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Advances in Drilling Fluid Preparation and Conditioning at Fluid Mixing Facilities

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Abstract

This paper will discuss liquid mud plant operations in conjunction with field integration of high-shear mixing, machinery limitations and performance data. The effects of high-shear mixing on fluid properties will be presented.

Offshore operations and, in particular deepwater projects, depend on drilling fluids supplied by a liquid mud plant (LMP). Land-based LMPs are able to provide high volumes of fluids and other chemicals needed for deepwater drilling and completion. Moreover, LMP facilities are needed to prepare specialized and complex drilling fluids that meet or exceed design parameters, quality and environmental compliance.

Drilling fluids chemistry and orderly preparation are essential for creating a quality fluid. The final product is affected by a wide variety of factors such as drilling fluid additive type and concentration, volumes mixed, the environment in which the fluid was prepared, the sequence of chemical addition and the type of equipment used for mixing.

From a process-engineering perspective, mud preparation is a process where the chemical and physical reactions and interactions are optimized by additions of required ingredients and applications of appropriate equipment in a timely and sequential manner. In terms of process parameters, drilling fluid preparation mainly includes the influences of mixing energy inputs and conditions of temperature and pressure. High-temperature and pressure conditions are extremely challenging to reach at a mud plant or during mud mixing on a rig. However, high mixing energy input can be achieved by the use of high-shear mixers.

Introduction

Following pioneering in the Gulf of Mexico region, liquid mud plants (LMP) have been built onshore near many deepwater drilling sites worldwide as the need for drilling and completion fluids expanded. Most LMPs serve a variety of drilling locations and needs. Millions of tons of bulk products, such as barite and bentonite, and massive volumes of drilling mud and completion fluids are handled and prepared at LMPs. Development of offshore operations will continue to stimulate the need for mud plants and brine plants as land-based supply facilities capable of supporting drilling activities.

Deepwater exploration and production activities have grown as a leading segment of business offshore of all five continents of the world. Even in a time of worldwide economic downturn, the deepwater segment remains the strongest in the drilling industry. With growing oil and gas demand and technological advances, the deepwater has continued to expand even deeper into the oceans, thus requiring longer distances to drill and larger volumes of fluid. For instance, to drill a deepwater or ultra-deepwater well that is often in water depths over 8,000 ft (2,400 m), an operator must first extend a 5-foot diameter riser from the rig down to the ocean bottom; the riser is then filled with drilling mud.[1]

Numerous technical challenges, technological advances in drilling techniques and equipment call for technologically advanced drilling fluids of highest quality. Fluid preparation, therefore, should be performed to achieve the peak of the fluid quality and assure top performance. Specialized in the preparation of drilling and completion fluid, LMPs are well-equipped to deliver higher volumes of superior quality fluids.

Drilling Fluid Mixing Facilities

Mixing fluids at a mud plant is different from mixing on the drilling rig. The mud plant has proven beneficial for operators and drilling contractors. LMPs, at large, are taking on responsibilities for managing fluids, including handling and storage of chemicals, preparation, returns, and other associated tasks. Fluid volumes that an LMP is capable of handling would significantly exceed any capabilities of offshore vessels and land rigs. Average volumes of mixing tank on a LMP are from 250 bbl to 1,000 bbl with each plant comprising two to four tanks in the mixing system and thousands of barrels of storage capacity. Standardized LMP design allows for more efficient and environmentally compliant operations, even under zero discharge policies.

Offshore deepwater operations use the largest volumes of fluids. Liquid mud plants are permanent installations on land or specialized offshore vessels that manage and service these fluids. Locating mud plants in close geographic proximity to deepwater drilling areas optimizes such services. Further development in drilling deep offshore will likely require increased numbers of smaller LMPs located close to the sites rather than large centralized facilities.

Chemical Composition and Processing

Mud preparation is the process whereby specific chemicals, adequate equipment and facilities are brought together to create the final product of optimum qualities. The fluid preparation process is designed to create particular chemical and physical reactions and interactions using mechanical equipment. Facility and equipment designs, utilities, such as electricity and water supply, and many other associated services support the same final goal. Narrowing complex processes, the interactions of chemicals and equipment are focused to supply drilling sites with the fluids in timely and efficient manner.

