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AADE 2009NTCE-13-03: A COMPARATIVE STUDY OF TORQUE REDUCTION ADDITIVES AND MECHANICAL DEVICES FOR IMPROVED DRILLING PERFORMANCE

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INDTRODUCTION

Extended reach wells have proven to be more demanding from both operational and economical viewpoints. The need for a means to reduce both drilling costs and operational complications has risen as the wells have become longer, deeper and more extreme in their trajectories. Current rotary drilling methods are effective, but have many drawbacks that can lead to costly downtime and a low rate of penetration (ROP). A means of reducing torque and casing wear can have the potential to increase ROP and drilling efficiency significantly. This dilemma has caused an increased interest in means of reducing torque and casing wear. This report investigates the performance of three commonly used methods and how they compare to each other. The three options tested include polymer drilling beads (both coarse and fine), surfactant type mud lubricants, and a non-rotating mechanical stand-off and torque reduction device.

OBJECTIVE

Comparing the performance of torque and casing wear reduction methods requires a set of data collected under realistic operating parameters. Current information is available on the individual characteristics of each of the common modes of casing protection and torque reduction. These tests, however, provide quantitative data based on ideal and unrealistic conditions where machined steel surfaces represent tool joint on casing contact and contact loads are minimal. Such reported tests are provided by the Society of Petroleum Engineers. Published reports include papers SPE 48939, SPE 56562, SPE 92002. To allow a direct comparison, a series of tests was performed characterizing each option's torque reduction and casing wear reduction ability under the same conditions in a more realistic loading environment.

TEST SET-UP

These tests required the use of a unique test fixture specially designed to apply a prescribed load and rotational speed while recording torque and load measurements. The test fixture assembly cross-section, shown in Figure 1, illustrates the manner in which the tool joint or mandrel is driven and how the data is recorded. Inside the sensor housing, a rotating torque transducer is attached in-line with the drive motor. This sensor allows for a direct reading of the torque induced by the friction of the sample being tested. The rotational speed is measured in revolutions per minute (RPM) by a proximity sensor that reads each revolution of the shaft. The side load is measured by a load cell attached in line with the applied load. All readings are fed into a Data Acquisition System (DAQ). The entire assembly was submerged in a mud trough, fabricated from a 9-5/8 inch, 53.5 pound per foot casing cut longitudinally and capped at the ends. Drilling mud was circulated along the casing by means of a sump pump. The drive assembly remained fixed in position while the casing was lifted to apply a specified load to the tool joint or test mandrel.

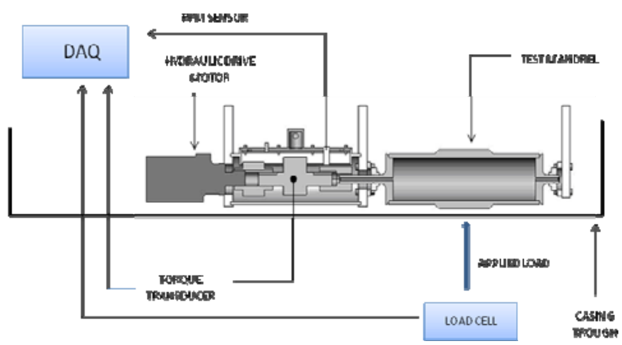

Figure 1. Test Fixture Diagram.

In efforts to create a test that simulates real down-hole conditions, a tool joint modified to fit the test fixture was prepared. Figure 2 shows the tool joint used. Shaft ends were fitted to an actual tool joint of a 5-1/2 inch drill pipe. The tool joint used had a nominal outside diameter of 7-1/2 inches with hard banding on the box (female) end creating a maximum diameter of 7.56 inches. For the non-rotating protector, a mandrel with a 5.50 inch diameter was used to simulate actual drill pipe, see Figure 3.

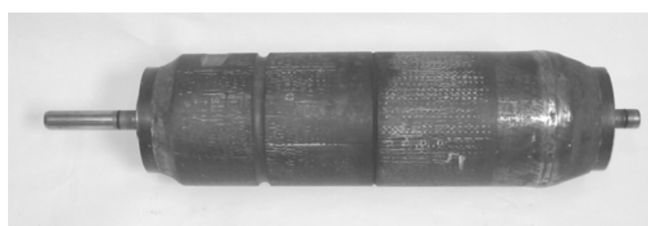

Figure 2. Sample Tool Joint.

