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Bringing Drilling Fluids into the Digital Era

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Abstract

The hardware and software traditionally used to manage drilling fluids have had limited advancements over several decades. M-I SWACO is carrying drilling fluids into the digital era by bringing together automation, remote operating centers, and cloud-based software platforms.

Recently, a device was developed to automate critical drilling fluid property measurements and allow for the data to be readily accessible to the rig and in-cloud environments. The results can then be digested in real time by multiple onsite and remote operations centers involved in drilling the well and also used for analysis to optimize current and future wells. Utilizing the increased data with advanced drilling fluids modeling software has enabled improvements in simulation accuracy for multiple drilling parameters. This allows for alerts to be communicated to critical team members in real time to avoid potential risks. Automated results sent to the rig site and remote operations centers allow for additional monitoring and improved communications among the drilling disciplines (i.e., directional drillers, measurement-while-drilling specialists, mud engineers, and mud loggers). Combining the increased accuracy and frequency of data has also been shown to reduce nonproductive time, to reduce the need for treatments, and to avoid drilling fluid issues related to solids and hydraulics in the wellbore. These enhancements lead to an overall improvement in well construction and drilling fluid performance, which then lead to a reduction in the total cost of operations to drill the wells while maintaining safety.

Introduction

The US oil and gas industry was established with the Drake Well during the mid-1800s. From this point, our predecessors began capturing lessons learned and pursuing efficiency by any means necessary, from equipment and drilling fluids to overall process improvements. As with any improvement, not all are created equal or perceived to have similar value, hence some components required to drill a well hold higher priority within the industry. After the Drake Well, drilling fluids remained unchanged until Anthony Lucas, who drilled Spindletop 50 years later, recognized that water alone was not enough to keep a wellbore open during the drilling phase. Over the next 120 years, drilling fluids transformed from a simple water and dirt mixture to an orchestrated combination of complex chemistry and solids formulations coupled with hydraulics calculations to allow the industry to drill the complex well geometries drilled today.

These fluid systems have been engineered to withstand vast temperature and pressure fluctuations due to their flat rheological profiles, to mitigate gas hydrates due to their internal salt phase, and to remain oil wet through emulsion with minimal sag after extended static periods—all while fulfilling the original purpose of cleaning the wellbore, maintaining wellbore integrity, and minimizing environmental impact. Drilling fluids have grown from the concept of mixing water and dirt to optimizing rheology (Brown 1955) through organophilic clays, controlled salt phase, and alkalinity—all while complying with testing under our governing standards (API RP 13 B1/B2).

Traditional Measurement Methods

Our industry relies on fluid specialists, project managers, engineers, drilling contractors, and company representatives to plan their business and maintain channels of communication with respect to each hole section and its objectives. Modern drilling bottomhole assembly (BHA) components give engineers downhole insight into equivalent static density (ESD), equivalent circulating density (ECD), temperature, and formation evaluation measurements on a minute-by-minute basis, distributing information to various parties for review. Drilling fluid systems are present from spud to total depth of the well, the same as drilling BHAs, but the information travels much slower and to fewer people and with fewer data points. This can be as low as once a day to four times per day on high-tier projects.

The instrumentation for testing drilling fluid systems is manual, is time-consuming, and remains unchanged since the 1950s (Brown 1955) with the invention of the Fann 35 viscometer. The temperature control equipment typically used makes it difficult to keep the fluid within standard tolerances of 1ºC. The testing and titration process to obtain electrical stability and deal with excess lime, chlorides, and solids analysis values is manual and, naturally, time-consuming. Once the "mud check" has been completed, the fluids representative will perform a quick analysis and create a treatment plan based on any deficiencies or reduce the existing treatment if target properties are adequate. Daily tour treatments are routine and occur seamlessly in the background, but where does the remainder of the drilling team come into play if additional support or guidance is needed? There is room to improve communication within the larger drilling fluids team and also the other people involved in the well.

Currently, the status quo for high tier wells is four mud checks a day, one nightly report (distributed around midnight) and a comprehensive set of hydraulics covering the past 24 hours along with present conditions used to forecast a depth not yet reached. All reports are viewed at least six to seven hours after distribution since the current support structure is in town working during the day. They are updated via phone, online chat, or through the network of people on the rig. Drilling fluid properties and analysis needs to be modernized and supplied with more real-time information that will allow the drilling fluids team and other stakeholders to improve performance when current fluid parameters are available for analysis and not several hours old. There is now a device to measure and communicate these properties more efficiently and couple with real time modeling and remote support.

Automated Measurements

Automated devices capable of measuring drilling fluid rheology, gel strengths, and density have been developed before (Vajargah and van Oort 2015; Stock et al. 2012) with some presence in the field.

