A NEW LUBRICANT DESIGN

Matthew Offenbacher and Richard Toomes, AES Drilling Fluids, USA, outline how new chemistry in drilling fluid lubricant technology could help create opportunities to extend pipe life through improved wear mitigation.

Drilling fluid lubricant technology focuses on the coefficient of friction reduction to maximise power at the drill bit. This is a critical function for drilling performance, but new chemistry is creating new opportunities to extend pipe life through improved wear mitigation.

Lubricants lower the coefficient of friction between two surfaces by creating a film that limits their interaction. In a drill string, this reduces energy lost due to rotation and transfers it to the drill bit. Drilling at lower torque reduces pipe stress, but in many cases, the torque reduction from a lubricant allows for more weight on the bit to increase the rate of penetration, while remaining within drilling rig system limitations. Torque remains constant while energy to the bit improves the rate of penetration.

Lubricants operate in the boundary between two moving parts to prevent contact that leads to an increase in friction (Figure 1). As the conditions under which metal-to-metal interactions become more severe, due to higher temperatures and pressures, the boundary lubricant becomes more stressed. The distance between the metal surfaces decreases to the point where rubbing and damage occurs. Traditional boundary lubricants do not remain on the metal surfaces and cannot prevent the increasing friction, wear, and damage to the metal surface seen under these conditions. Special additives can be used to provide film strength to reduce pipe wear and maintenance. Additives that perform this function are referred to as extreme pressure additives (Figure 2).

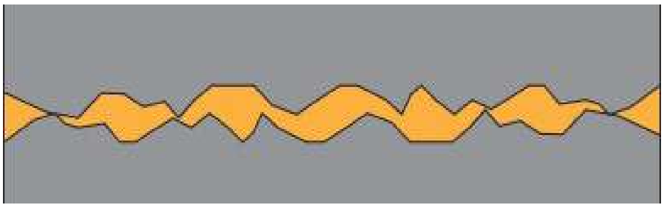

Figure 1. *A lubricant creates a film to limit interaction between two surfaces.*

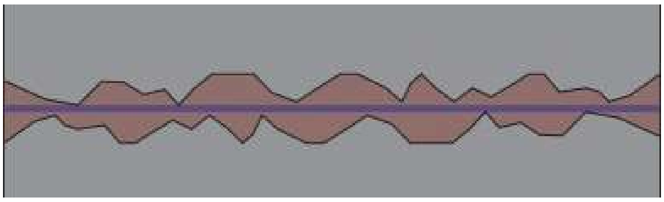

Figure 2. *An extreme pressure lubricant limits wear by creating a film to limit interaction between rough surfaces.*

Figure 3. *The modified extreme pressure lubricity tester includes a larger motor and stirring assembly to ensure proper lubricant dispersion during testing.*

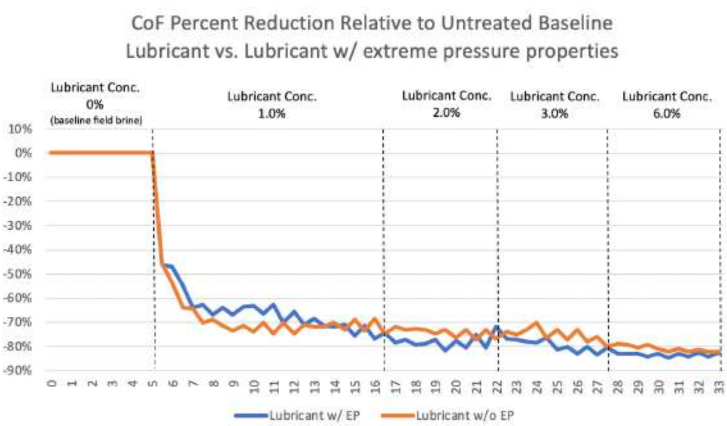

Figure 4. *Coefficient of friction reduction comparison of a lubricant vs lubricant containing extreme pressure properties on the LEM.*

There are many lubricant offerings that claim extreme pressure benefits. Measurement of lubricant performance, particularly extreme pressure performance, is poorly defined throughout the drilling fluid industry. Capturing performance characteristics is again in the spotlight as drill pipe costs remain elevated and more operators choose water-based drilling fluids for longer laterals.

