

Product Selection Process Utilizing New Lubricity Device Accurately Predicts Field Lubricant Performance

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Abstract

Excessive torque and drag (ETD) caused operation problems in two separate extended-reach wells in Alaska and Oklahoma. The first well involved lateral installations where target depth attainment was at risk for both drilling and liner installations. The second well experienced ETD of a magnitude which prevented attainment of targeted depths. In both cases, the ETD was successfully managed by implementing a lubricant selection process using a new lubricity device to determine both which lubricant to use and the optimum concentration.

Introduction

Extended-reach drilling (ERD) operations, typical in gas shale plays, are situations where ETD poses serious problems. Problems include, but are not limited to, lower penetration rates, increased hook-load, and excessive fatigue and failure of downhole tubulars. Additionally ETD can prevent attainment of planned target zones. While ETD can result from various independent or combined factors such as cuttings beds, key-seating, sloughing shales, etc., a key factor to evaluate is the mechanical friction between the wellbore and tubulars.¹ When excessive mechanical friction is encountered, increasing wellbore fluid lubricity by lubricant addition is an effective and economical option. The decision of which lubricant to use, like any other additive, is driven primarily by potential effectiveness, fluid compatibility, environmental regulations, and economic factors.

Lubricant Selection Process

The first step of the lubricant selection process is an initial cost-benefit analysis to determine if cost of the lubricant additions is justified by the projected savings from reduced rig time, increased penetration rates, and/or reduction of wear on tubulars and drilling equipment. If a lubricant is justified, an evaluation matrix of environmentally acceptable lubricant candidates should be determined. Testing should be conducted to ensure chemical compatibility between the lubricant and drilling fluid, and where applicable, formation fluids. Lubricants, on some applications, are known to reduce drilling fluid rheology, be solids' intolerant or potentially "cheese-out", especially in high calcium environments. Products exhibiting severe compatibility problems must be eliminated from the evaluation matrix to avoid poor

performance resulting in an increased overall cost and possible failure to reach target zones.

Once incompatible lubricants are eliminated, the next step of the process is performance testing. Performance testing is accomplished through the use of lubricity test devices for comparison of the relative changes in the coefficient of friction (C_f) resulting from the addition of various lubricant candidates. The most versatile testers are those which can simulate both cased and openhole in the same way as the original Lubricity Evaluation Monitor (LEM) concept described by Alford² and also Quigley.³ A new device, the Lubricity Evaluation Monitor with new technology (LEM-NT⁴) allows quick, accurate testing on both formation and cased simulated wellbores. By incorporating the LEM-NT device in the lubricant selection process, the ability to predict lubricant field performance is greatly increased.

LEM-NT Description

The LEM-NT (Figure 1) was used to evaluate lubricant candidates by direct comparison of lubricity measurements. The LEM-NT is a benchtop-scale electro-pneumatic device which measures the C_f between a sample wellbore pressed against a rotating steel cylinder (bob) immersed in a circulating bath of the fluid being evaluated. The lubricity measurement is based on a model where the force of friction is directly proportional to the applied load with C_f being the proportionality constant. The model as applied to the LEM-NT takes the form $C_f = T / (F_{sl} * R)$. Where T is the resultant bob torque from friction, F_{sl} is the applied side load and R is the bob radius.

While the LEM and LEM-NT both share the advantage of being able to test formation and cased sample wellbores, the LEM-NT provides innovative updates to improve measurement repeatability, operational ease, safety and reliability. Key improvements of the LEM-NT include the following:

- Controlled pneumatic side load application using an electronic regulator feedback-controlled by a computerized data acquisition system.
- Periodic fluid refreshment in the bob/wellbore interface by pulling the wellbore away from the bob at definable regular intervals during the test similar to Skalle⁵ and more directly Alford.⁶