M-I SWACO has developed a device that can be deployed and paired with real-time hydraulics modeling to capitalize on optimizing drilling processes and learn more about efficiency improvements (Contreras et al. 2019). It introduces new value by improving measurement QA/QC, increasing data accessibility, improving hydraulics modeling, enabling remote operations, and potentially reducing crew levels. The results are transmitted via the Wellsite Information Transfer Specification (WITS) protocol to various destinations. The unit has been designed to increase the efficiency of the fluids engineer while allowing for on-demand data visibility. The results reduce risk and enhance operations.

In its current embodiment, the unit can measure a drilling fluid's rheology profile over various temperatures (4ºC to 65ºC), including gels (up to 30 min), and density (up to 23 ppg). The sample is heated or cooled to the desired temperature in less than 10 minutes, and then the rheology measurements are conducted at multiple temperatures to comply with API drilling fluid standards. The accuracy of the measurements is of the utmost importance. The equipment has been shown to hold temperature more precisely than the standard manual offerings and is within the tolerance of the API standard of 1ºC. This improves repeatability and removes any human influence on the measurements. Measuring the fluid sample at temperature also removes the need to apply extrapolations to the results of fluid measurements taken at ambient conditions. The repeatability of the viscosity measurements was observed to be better than an engineer running a Fann 35 or OFITE 800 device over three temperature points with a synthetic-based fluid commonly used in deepwater operations.

Figure 1 – Outside view of the semiautomatic rheology and density device. The sample container is on the right side and the touchscreen at the front.

All types of drilling fluid can be measured using the technology. The unit operates in a safe area and samples are manually collected and brought to unit. Not having the unit in-line allows for flexible sampling points. Information on the sample can be added and stored with the results for context later. The results are time stamped and depth recorded on active system samples for corelating with other measurements taken at the rig.

Linking the device to real-time hydraulics software improves the value of the automated measurements by providing a suite of simulations to ensure the best drilling performance at the well site by optimizing ROP, maximizing hole cleaning, and avoiding potential lost time events. The hydraulic simulations have been shown to be more accurate and closer to APWD results when the fluid viscosity is measured at three temperatures.

Data Accessibility

The technology expands the level of drilling fluid properties data visibility. The results are time-stamped with recorded depths and are available for display, storage, or processing via:

- The unit's touchscreen
- Rig electronic drilling recorder (EDR) monitors
- Cloud-based server (storage)
- Real-time hydraulics software
- Visualization software platforms

Previous measurements can be accessed locally on the unit on the touchscreen, enabling a quick review of mud properties without a laptop. The units will allow for more frequent checks, increase rig personnel efficiency, and generate a faster response to changes in the drilling fluid by giving the team real-time access to drilling fluid properties. It is a major step change in drilling fluids measurements and data communications.

Software Platform

Creating the best overall drilling project outcome is inherently tied to information. Providing the most accurate, frequent, and interchangeable data to the right expert enhances operations and reduces the total cost of the project.

An initial challenge with data is consolidating it from separate sources and delivering it within the proper context required to transform the data into actionable information. EDR systems are considered a wellsite standard in today's oil and gas industry, aggregating operational measurement into a digital format via WITS protocol, allowing for common data storage at the wellsite. Collected information can then be visualized on wellsite monitors, transferred to other local third-party systems, and transmitted to servers or the cloud.

Once the data have been aggregated into a single space and format, machine logic is applied to drilling fluid data at a rate much faster than any human can. Traditionally, formulating recommendations requires hours of labor. Now they can be calculated and visualized within seconds through software platforms (Contreras et al. 2019) after determining drilling fluid health and treatment solutions. The recommendation needs to be delivered to the actionable party in an inclusive format.

Data security standards and ownership demand a new structure from the traditional physical servers located within each stakeholder that are behind multiple firewalls restricting flow of information. The digital era has brought about the consolidation of data storage, networking, software programs at secure, well-operated, remote server facilities that provide the industry with cloud computing. Organizations in the oil and gas industry use cloud computing to benefit from the increased speed, security, efficiency, processing power, and accessibility available to all customers, but at a fraction of the cost.

Cloud computing allows the oil and gas industry to use industry-recognized protocols, such as the Open Subsurface Data Universe (OSDU). The user can use accurate, structured, and contextual data in a secure, customer-empowered cloud environment, which is the clear future of the petroleum industry.

Remote Centers

Digitally connected operations and data liberation combined with automated measurements can limit physical exposure of workers at a wellsite. This remains the most advantageous way to reduce health and safety risks, making better use of vital resources for our industry. Companies have implemented borderless access to expertise without sending personnel cross country, offshore, or internationally. Remote operations centers provide many added benefits outside of reducing health safety exposure. Placing the best subject matter experts in one location, such as directional drillers and drilling fluid engineers, allows for a collaboration of experience and ideas that greatly increases productivity and avoids nonproductive time.