Figure 3. Drill Pipe Test Mandrel.

To address the issue of casing wear, casing inserts were fabricated to set inside the mud trough. All the casing samples were fabricated from 4130 steel with a measured hardness of 51-54 Rockwell A. A new casing liner was installed prior to each test allowing a measurement of the casing wear accrued during each test. Figure 4 shows a casing insert prior to installation.

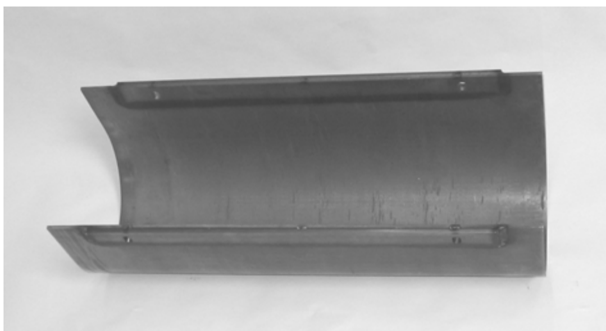

Figure 4. Casing Insert.

To perform such tests where the objective is to obtain both qualitative and quantitative data, controlling the test parameters is critical. It was decided that a moderate loading condition of 1000 lbs at 160 RPM for 2 hours would be adequate. Torque and load data would be recorded every 15 minutes. From this, the coefficient of friction (COF) could be plotted over time to investigate possible changes or trends that may occur throughout the duration of the test. In addition, this two hour interval was estimated to be long enough to accrue sufficient measurable wear for comparisons.

Water based high viscosity and high gel drilling mud with a weight of 9.6 pounds per gallon was used as the base media to test all trials. The same batch of mud was used throughout the series of trials for consistency; proper amounts were allotted for each additive and trial. After each run, the test fixture was cleaned and wiped down in preparation for the next run.

The tested matrix was as follows:

- Test bare tool joint in water base mud with no additives or friction reduction mechanisms. This would establish the standard for comparison between torque and wear reduction methods

- Test bare tool joint with coarse polymer beads at recommended concentration (6 pounds per barrel (lb/bbl)) in water base mud.

- Test bare tool joint with fine polymer beads at recommended concentration (6lb/bbl) in water base mud.

- Test non-rotating drill pipe protector with no additives in water base mud

- Test non-rotating protector with fine polymer beads (6lb/bbl) in water base mud

- Test bare tool joint with Lubricant #1 at recommended concentration (5lb/bbl) in water base mud.

- Test bare tool joint with Lubricant #2 at recommended concentration (0.5lb/bbl dry emulsion) in water base mud

RESULTS

The torque and wear data collected for the various methods of torque reduction displayed a wide range of results. Both fine and coarse beads displayed moderate torque and casing wear reduction. One of the lubricants showed moderate performance similar to the beads, while the other showed no reduction in torque or wear at all. The non-rotating drill pipe protector provided the greatest torque reduction and prevented any casing wear from occurring. Results can be examined in tabulated form in Tables 1 and 2.

The base line test with the bare tool joint showed a COF range of 0.29-0.36. The correlated wear depth of this baseline was measured to be 0.026 inches; taken as an average from five measurements at the deepest point of the wear patch. A scatter of approximately +/- 10% in torque is attributable to vibration during testing. Figure 5 depicts the base sample after testing.

Figure 5. Baseline Wear Patch.

The first additive tested was the Polymer Divinyl Benzene Styrene Copolymer Drilling Beads. Both the coarse and the fine beads at the same concentration yielded similar results. A separate container was prepared for each. Fine and coarse beads were added to their designated containers at a 1.5% by weight (6 lb/bbl) concentration. Over the designated time interval, average torque reduction was 67% for the coarse beads and 65% for the fine beads. The wear depth was measured at the deepest point of the contoured groove to be 0.010 and 0.016 inches for the fine and coarse beads, respectively. This correlates to a 72% and 51% reduction in casing wear, taken from a volumetric removal of material based on dimensions of the wear groove. It was observed throughout the duration of both tests that the beads break down and crush over time. The two hour test interval was not long enough to see an appreciable decrease in performance, but the crushed beads began to accumulate over time suggesting that there may be reduction in performance and supplemental additions of beads may be required maintain adequate concentrations. Figure 6 shows the crushed beads accumulating at the end of the mud trough.