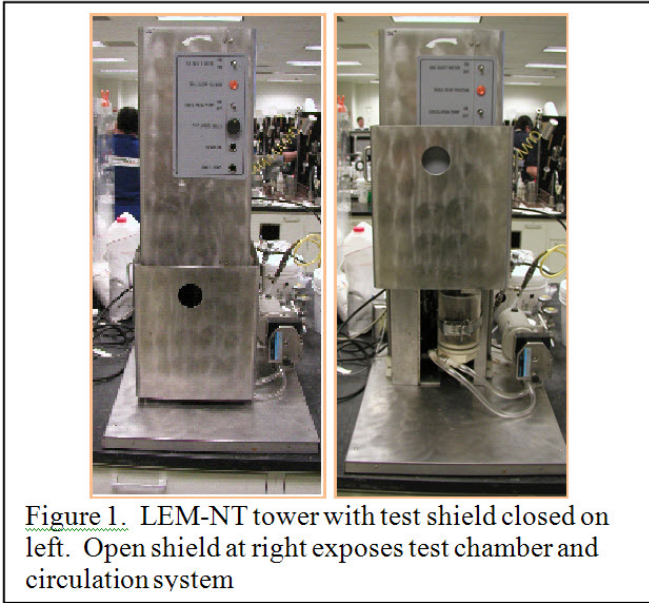


Figure 1. LEM-NT tower with test shield closed on left. Open shield at right exposes test chamber and circulation system

Table 1. LEM-NT specifications

| Parameter | Metric |
|------------------------|---------------------------|
| Side Load | 5-50 lb _f |
| Bob Speed | 10-250 rev/min |
| Bob Frictional Surface | 1.25-in dia. X 1.5-in L |
| Test fluid Volume | 350 ml (1 bbl equivalent) |

- Innovative sample wellbore clamping allowing both casing and formation sample wellbores to be tested in the same fixture
- Bob and shaft integration into single unit resulting in more rigid rotational system and allowing easy renewal of the bob sliding surface.
- Automated, computerized data acquisition and control including side load and bob rotational speed feedback.

While test parameters can vary as shown by the specifications (Table 1), standard test conditions are 200 rev/min bob speed and 32-lb_f side load. Sample wellbores are lapped (casing) or ground (formation) to assure the full length bob/wellbore contact. A test with water and steel casing is run to verify calibration prior to and periodically during evaluations.

Lubricants are typically evaluated by measuring the C_f of a control sample, adding a lubricant and then repeating the measurement to determine the change in lubricity. Some lubricants are tested with increasing concentration to determine optimum concentration. If multiple lubricants are to be tested, all wetted parts must be thoroughly cleaned between lubricants. If a permeable sample is used, that sample must be discarded to prevent cross-contamination.

After testing, lubricants are ranked by comparative lubricity, usually by percentage of C_f reduction. If more than one concentration is tested, product selection may not be solely based on friction reduction. Factors to be considered include cost of additions based on volumes as well as fluid property changes based on lubricant additions.

Field Implementation

Lateral Drilling Improvements (Western Operating Area North Slope, Alaska)

ETD was experienced while running the 4.5-in. liner on the first of four 90° laterals from an intermediate base at 9,700 ft to a depth between 14,000 and 14,500 ft. The drilling fluid was a 9.2-lb/gal oil-based fluid (OBM). Upon reaching the targeted depth, the OBM was displaced to a solids-free oil-based completions fluid (SFOCM) and then a liner was run in the hole. The measured C_f encountered during the liner run was 0.34. Four liner joints were pulled and excessive wear was noted. There was concern that the high C_f posed a significant risk of preventing successful liner runs in the three remaining laterals. There was an economic decision to evaluate a lubricant and review the overall well plan.

Lubricant A was tested for fluid compatibility with both the OBM and SFOCM. The LEM-NT was then used to determine lubricity performance using formation for the OBM and casing for the SFOCM tests. The LEM-NT indicated a 37% reduction in the C_f when using Lubricant A as compared to the base OBM drilling fluid and a 7% reduction in C_f as compared to base SFOCM. Operations decided to add 3% by volume of Lubricant A to the SFOCM at the warehouse prior to the displacement for the liner run on the second lateral.