Supplementing remote monitoring centers with cloud computing technologies takes drilling fluids experts to a level of performance never seen before. Drilling fluid cloud ecosystems provide context to chemical operations data in the form of interactive visualizations, automated calculations, and treatment recommendations. The ecosystem not only monitors the chemical treatment program, but also enables proactive management of key aspects of the drilling fluid performance as well as rapid identification of potential issues.

Workflows and data are managed by the drilling fluid software. Real-time operations objectives are available in a single visualization platform. The drilling fluid cloud platform can integrate offset well data during planning or project execution, adding value to the analysis available to the well management team. Continuous monitoring with notifications for chemical additions and fluid properties allows quick well prioritization for subject matter experts focusing on several projects in remote operations centers. Using visualization to analyze crucial data against real-time objectives helps project stakeholders track priorities for an ever-changing wellbore and better plan for future projects in the area.

Knowledge is only as powerful as the ability to quickly access and analyze it. Connected instrumentation and contextual archiving of data enable performance-enhancing solutions within seconds instead of weeks. Innovative communication methods enabled by cloud-accessible applications replace unreliable verbal conversations with retrievable data points. As we continue physical distancing to maintain health and safety requirements, the flexibility offered by drilling fluid cloud platforms and automated measurement equipment provide a timely and robust solution for managing drilling fluid operations from anywhere.

Bringing Value to Operations

The advancements in automation, software, and remote centers have proven to bring value when they operate together. This has been observed in the field in various locations.

In South America, an offset well was riddled with hole-cleaning issues. The well spent a significant amount of time circulating hole-cleaning pills prior to pulling out of hole (POOH). Additionally, a liner run required a fishing job after becoming stuck in the hole. For the next well, the planning team examined other wells in the area, switched the fluid type to water-based mud (WBM), and recommended using real time hydraulics software to advise on hole cleaning, tripping speeds, and circulating times. Automated rheology and density measurements were also utilized and results were sent to the software to update the modeling.

The software advised to not run high-viscosity pills for hole cleaning, which are routine in the area. High viscosity pills were eliminated from two hole sections, reducing the drilling fluid products required and also reduced circulating time in half at the interval TD. The liner run and cement job were performed without pressure spikes. No costly fishing operations were necessary, unlike the closest offset well. Valuable rig time, chemicals, and transportation were saved by utilizing these advanced technologies with a remote operations center.

In Mexico, the same technologies were used in concert on a well with a narrow ECD drilling window. ECD management was closely monitored and real-time fluid conditions were vital for accurate modeling. The operations team was able to save rig time in the 12.25-in section by safely increasing the tripping rate in casing hole from the standard 300 ft/hr to over 1,300 ft/hr. They had similar results in the 8.5-in section, where the standard tripping rate (600 ft/hr) was increased by over 50% (920 ft/hr). These dramatic improvements saved several hours of valuable rig time while maintaining safety and drilling performance.

Another example was observed in the Middle East. Increased measurement frequency by the automated device exhibited better hydraulics accuracy when the software results were compared to the APWD tools. Once confidence was established in the automated measurements and hydraulics software, these tools could be used less, leading to reduced costs for drilling the wells.

On the same well, ECD management was again critical. The software recommended lowering the flow rate to keep ECD at the lowest possible value to eliminate the risk of losing fluid to the formation while still maintaining acceptable hole cleaning. Offset wells had lost significant volumes (over 5,000 bbl) of OBM due to poor ECD management. The team successfully drilled the well with minimal losses to formation and zero nonproductive time from well control safety concerns when severe lose scenarios occur. Significant savings were realized by using the technologies together, enabling the remote engineers to advise the rig personnel quickly and accurately.

Other examples of how the technologies and remote operations centers can provide value are summarized below:

- Increased drilling fluid property measurements will enable analysis of correlations between fluid properties and tool performance/failures, bit life, solids control equipment performance, etc.
- Increased data availability will enable mud programs to be better optimized and executed.
- Real-time visualization tools help to keep drilling engineers better informed of information such as barite sag, basic hole cleaning, and packing-off indicators.

Conclusions

Traditional drilling fluids measurements have gone virtually unchanged for several decades. Automated measurements have provided a way to increase measurement frequency and accuracy, to improve data visibility, and to provide software models with more real-time input on drilling fluid conditions. Today's software platforms are becoming more comprehensive and accessible. Remote operations centers are bringing subject matter experts from different parts of the drilling world together to maximize results and reduce risks.

The three components have now been joined together to bring more value and improve drilling efficiency. The examples described above are only the first step. Advancing drilling fluids into the digital era will allow for even more complex wells with further cost optimizations and improved production.

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Nomenclature

ºC = degrees Celsius
API = American Petroleum Institute
APWD = annular pressure while drilling
bbl = barrel
ft/hr = feet per hour
in = inch
POOH = pull out of hole
ppg = pounds per gallon
QA/QC = quality control/quality assurance
TD = total depth
SG = specific gravity
WITS = Wellsite Information Transfer Specification

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