

Sustained Lubricity: New Case Studies Using a Novel Invert Emulsion Lubricant

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Abstract

A novel invert emulsion lubricant continues to yield successful results in the field, delivering sustained torque reduction across several unconventional basins. Deeper and/or extended lateral targets utilize oil-based drilling fluid to promote lubricity and rate of penetration. Despite these inherent benefits of a non-aqueous fluid, issues of poor directional control, insufficient weight on bit (WOB), and torque limitations remain a challenge to reaching target depth.

A mixed track record of invert emulsion lubricant performance in the field has warranted scrutiny by experts due to a history of inconsistent, inconclusive, or underwhelming results. Many early invert emulsion lubricants had strong oil-wetting capabilities that demonstrated a temporary reduction in coefficient of friction, but rapidly diminish with the introduction of more drilled solids as drilling progresses. Other lubricant options include varying oil types with differentiating properties relative to the active system base oil but offer little to no torque reduction at the typical treatment levels demanded.

In the field, the unique chemistry continues to yield positive results. The authors review several case studies where the lubricant has provided more than 20% torque reduction and over 15% increase in rate of penetration on multiple occasions. New laboratory data is reviewed which suggests the lubricant chemistry is performing in a unique fashion, different from third party predecessors.

Introduction

Invert emulsion systems are preferred for many drilling environments. A key feature of oil-continuous systems is their inherent lubricity, which is usually sufficient to reach total depth without additional treatment.

Where possible, mud motors are used as cheaper alternatives to rotary steerable systems (RSS). Directional control and corrections require sufficient weight for sliding. With excess torque, more corrections are required, resulting in more doglegs and poor wellbore quality. RSS provide a smoother wellbore, but longer lateral lengths can result in higher torque.

In any case where excessive torque is an issue, there is potential for lower rate of penetration, poor directional control, and diminished pipe life. Invert emulsion lubricants are one of several techniques available. Field case studies with invert emulsion lubricants yield mixed results over the years.

Payne, Cocking, and Hatch (1994) found no benefit to invert emulsion drilling fluid lubricants. Schamp, Estes, and Keller (2006) found limited benefits.

Lubricant development included screening of more than 300 materials, including commercially available invert emulsion lubricants.

A key finding in the development process was that many lubricants passed initial screening, demonstrating promising torque reductions, but this effect diminished rapidly. In some cases, the lubricants offered no reduction after dynamic ageing.

The new chemistry provided both promising initial results and sustained torque reduction after dynamic ageing (Figure 1). The development process is discussed in Toomes et al (2022). The trial phase confirmed the laboratory results carried over to drilling. Field case studies demonstrate 20%+ torque reduction.

OBM Lubricant Testing at 3% v/v - AHR at 250°F
LEM Results

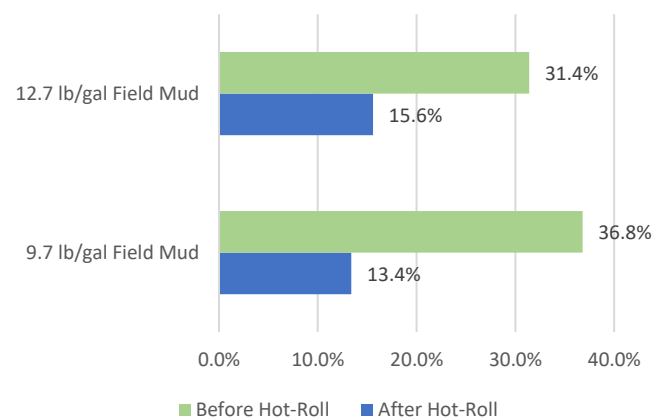


Figure 1: Coefficient of Friction measured on field IEFs using the LEM results in significant reduction at 3% v/v OBM Lubricant before and after hot roll at 250°F

Alternate Torque Reduction Methods

Invert emulsion lubricants are a tool in the drilling fluids toolbox. Selecting the right solution to the challenge is an important factor to achieve the desired torque reduction.

Directional Quality

Lubricants can improve weight-on-bit, poor directional control causes doglegs requiring corrections. Multiple doglegs and corrections lead to a highly tortuous well path.

Addressing torque before it reaches excessive levels limits the number of corrections and doglegs to avoid using a lubricant, which may have mixed success in such a challenging wellbore scenario.