Measurement challenges

Lubricity is measured as the coefficient of friction between two surfaces at an applied torque. A traditional lubricity meter features a rotating ring pressed against a block immersed in the test fluid. Torque is applied to generate a coefficient of friction reading from the current on the motor required to rotate the ring. This equipment is found in most drilling fluid laboratories, but it has several shortcomings. Data sets are inconsistent, and coefficients of friction values are difficult to compare across instruments. The sample cup remains static, preventing dispersion of insoluble lubricant components when testing with a drilling fluid sample. Consistent and reliable data depends heavily on proper practices and behaviours outside of the test procedure.

A lubricity evaluation monitor uses a torque sensor for coefficient of friction readings and features a circulating pump to blend fluid as the knurled bob is pressed against test media at different readings. Low circulation rates limit the blending effects.

To screen for torque reduction, the lubricity evaluation monitor was modified to increase mixing power for full dispersion. A syringe pump was added to the cell to inject lubricant in set increments over time. As the computer acquires data, it is possible to view an untreated drilling fluid against gradually increasing lubricant volumes until the torque reduction stops.

Extreme pressure testing uses applied pressure between two surfaces to measure film strength calculated from the force applied and the scar dimensions as the film fails. Dedicated extreme pressure testers have their own limitations. The Timken OK tester determines the presence of extreme pressure additives but fails to consistently quantify the film strength. A four-ball tester can only test neat samples and there are comparative data sets using drilling fluid additives.

A traditional lubricity meter using a grooved ring and flat block for the test surface provides a practical option because it is already present in many drilling fluids laboratories. The sample remains static and test procedures vary, creating inconsistent results. The stock ½ horsepower motor stalls at high torque and excess friction can heat the samples beyond 149°C/300°F where critical components may degrade.

For extreme pressure measurement, the motor was upgraded to 1 horsepower to eliminate stalling. The stock sample cup was replaced with a stirring assembly for sustained dispersion and cooling (Figure 3). Methods were compared and optimised, confirming the procedure no longer demonstrated variability between technicians performing the test.

Lubricity screening

General lubricant screening begins with operating environment factors. Many lubricant chemistries offer excellent performance but have higher risk of incompatibilities. Cheesing (emulsification) or greasing (oil-wet solids) are incompatibilities which can wreak havoc on drilling fluids and the drilling process. Stress testing identifies compatible materials for subsequent performance testing.

After compatibility testing, lubricant blends are tested for coefficient of friction reduction. Samples were tested on the lubricity evaluation monitor at increasing concentrations up to 6% v/v (percent by volume). The torque reduction relative to the baseline (untreated) field brine in Figure 4 should be noted.

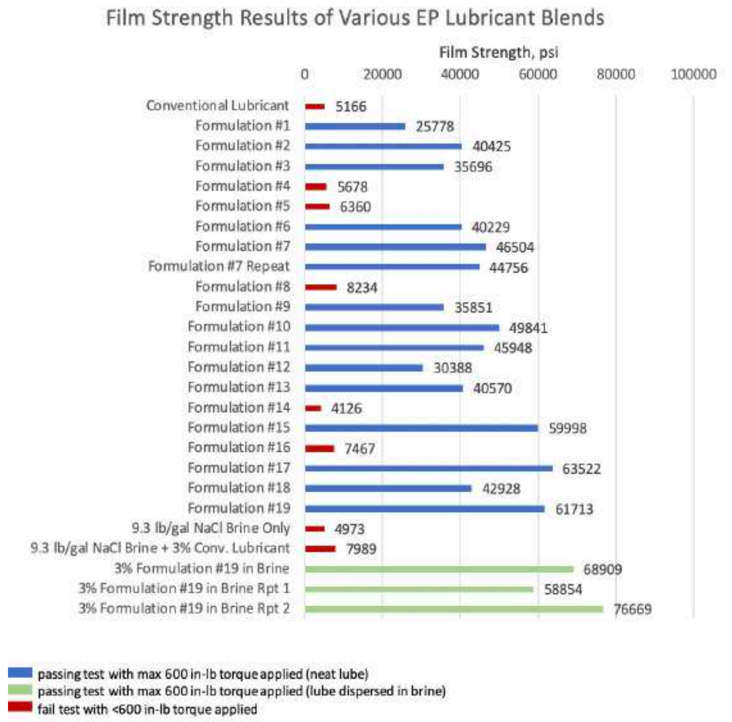

Figure 5. *Extreme pressure testing results – formulation 19 was selected due to repeatability of desired results.*

