, a tool was deployed to a field on the Norwegian Continental Shelf operated by ConocoPhillips as a part of a BHA aimed to mill a relatively long section of hard scale from a minimum drift of 1.75” and open up to 4”. Due to the efficient penetration with the initial 3 ½” step mill and AST, a planned intermediate run was left out and the final 4” mill was used in the second run. The comment in the Final Job Summary from the well was; “Stall tool in BHA seems to work perfect, since no stall out seen on motor while commence milling”.

The AST was consequently called back for another well on the same field. Again the number of motor stall-outs where reduced and the Final Job Summary concluded; “We had some stall outs on each run, but it looks like the anti stall tool is doing a good job”.

Three runs to TD were performed in fast order with sequencing circulating tools for cleaning out the scale. No tool problems combined with very efficient milling made this an extraordinary effective job.

First international deployment
Based on the results from the ConocoPhillips operations a 3” AST was deployed to a field in Brunei and the Technical Supervisor gave the following feedback: “The job was a 100% success and the tool worked perfectly although we did manage to stall the motor twice. “

Through eight consecutive field deployments listed in Table 3, the initial results were to a far extent repeated:
• Significant reduction in stall-outs
• Minimum fatigue cycles on CT
• No BHA failures
• No loose or over-torqued connections
• Remarkably low bit wear
• Remarkably good motor condition after use
• Jobs completed ahead of plan

Table 3 – Job summary

<table>
<thead>
<tr>
<th>Well</th>
<th>Operator</th>
<th>Objective</th>
<th>Stall-out</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Conoco Phillips</td>
<td>Drill scale</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>Statoil</td>
<td>Drill scale</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>Shell Brunei</td>
<td>Drill plug</td>
<td>Minor (2)</td>
</tr>
<tr>
<td>4</td>
<td>Statoil</td>
<td>Drill scale</td>
<td>Minor</td>
</tr>
<tr>
<td>5</td>
<td>Statoil</td>
<td>Drill scale</td>
<td>Minor</td>
</tr>
<tr>
<td>6</td>
<td>Statoil</td>
<td>Drill scale</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>ConocoPhillips</td>
<td>Drill scale</td>
<td>Minor</td>
</tr>
<tr>
<td>8</td>
<td>Statoil</td>
<td>Drill scale</td>
<td>None</td>
</tr>
</tbody>
</table>

With reference to the introduction and the technical background for the AST, the documented reduction in BHA failures, overload and wear provides strong evidence to support the statement that counteracting stall-outs and stick-slip will produce a reduction in damages from lateral shocks and vibration.

Applications
Based on the documented advantages and the possible added value of improved penetration, the AST can provide significant gains in several areas:

• Window milling / sidetracking
• Wells with marginal friction drag conditions – i.e. extended reach drilling
• Wells with hard or irregular scale
• Operations close to the temperature limit for the motor
• Operations from floating vessels
• Possibly improvements for rotary drilling applications
• Drilling in abrasive formations
• Increased LWD/MWD lifetime
• Increased ROP

Conclusion
It has been proven through comparative tests and operations that the new AST technology has met the objective of significantly reducing stick-slip and stall-outs. Some additional advantages have been improved bit life and faster penetration. The AST is now in regular service with more than eight operations on the record and tool sizes up to 4 ¾” for coiled tubing and rotary drilling operations.

It is anticipated that the presented results will make coiled tubing milling and drilling a more feasible method for well services; in frontier, extended reach operations as well as in brown-field maintenance.

Acknowledgments
The authors wish to acknowledge ConocoPhillips Norway for their pioneer spirit as the first company to use the invention and for their contribution through release of information to properly document field results.

Additionally, the authors want to thank inventor and development project manager Nils Reimers, Statoil ASA and Weatherford Inc. for access to background technical information used as basis for this paper.

Nomenclature
AST = Anti Stall Tool
CT = Coiled Tubing
CTD = Coiled Tubing Drilling
PDM = Positive Displacement Motor
OD = Outside Diameter
ID = Internal Diameter
BHA = Bottom Hole Assembly
WOB = Weight (force) On Bit
TOB = Torque On Bit
TM = Trademark
BJ = BJ Services Inc.

References
Norwegian Patent NO 315209 filed October 18th 2001; DYNAMISK DEMPER FOR BRUK I EN BORESTRENG

International Publication Number WO2004/090278 A1 filed 14th of April 2003 under the international Patent Cooperation Treaty; DYNAMIC DAMPER FOR USE IN A DRILL STRING
Figures

Figure 3; Weatherford-Bakke motor test bench

Figure 4-1; Test without AST

Figure 4-2; Test with AST. Identical scales on from figure 4-1)

WOB in kdaN

TOB in daNm

< - WOB KdaN

< - Torque in daNm
Figure 5; AST tool placed on top of Weatherford CTD motor in test bench as illustrated in figure 3

Figure 6; Motor output graph showing an improvement in available drilling torque of 250 ft-lbs or 50% by raising the differential pressure from 30% to 80% of capacity