Chemical compositions of drilling fluids are engineered for performance. Properties of the chemical ingredients can differ depending on origin, manufacturing facility, storage and handling conditions. Certain chemical ingredients are responsible for corresponding properties and ability to modify overall drilling fluids properties like viscosity, yield point, gel strength, density and reactivity. If properties of ingredients are modified in any way, the fluid properties would also be changed. Additionally, change of a critical preparation sequence will also cause modified or adverse chemical reactions and interactions. Therefore, applying fluid mechanical energy in any form, including the use of a variety of mixing techniques, only assists in achieving the full potential of the fluid by creating optimal conditions for the ingredients to react and interact. Conversely, the lack of chemicals, the presence of unwanted chemicals, or improper sequence of preparation are primary factors negatively affecting fluid preparation. The more care and attention paid to the process, the better quality of the fluid. LMPs, with specialized facilities and trained and qualified technical personnel, have the best capabilities to service cradle-to-grave care for drilling fluids.

Equipment

Industry professionals understand that the best mixing and shearing of drilling fluids happen downhole when the fluid is passed through the drill bit under pressure. Factors that assist in the mixing are pressure, temperature, fluid velocities and geometry of the orifice as the drilling fluid passes through the bit and circulates back to the surface.

Many attempts to simulate such conditions above ground have been tried by different companies. These attempts have either been unsuccessful or were rejected due to safety and cost concerns, or simply for practicality reasons. For instance, thick piping, grand concrete barrier, underground structures may be needed to mitigate high-pressure issues if shearing through an orifice while using high-pressure pumps. Tanks and orifices would be subject to quick wash out by relatively thin, pressurized streams of mud that will become dangerous if not contained in a vessel. Construction materials for fabrication of vessels that can support high pressure in the thousands of psi necessary to contain a thin, pressurized fluid stream would be very costly. An alternative method was sought to realize the advantages of downhole mixing, but without the high cost of simulating downhole conditions.

High-Shear Mixer

After engineering evaluation of different mixing technologies, a novel solution was found using continuous in-line, multi-stage, high-shear mixers for drilling fluids. This equipment is designed to be used as an integrated part of mixing equipment installed on a liquid mud plant as a safe and effective tool for drilling fluid preparation. In terms of mechanical equipment such integration into existing setup is a simple and seamless process requiring only two piping connections, inlet and outlet, and a connection to the electrical power supply. The power supply can be either the facility main grid or a generator. The standard high-shear mixing unit contains of primary movers, such as pumps, piping and valves, mixing apparatus, strainer and instrumentation.

In practice, the process of mud preparation is engineered at an LMP with a specifically designed set-up of mixing equipment to create a fluid with required parameters. Several installation options may be permitted, such as, for example, the placement of the in-line, high-shear mixer between the mixing tank and the storage tank to allow one-pass sharing when the drilling fluid is pumped from mixing tank to storage tank, or vice versa. Thus, the mud is sufficiently prepared in mixing tank and the shearing unit is used to quickly bring the fluid to the optimal condition. With a different setup, placing the mixer just before loading the fluid on the boat could bring additional time-saving benefits. In another configuration, the in-line, high-shear mixer is placed in such way to create multi-pass recirculation from the mud tank through the mixing unit to the mud tank if the fluid needs higher input of mixing energy to create the optimum fluid properties. In some cases, the fluid can be sheared through the in-line, high-shear mixer while prepared in the mixing tank and additional ingredients are added while providing additional shear to assist in dispersion and dissolving the chemicals. Good engineering practices, applied knowledge of fluids, and experience of LMP operators make an in-line, high-shear mixer is a capable tool for a plant use.

High-Shear Mixer Selection

During the research and development stage, several trials were conducted to develop the best equipment and process suited for shearing of oil-based fluid technology.[3] As a result of that evaluation, high-shear mixing with a rotor-stator type of device was found to satisfy the mud-shearing requirements. These trials compared wear and operational characteristics of the two rotor-stator high-shear units: a single stage (740 gal/min, 168 m^3/hr) and a three-stage (90 gal/min, 20 m^3/hr). Next, the single-stage high-shear mixer (650 gal/min, 148 m^3/hr) was tested with both water-based drilling fluid (WBM) and oil-based drilling fluid (OBM) systems. The multi-stage mixer (90 gal/min), 20 m^3/hr) was trialed with OBM and synthetic-based drilling fluid (SBM) systems. From the test results, it was concluded that in terms of maintenance, wear and overall efficiency, the multi-stage unit was superior to the single-stage unit.