Figure 6. *Image of the block and ring as part of the EP testing assembly (left) and an image of the block and ring as part of the standard lubricity tester (right). A torque wrench is utilised to apply pressure, forcing the block against the ring as it rotates, while immersed in a test solution.*

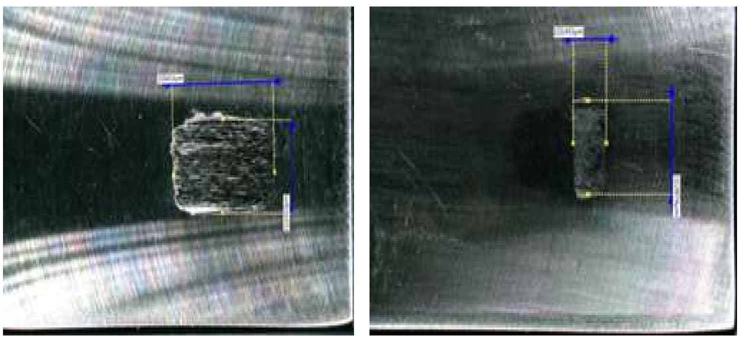

Figure 7. *Scar image on block using neat lubricant without EP, resulting in 5166 psi film strength (left). Scar image on block using extreme pressure lubricant blend 19, resulting in 61 713 psi film strength (right).*

The standard lubricant without extreme pressure additives resulted in a coefficient of friction reduction of 70 – 75% at 1.5 – 2% lubricant treatment volume. The same lubricant with the addition of extreme pressure additives resulted in a slightly improved reduction at the same treatment volume – a 75 – 80% coefficient of friction reduction. A continued reduction was observed as treatment levels increased to 6%, but not at a rate to justify such elevated concentrations at given costs.

Extreme pressure testing of conventional materials demonstrated film strengths of 4000 – 8000 psi. These lubricant blends featured no extreme pressure additive materials and provided a baseline for new materials. The historically high cost of materials with extreme pressure properties limits practical utilisation. New additives were evaluated that could meet the demand for performance for economic cost.

New blends were prepared, and testing was repeated for compatibility and coefficient of friction reduction. Lubricity reduction remained consistent with the original lubricant blends. Film strength was tested using the EP testing feature following the new procedure, and testing was repeated multiple times to confirm results. For each test, the groove ring and block were replaced even when no visible damage was apparent.

Film strength calculations rely on accurate scar measurements as the maximum applied torque is divided by the area of the scar to calculate an equivalent pressure. The equation is shown below:

$$\textit{Film Strength (psi)}$$
$$= \textit{Torque Meter Dial Reading (in} - \textit{lb)}\,\frac{\textit{Torque meter dial reading (in} - \textit{lb)}}{1.5\ x\ \textit{Scar Height (inches) x Scar Width (inches)}}$$

To minimise error, a computerised optical microscope was used to precisely measure scar dimensions. The film strength was calculated to compare materials, blends of materials, and different concentrations (Figure 5).

Initial tests utilised neat lubricant blends with extreme pressure properties, and results in the form of film strength varied as candidate chemistries were evaluated. Lubricant blend 19 demonstrated repeatable results, confirmed with multiple tests among varied technicians. Further extreme pressure testing with 3% v/v extreme pressure lubricant blend 19 + 97% v/v field brine was performed using a modified fluid reservoir to ensure proper lubricant dispersion – successful results validated the initial trend. Extreme pressure lubricant blend 19 resulted in a complete lubricant: good coefficient of friction reduction and film strength exceeding 60 000 psi on average.

Scarring resulting from the lubricant without extreme pressure properties is significantly larger, resulting in a much lower film strength of 5166 psi (Figure 5). During this test, the torque applied reached a maximum value of 200 in-lbs when the machine began to seize, typically an audible grind/whistle sound accompanied by a rapid torque increase. Comparatively, extreme pressure lubricant blend 19 resulted in a much smaller scar after applying the maximum torque limit of 600 in-lbs, resulting in a much-improved film strength of 61 713 psi (Figure 6).

The new lubricant blend extends drilling performance beyond simple torque reduction to potential savings in drill pipe maintenance and wear. Trials are planned using baseline drilling performance data and historical pipe inspection reports to evaluate the practical savings, which may include less hard banding replacement (Figure 7), less pipe rejection, and lower inspection frequency – all while improving rate of penetration.