Once the second lateral was drilled with the OBM, the fluid was displaced to the SFOCM treated with 3% Lubricant A. In addition to lubricant additions, it was decided to add centralizers to the liner. The liner was run to bottom without any incidents with a 0.285 C_f recorded during the run. Centralizers in area offset wells contributed to a 0.025 reduction in C_f . Even removing the centralizer contribution, a comparison of the liner run data indicated a 9% reduction in C_f was attributed by the addition of lubricant.

The third lateral was drilled using the same practices as the second lateral. The 3% lubricant addition was added to the SFOBM liner fluid prior to displacement. Once TD was reached, the OBM drilling fluid was displaced to the SFOCM and the liner was run with centralizers in the same fashion as the second lateral. The C_f was recorded at 0.24. Factoring out the centralizer contribution, the lubricant showed a 22% reduction in C_f as compared to the first lateral.

While drilling the fourth and final lateral with the OBM, operations experienced increased torque and reached the maximum allowed weight on bit at 13,709 ft, 481 ft short of the target zone of 14,190 ft. Operations decided to add 2% by volume lubricant, based upon the 37% reduction in the C_f indicated by the LEM-NT at a 3% concentration. Once the lubricant was added to the system a 23% reduction of torque was recorded along with an improvement of 10,000 lb weight on bit. Lubricant addition allowed target attainment. The liner was run after displacement to the SFOCM containing 3% lubricant. Again factoring out the centralizer contribution, the C_f was reduced 15.3% as compared to the first lateral. The average C_f reduction of 15.39% for the last three liner runs can be attributed to the addition of lubricant (Table 2).

Table 2: Impact of Lubricant on C_f Liner Runs in Laterals 2, 3 and 4

| | 1st Lateral | 2nd Lateral | 3rd Lateral | 4th Lateral |
|---|-------------|-------------|-------------|-------------|
| Friction factor (C_f) | 0.34 | 0.285 | 0.24 | 0.263 |
| C_f Reduction with Centralizers | - | 0.025 | 0.025 | 0.025 |
| C_f Lubricant without Centralizers | - | 0.03 | 0.075 | 0.052 |
| Percentage C_f Reduction due to Lubricant A | - | 8.82% | 22.06% | 15.29% |

ETD Potentially Risking Target Attainment (Pittsburg County, Oklahoma)

Having experienced high static friction when picking the drillstring off bottom and difficulties drilling a 15,000+ ft lateral section, a request for an OBM lubricant was submitted by the operator for an upcoming well in the same area with a 17,000-ft, 90° lateral section. An environmentally acceptable lubricant, Lubricant B, was selected and the required concentration was optimized using the LEM-NT to compare sandstone lubricity on 1, 2 and 3% by volume concentrations of Lubricant B to the base fluid shown in Table 3.

Table 3: LEM-NT Lubricity Results Sandstone Wellbore and Lubricant B

| Sample | % C_f Reduction* |
|----------------------------------|--------------------|
| Base OBM | - |
| Base OBM + 1% Lubricant B | 15.38% |
| Base OBM + 2% Lubricant B | 19.23% |
| Base OBM + 3% Lubricant B | 26.92% |
| Samples Hot Rolled 16 hr @ 150°F | |
| Base OBM + 1% Lubricant B | 7.69% |
| Base OBM + 2% Lubricant B | 15.38% |
| Base OBM + 3% Lubricant B | 19.23% |

* All C_f reductions are percentage comparison to the base fluid results.

LEM-NT results indicated nearly a doubling in the percentage of C_f reduction between the hot-rolled 2% concentration and the 1% concentration. In comparison increasing the concentration to 3 vol% yielded only an additional 4 percentage points reduction compared to the 2% concentration. Based on the LEM-NT results and other considerations, a 2% concentration of Lubricant B was selected. To confirm that 2% lubricant was compatible with the drilling fluid, compatibility testing was performed on drilling fluid collected from the drillsite.

Mud properties were recorded and the sample was hot rolled for 16 hr at 150°F to observe if the lubricant would “cheese-out”. The mud properties before and after hot rolling are given in Table 4. No “cheese-out” or greasing was seen after hot rolling the sample.