High-Shear Mixer Characteristics

The shearing unit is designed to be easily installed on a LMP by connecting hoses from the plant equipment to the inlet and the outlet of the skid and establishing connections to 460-volt power source. Fluid for processing is supplied to the unit from a mud mixing tank via a plant mud pump. Flow must be controlled via throttling valves and the flow rate is displayed on the shearing unit's flow meter to assist operators in monitoring this function. The strainer installed on the skid protects the mixing tools of the high-shear mixer and protects from damage inflicted by the foreign objects in the mud stream. The shearing unit uses an in-line, multi-stage, high-shear, dynamic mixing device (Figure 1). This mixer is equipped with three sets of mixing tools arranged in three stages. Each set of tools contains one rotor and one stator with mixing teeth designed to shear a variety of fluids (Figure 2).

Figure 1. High-shear mixing unit installed on LMP.

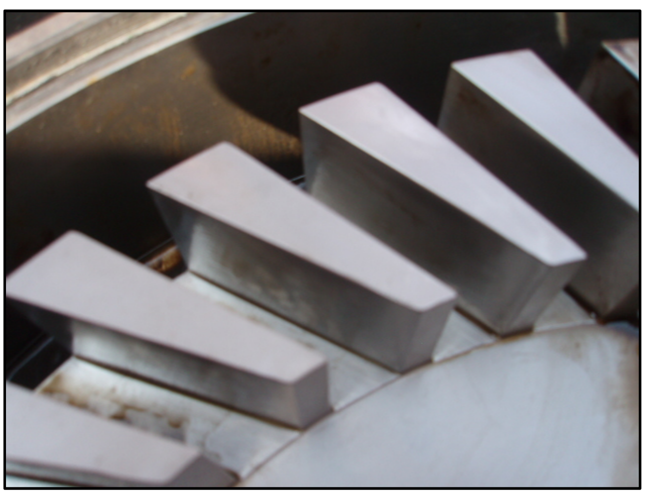

Figure 2. Mixing teeth on the rotor.

The high-shear unit is operated via the control panel which is equipped with a controlled start device. The control panel contains only Start, Stop and E-Stop buttons and corresponding lights or indicators for easy operation and safety. The controlled starting system increases longevity of electric motors and prevents damage occurring during start-up and shut-down sequence.

Safety of operations is a primary concern. The in-line, high-shear mixer by design is one of the safest mixers to operate. This device does not require high pressure for efficient mixing and has no exposed moving parts. All process fluids are safely contained in piping or hosing. Lubrication fluids are contained in appropriate housing. The unit also is equipped with a spill-containing base for added environmental protection.

High-Shear Mixer Installation and Testing

An in-line, multi-stage high-shear mixing unit with capacity 550 gal/min (114 m^3/hr) was delivered to the LMP in West Africa that supplies drilling and brines for offshore operations. As QHSE is always the first priority, all LMP personnel were involved in safety meetings and familiarization with equipment activities on location. The unit (Figure 1) was installed and connected to the LMP piping and fully function tested. Collected performance data showed that the equipment experienced no upset conditions of unusual events. Regular maintenance performed in timely manner would support longevity of the shearing unit in the future.

Fluids traditionally prepared by the mud plant were non-dispersed OBM and premixes. All fluids were built and sheared per customer's specifications. During preparation, all fluids were premixed for shearing with no barite addition, however calcium carbonate was added. Fluids were weighted with barite after shearing was completed.

In most cases, as soon as desired fluid properties are achieved, the shearing should be stopped. To determine the optimum point, fluid properties were checked[1,2] after each pass to determine if the proper rheology has been reached. Full mud checks were done for a base sample and for samples collected after each pass through the shearing unit.

High-Shear Mixer Performance

Electrical stability (ES) is an indicator of the relative stability of invert emulsions. Therefore, higher electrical stability will correspond to a more stable water-in-oil emulsion with uniform, smaller and better dispersed water droplets and reduced coalescence effect. It is also understood that to obtain smaller droplets of uniform size, energy or work must be applied in form of shear. Therefore, the ES and fluid rheology were selected to measure the performance of the high-shear mixer on OBM and SBM.