Drilling Fluid Quality and Hole Cleaning

A wellbore free of excess solids, including low gravity solids in the drilling fluid and free of cuttings accumulations provides the lowest torque (Schamp, Estes, and Keller, 2006). Some chemical lubricants are simply strong wetting agents that disperse drill solids and improve overall fluid quality. Figure 2 shows a comparison between a clean, lab stock (sourced from the liquid mud plant) invert emulsion drilling fluid and an average of solids contaminated invert emulsion samples collected from the field.

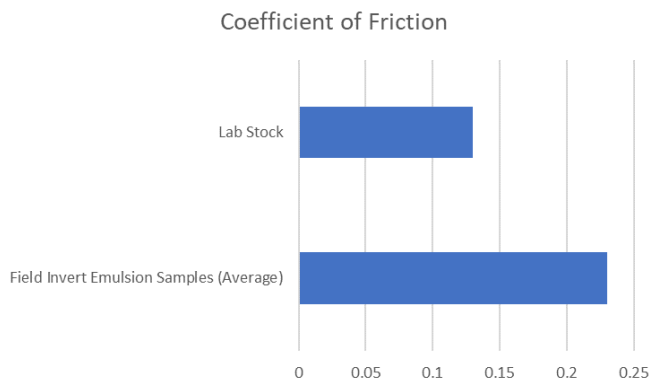


Figure 2: Coefficient of friction comparison example to show the difference between clean drilling fluid and contaminated field samples.

Mechanical Lubricants

Mechanical lubricants include graphite, nut shells, and glass or ceramic beads. Graphite and nut shells slide between surfaces to reduce torque at relatively low concentrations. Beads act as ball bearings, reducing the contact area (Zhou et al, 2012).

Mechanical lubricants provide a low cost and effective torque reduction, but they require continuous addition and contribute to solids accumulation that can impact drilling fluid properties. Retaining beads in weighted drilling fluid systems is challenging and requires extra equipment to recover and recirculate them without retaining drill cuttings.

Robertson, Hancock, and Mota (2005) found a continuous program of ground walnut shell loss circulation material (LCM) provided a twofold benefit. In a complex, extended reach well, the LCM facilitated better hole cleaning and provided torque reduction. Sweeps provided temporary relief, but system-wide treatment provided sustained torque reduction.

New Lubricant

The new lubricant was developed using the inventor's new product development process described in its product quality control plan. This includes the initial testing, stress testing, pilot mixing, field trial, and commercialization phases. After successful field trials, the new lubricant was commercialized, where it was exposed to new and expanded drilling environments beyond the initial design concept phase.

Lubricant qualification in third-party laboratories presents numerous challenges for data quality and consistency. Many laboratories utilize traditional lubricity meters, which require careful calibration and monitoring to achieve insightful results.

Lubricity meters, particularly the traditional equipment found in most laboratories, have significant limitations. One issue is precision at low coefficients of friction, where precision is lacking compared to higher values. In addition, the results are subject to the experience and methodology of the technician, which can vary across laboratories.

Significant effort was made to establish definitive data, including comparative data sets between different technicians. The lubricity evaluation monitor (LEM) provided better insight because it has a torque sensor instead of converting current to coefficient of friction.

Application and Measurement Strategies

Proper lubricant addition is subject to extensive debate. Many operators prefer concentrated sweeps during sliding operations while others treat the entire system at once.

In many cases, an initial concentrated sweep is used as a "validation demonstration" and then the remaining lubricant is added to the system to about 3% by volume, tracking the relative torque reduction throughout the treatment. Concentrations are monitored and maintained through volume accounting and performance as observed on the drilling recorder. It appears that bleeding a small continuous flow of lubricant to maintain concentration is most effective because it constantly adds fresh product to the system.

Performance information is difficult to capture beyond data visible on the electronic data recorder. With expanded sharing of data such as shock, vibration, torque, and mechanical specific energy, lubricants can be properly evaluated in dynamic drilling environments.

A challenge with torque reduction measurement is that drillers increase weight on bit as soon as torque falls below set limits. This, in turn, increases torque. Torque is also expected to increase as the drilling assembly reaches further and there is more frictional area in the form of new wellbore and drill pipe. The feedback from the field becomes that the lubricant didn't work as intended – even as rate of penetration improves.

Real-time and post-well torque and drag analysis can determine the efficacy of a given lubricant additive, particularly as multiple sensors and data trends can be compared with offset wells to validate models.

Case Studies

The authors will conclude with several short case histories, capturing successful scenarios using the new lubricant. Not all applications are ideally suited for a lubricant, but these case studies demonstrate use cases where the product was added to address torque issues and delivered desired results.