Lubricant B was added to the OBM system when operations reached a measured depth of 13,308 ft. Torque and drag were significantly reduced by the lubricant addition as shown in Table 5.

Table 4: Impact of Lubricant B on Drilling Fluid Properties

| Testing Parameters | OBM | Lab Results | | Field Results (OBM Fluid + 2% Lubricant B) |
|------------------------------|------|----------------------|--------------------|--|
| | | OBM + 2% Lubricant B | After Hot Rolling* | |
| Mud Weight (lb/gal) | 8.75 | 8.67 | 8.64 | 8.8 |
| Rheology Temp (°F) | 150 | 150 | 150 | 150 |
| 600-rpm | 54 | 54 | 56 | 51 |
| 300-rpm | 38 | 36 | 36 | 33 |
| 200-rpm | 32 | 28 | 29 | 27 |
| 100-rpm | 24 | 21 | 21 | 19 |
| 6-rpm | 13 | 10 | 10 | 9 |
| 3-rpm | 12 | 9 | 9 | 8 |
| PV (cP) | 16 | 18 | 20 | 18 |
| YP (lb/100 ft ²) | 22 | 18 | 16 | 15 |
| 10-sec Gel | 15 | 13 | 13 | 10 |
| 10-min Gel | 16 | 17 | 17 | 18 |
| 30-min Gel | 17 | 16 | 14 | 17 |
| ES | 937 | 758 | 781 | 826 |
| Excess Lime (lb/bbl) | 4.81 | 4.55 | 4.29 | 3.9 |
| Solids vol% | 8.5 | 8.33 | 8.3 | 8 |
| LGS vol% | 6.02 | 5.7 | 5.7 | 5.1 |

* Hot rolling for 16 hr @ 150°F

ES = Electrical Stability measured at 120°F

Table 5: C_f Reduction using 2% Lubricant B

| Measured Property | % C_f Reduction |
|-----------------------|-------------------|
| Static Pick-Up Weight | 6.50% |
| Slack Off Weight | 4.00% |
| On Bottom Torque | 47.50% |
| Off Bottom Torque | 41.30% |

Conclusions

- Proper selection of lubricants is important to ensure field success.
- Lubricant selection cannot be solely based on laboratory lubricity performance.
- Economics, environmental impact and regulations, and fluid compatibility are among the factors that must be considered when choosing lubricants.
- When excess torque and drag are encountered, changes to the well plan which reduce torque and drag should also be considered in addition to lubricants.
- The LEM-NT can accurately predicted lubricant performance in the field as illustrated by these two cases.

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References

1. Navarro, A.R. and Dannels, W.R. “Maximizing Drilling Operations by Mitigating the Adverse Affects of Friction Through Advanced Drilling Fluid Technology.” AADE-11-NTCE-17, AADE National Technical Conference, Houston, 12-14 April 2011.
2. Alford, S. “New Technique Evaluates Drilling Mud Lubricants.” World Oil (July 1976) 105-110.
3. Quigley, S. “Advanced Technology for Laboratory

- Measurements of Drilling Fluid Friction Coefficient.” SPE 19537, SPE Annual Technical Conference, San Antonio, 8-11 October 1989.
4. Slater, K. and Amer, A. I “New Automated Lubricity Tester Evaluates Fluid Additives, Systems and Their Application.” Offshore Mediterranean Conference, Ravenna, Italy, 20-22 March 2013, *In press*.
 5. Skalle, P., Backe, S., Kilass, A. and Sveen, J. “Microbeads as Lubricants in Drilling Muds Using a Modified Lubricity Tester.” SPE 56562, SPE Annual Technical Conference, Houston, 3-6 October 1999.
 6. Alford, S., Dzialowski, A. and Ullman, H. “Research into Lubricity, Formation Damage Promises to Expand Applications for Silicate Drilling Fluids.” SPE 67737, SPE/IADC Drilling Conference, Amsterdam, 27 February – 1 March 2001.