Figure 6. Accumulation of Bead Particulate.

The lubricants tested varied greatly in their torque reduction and wear performance. Lubricant #1 was of a composition having polymers of fatty acid and fatty acid derivatives. Lubricant #2 was a Potassium blend compounded with surfactants and anti-caking agents. Lubricant #1 showed a 68% reduction of torque, while the Lubricant #2 reduced the torque by only 6%. Lubricant #2 wear depth was measured to be 0.027 inches at the deepest point, 0.001 inches greater than the base test. Lubricant #1 wear depth was measured to be 0.015 inches deep, correlating to a 56% reduction in casing wear. Both the lubricants showed increased sludge build up. Lubricant #2 displayed the sludge buildup the most. Figure 6 shows sludge from Lubricant #2.

Figure 7. Accumulation of Lubricant Sludge During Lubricant #2 Trial.

The tests utilizing the non-rotating protector showed a significant amount of torque and vibration reduction. The mechanical friction reduction device used for this test was of a type utilizing a fluid bearing. As the drill pipe rotates, a fluid film is created between the outside surface of the drill pipe and the inside surface of the protector. The loose fit of the protector around the drill pipe allows the protector to slide down hole without rotating. By doing this, not only is the friction factor greatly reduced due to the fluid bearing, but the effective diameter at which contact occurs is reduced. The tabulated results list the friction factor normalized to the tool joint OD, providing an equal scale. For this device tested, the overall torque was reduced by 90%. This device also completely prevented any casing wear due to the physical offset the device provides. When tested in conjunction with fine drilling beads, the non-rotating protector showed minimal reduction in effectiveness. The torque reduction dropped to 86%. The addition of the beads did not appear to show any change in the vibration dampening characteristics of the tool.

Table 1. Test concentrations and Associated Friction Factor Range.

Friction Reduction Additive/Device	Description	Concentration/ Frequency	Friction Factor Range
None/Bare tool joint	NA	NA	0.31 - 0.35
Non-rotating protector	Non-Rotating Drill Pipe Protector	1 per joint	0.03 - 0.04*
Non-rotating protector w/ fine beads	Non-Rotating Drill Pipe Protector and Divinyl Benzene Styrene Copolymer beads	1 per joint (Protector) 6 lb/bbl (Beads)	0.03 - 0.05*
Lube #1	Polymers of fatty acid and fatty acid derivatives	1.3 % (5 lb/bbl)	0.08 - 0.13
Fine Beads	Divinyl Benzene Styrene Copolymer	6 lb/bbl	0.09 - 0.13
Coarse Beads	Divinyl Benzene Styrene Copolymer	6 lb/bbl	0.09 - 0.14
Lube #2	Potassium blend compounded with surfactants and anti-caking agents	1 % (0.5 lb/bbl)	0.29 - 0.33

2hrs @ 160 rpm @ 1000lbs
* Friction factors listed for non-rotating protector normalized to tool joint outer diameter.

Table 2. Relative Torque and Casing Wear Reduction With Respect to Base Case.

Friction Reduction Additive/Device	Percent Reduction in Torque (average)	Percent Reduction in Casing Wear
None/Bare tool joint	NA	NA
Non-rotating protector	90	100
Non-rotating protector with fine beads	86	100
Lube #1	68	56
Fine Beads	67	72
Coarse Beads	65	51
Lube #2	6	0

CONCLUSIONS

Based on the results of the series of tests, the following conclusions can be made:

- The non-rotating protector outperformed the tested alternatives in both torque and wear reduction; reducing torque by up to 90% and eliminating casing wear.
- The beads and lubricants provide moderate torque and wear reduction with torque reduction ranging between 65-68% and casing wear reduction ranging between 51-72%, with exception to Lubricant #2.

- Both coarse and fine beads appeared to break down overtime, indicating the necessity to maintain adequate concentrations.
- The lubricants altered the properties of the mud; significantly increasing viscosity and sludge.
- The use of beads in conjunction with the mechanical device showed no adverse effects on the operational characteristics of the protectors.