Case Study #1

In Eddy County, New Mexico, an operator was drilling with a conventional 9.6 lbm/gal invert emulsion system. At 17,300' torque concerns became an issue. Torque ranged between 27,000 and 30,000 ft-lb.

1.8% v/v of the new lubricant was added to the system while maintaining 40,000 lb weight on bit and rotating at 60 rev/min. Initial torque reduced to 24,000 to 26,000 ft-lb maintaining the same drilling parameters.

At ~19,500' the drilling motor and bit was changed due to low rate of penetration. When drilling resumed, additional lubricant was added to reach the recommended concentration of 3% v/v. Total depth was reached at 22,500'. 5 lb/bbl glass beads were spotted for casing running. Casing was run to depth with no issues.

Case Study #2

In Lea County, New Mexico, an operator was drilling a Bone Springs reservoir using a ~9.0 lbm/gal conventional invert emulsion drilling fluid.

High torque was encountered, creating issues with rate of penetration and directional control. The operator decided to initiate a sweeps program using walnut shells and graphite to address torque, particularly while sliding.

As torque challenges persisted beyond 18,000', lubricant was added in concentrated sweeps along with the walnut shells and graphite. Rate of penetration increased about 50 feet per hour while torque reduced by ~4,000 ft-lbs to reach total depth at ~21,000'.

Case Study #3

In Loving County, Texas, an operator was drilling a slim-hole well targeting the bone springs producing formation. The intermediate 9 5/8" casing was set at 5175 ft. The operator was utilizing 10.5 lbm/gal oil-based drilling fluid. The driller encountered elevated torque and diminishing rate of penetration while drilling a 6 3/4" production section. At approximately 18,804 ft. measured depth, ROP slowed to 34 feet per hour, with 35,000 pounds of weight applied to the bit. Drilling parameters were adjusted to apply more energy to the bit, but results were unsuccessful.

At approximately 21,142 feet measured depth, after adding 550 gallons of lubricant, ROP increased to 60-67 feet per hour while weight on bit increased to 36,000 pounds. The well was drilled to total depth of 21,524 feet with no issues. The 7 5/8" liner was run and cemented in place with full returns.

Case Study #4: Casing Running

Long lateral require casing floatation to minimize torque. Casing floatation eliminates the ability to circulate, reducing

options when tight spots are encountered. Therefore, a clear, lubricious wellbore is essential to reaching casing depth without rupturing air lock.

On several wells, casing running pills were spotted prior to tripping out of the hole at TD. Lubricant concentrations ranged from 3.0 to 5.0 % v/v to account for the new, uncoated metal surface of the casing.

Casing running pills offer extra assurance of a successful casing run. Given the small volume of open hole, a casing running pill is a low cost torque mitigation options. Approximately 150 wells have utilized the lubricant as a spotting fluid in the open hole to improve casing running operations. Applications include the Eagle Ford and Permian Basins.

Ancillary Benefits

The new invert emulsion lubricant is designed and intended to perform as a lubricant, but field results show other indirect benefits. This includes elevated electrical stability (ES) and reduced fluid loss.

The exact mechanism of the sustained lubricity is not fully understood, but one theory is that the surfactant blend retains an affinity for metal surfaces over oil-wet solids, reducing depletion rate. As a surfactant blend, it is possible that different components contribute in different ways. Feedback from the field repeatedly cites improvements in fluid quality. Figure 3 compares electrical stability and fluid loss before and after lubricant additions.

While the lubricant provides improved lubricity in fresh laboratory fluids and field fluids, it is possible that components in the product also provide supplemental dispersion and oil-wetting to solids and improve emulsion quality.

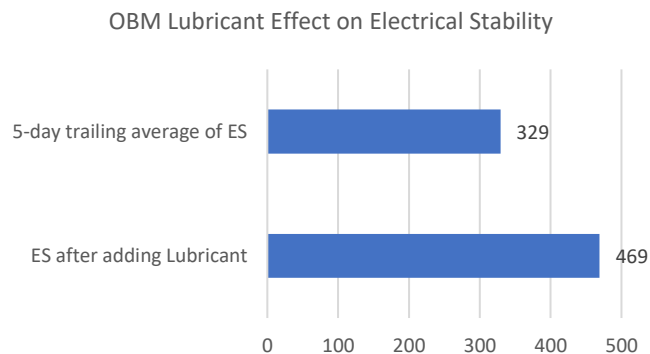


Figure 3: Lubricant impact on electrical stability

Future Work

Torque reduction is a primary objective of a drilling fluid lubricant. New supplements introduce the capacity to increase the film strength of fluids for extreme pressure (EP) properties. Extreme pressure additives reduce metal wear by bonding to imperfections on metal surfaces.