Results show that processing OBM or SBM through the shearing unit leads to an ES increase. The highest increase of ES was noted after the first pass though the mixing unit. Moreover, for some fluids (Fluid 2, Figure 3) ES reached a plateau then remained flat even if subjected to more shearing. This suggests that continued shearing would be a waste of energy for Fluid 2; possibly due to fluid-chemistry related limitations. The ES for Fluids 1 and 3 (Figure 3 and Figure 4) continued to increase with shearing.

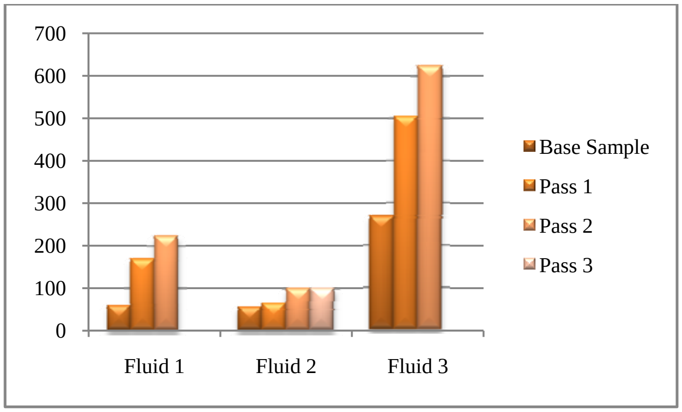

Figure 3. Electrical stability (in volts) increased during shearing.

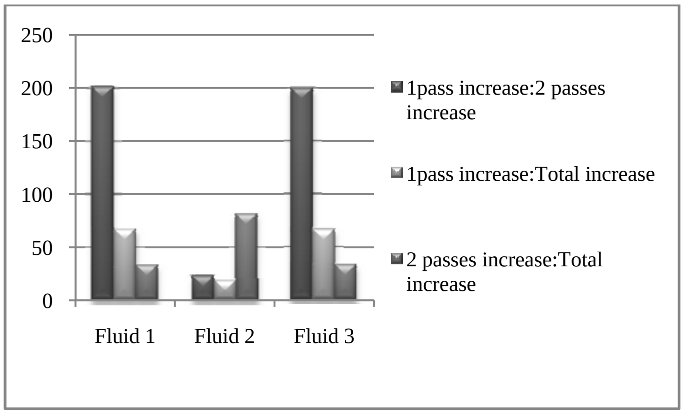

Figure 4. Electrical stability as a percentage increase over previous shear pass.

A similar trend was noted for the rheology of the premix. This phenomenon could be considered an illustration of how chemical composition is affecting the fluid properties when significant mechanical mixing energy in applied. Rheology and HTHP fluid loss were measured and monitored continuously. HTHP data for all fluids are shown in Table 1. When tested, the sheared fluid produced a better filter cake than the unsheared fluid. Rheology data showed trends of plastic viscosity and yield point increase with shearing.

Table 1. Fluid Loss (in cc/30 min)

Fluid	Before shearing	Sheared 1 pass	Sheared 2 passes	Sheared 3 passes	Barite addition after shearing
Fluid 1	6.2	5.8	5.8	-	-
Fluid 2	5.6	5.6	5.6	5.6	6
Fluid 3	6	5.8	5.8	-	6

After approximately 4,000 bbl was sheared, the multi-stage high-shear mixer was disassembled to check for wear on the mixing tool. All three stages of 316 SS mixing tools showed no detectable wear. Wear on mixing tolls is a subject to monitoring as a part of regular maintenance on the equipment.

Conclusions

High-shear mixing has been validated as an effective, safe and environmentally responsible method for drilling fluid preparation. The equipment package has been proven to be simple to install, operate, maintain and use as an integrated part of a liquid mud plant (LMP) or drilling rig for mud preparation and conditioning.

Depending how the fluid mixing process is engineered, benefits should be overall time saving and energy use optimization.

The most important issue in fluid preparation is amount of chemical, quality of chemical ingredients, the sequential process of fluid preparation including such process parameters as time, temperature and pressure. Once the fluid is properly prepared, input of mixing energy in ambient conditions has only limited affects. Therefore, to prepare quality fluid special attention is paid to initial ingredients and processing. The more care and attention that is paid during whole process of a fluid preparation process, the better the quality of fluid that is achieved.

Acknowledgments

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Nomenclature

HTHP = *High Temperature, High Pressure*
LMP = *Liquid mud plant*
QHSE = *Quality, Health, Safety and Environment*

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