EP additives are not new to the oil and gas industry; however, their cost has remained prohibitive as an additive for drilling fluid lubricants. New EP additives provide cost-effective materials to increase film strength, which has the

potential to increase pipe life and improve surface interactions for superior lubricity.

EP testing methods vary by device and manufacturer. A key aspect of developing low-cost supplements included replacing the motor of a traditional EP tester with a ½ horsepower option and establishing repeatability to establish maximum torque and scar dimensions.

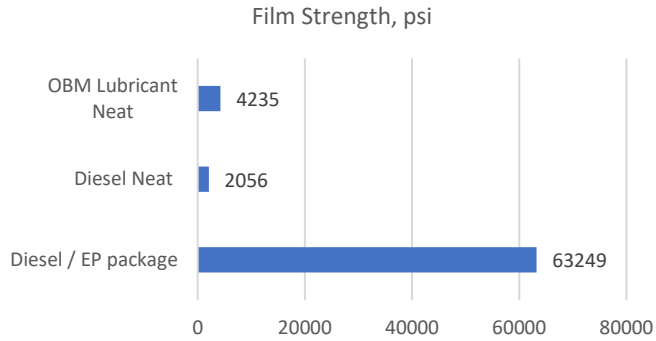


Figure 4: Select extreme pressure lubricity results revealing the impact of EP additives in non-aqueous base fluids

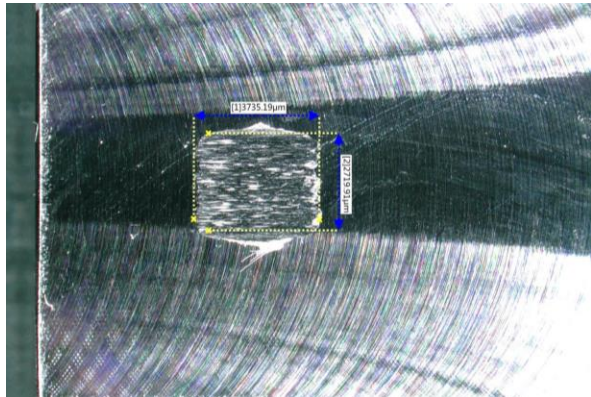


Figure 5: Image of scar left after EP testing on neat OBM lubricant sample

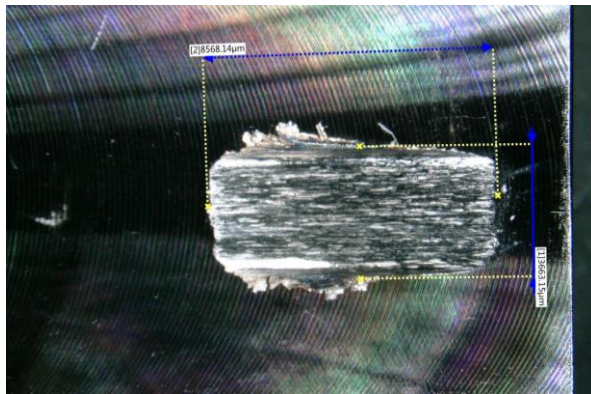


Figure 6: Image of scar left after EP testing on neat diesel sample

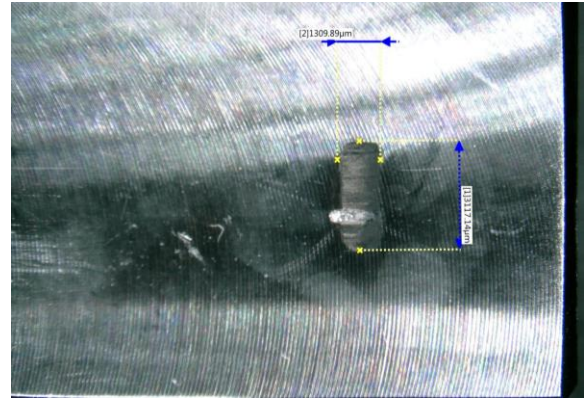


Figure 7: Image of scar left after EP testing on neat diesel / EP additive package

Conclusions

A novel invert emulsion lubricant continues to provide torque reduction in challenging wells:

- Invert emulsion lubricants can provide supplemental torque and drag mitigation
- Wellbore quality (directional control) and drilling fluid properties are important factors in torque and drag mitigation
- Multiple wells have used the new lubricant to reduce torque while drilling and running casing
- The new lubricant also improves fluid properties, which may contribute to additional torque reduction via oil-wetting and a strong emulsion

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