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Standardizing and Optimizing Lab-Scale Performance Evaluation of Anti-Accretion Additives in Drilling Fluids

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Abstract

Preventing and mitigating cuttings accretion is crucial for successful drilling operations with aqueous drilling fluids. Anti-accretion additives are employed in these fluids to prevent clay from sticking to the drill string. To evaluate the effectiveness of these additives, the industry has relied on laboratory accretion testing for many years. However, accurately measuring accretion in the lab is influenced by several variables such as fluid composition, steel tube characteristics, mineralogy of drill solids, temperature, and time, leading to inconsistent results. This study builds on previous research conducted on the correlation between clay mineralogy and accretion.

This study aims to establish a standardized method for testing anti-accretion additives with various simulated clay cuttings, thereby reducing variability and creating reliable performance parameters.

Design of this method was focused on two main objectives: optimizing the general drilling fluid formulation to be both simple and easily accessible for a wide range of lab capabilities and optimizing the time which the maximum amount of accretion occurs normalized to individual lab equipment. Data from this study was collected from multiple laboratories and personnel, using the same procedure with different types of clay cuttings.

The results demonstrate that by controlling procedural variables, consistent results could be achieved across different labs. This data led to creation of a new universal procedure for evaluating performance of drilling fluid anti-accretion additives.

Introduction

In the field of drilling operations, the prevention and mitigation of clay accretion are critical to ensuring efficiency and success, particularly when utilizing aqueous drilling fluids. Clay accretion, the adherence of clay particles to the drill string, can lead to significant operational challenges, including increased torque and drag, stuck pipe incidents, and reduced rate of penetration. To combat this, the industry employs anti-accretion additives in drilling fluids, which are designed to prevent clay particles from sticking to the drill string. Despite their importance, evaluating the effectiveness of these additives remains a complex task due to the variability in laboratory accretion testing.

Accretion testing in laboratories has been a longstanding method for assessing the performance of anti-accretion additives. However, the accuracy and consistency of these tests are often compromised by numerous variables. Factors such as fluid composition, the characteristics of the steel tubes used in testing, the mineralogy of the drill solids, temperature, and duration of the tests can all influence the results. This variability makes it challenging to obtain reliable and reproducible data, hindering the ability to draw definitive conclusions about the effectiveness of different additives.

This study aims to address these challenges by establishing a standardized method for testing anti-accretion additives using various simulated clay cuttings. Building on previous research that explored the correlation between clay mineralogy and accretion, this study focuses on reducing the influence of variables in laboratory testing and creating reliable performance parameters. The primary objectives were to optimize the general drilling fluid formulation to be both simple and accessible for a wide range of laboratory capabilities, and to determine the optimal time for maximum accretion normalized to individual lab equipment.

Data for this study were collected from multiple laboratories and personnel, all following the same standardized procedure with different types of clay cuttings. By controlling procedural variables, this study demonstrates that consistent results can be achieved across different labs. The findings have led to the creation of a new universal procedure for evaluating the performance of drilling fluid anti-accretion additives, promising more reliable and actionable insights for the industry.

In the following sections, we will delve into the methodology used to develop this standardized testing procedure, present the results obtained from the multi-laboratory study, and discuss the implications of these findings for improving the evaluation of anti-accretion additives in drilling operations.

Literature Review

Historical Overview of Clay Accretion Challenges and Their Mitigation

Clay accretion poses significant challenges during drilling operations, impacting both efficiency and safety. Adhesion of clay to drill tools can reduce rates of penetration (ROP) (Mettath, 2011; Van, 2003; Van, 2015), disrupt the proper circulation of drilling fluid (Mettath, 2011; Van Oort, 2003), and cause operational complications such as stuck pipe incidents and bit balling mechanisms (Van Oort, 2003). These challenges became prominent in the mid-20th century with the widespread adoption of water-based muds (WBMs) as environmentally compliant alternatives to oil-based muds (OBMs). While WBMs offered significant environmental advantages, they also exposed substantial challenges in reactive shale formations where clay swelling, adhesion, and dispersion were problematic (Bland, 2002; Bland, 1997).

Efforts to mitigate these challenges date back to the 1930s, beginning with the use of electrolytes like calcium chloride and potassium chloride (KCl) to reduce clay swelling. The 1950s saw the introduction of polyglycol ether for shale stabilization, and by 1937, oil-based materials were being incorporated into WBMs to decrease torque and enhance penetration (Bland, 2002; Bland, 1997). By the late 1960s, KCl-based muds had become the first widely used shale inhibition systems (Patel, 2007; Hegazy, 2018).

Silicate-based systems, initially developed in the 1930s for wellbore stability, were revisited in the 1980s and 1990s alongside advancements in polymer/KCl systems and other inhibitors, were designed to enhance shale stability and control accretion (Bailey, 1996; Bland, 2002; Patel, 2007; Iskander, 2009). By the early 2000s, high-performance WBMs integrating amine-based inhibitors, polyacrylamides, and encapsulating polymers were developed, offering performance comparable to OBMs while simultaneously meeting environmental and economic requirements (Van Oort, 2003; Mettath, 2011).

Among these advancements, two additives have proven particularly effective in mitigating clay accretion challenges:

- Potassium Chloride (KCl): A cost-effective hydration inhibitor that dehydrates clay by reducing water activity, mitigating swelling and adhesion (Friedheim, 2003).
- Partially Hydrolyzed Polyacrylamide (PHPA): A thermal-stable polymer that enhances fluid-clay interaction, improve rheological performance, and withstands temperatures up to 350°F. PHPA formulations also reduce hydraulic friction, as observed in extended-reach drilling applications (Metwally, 2024).

These innovations highlight the industry's progress in managing clay-related challenges and provide a foundation for this study, which evaluates standardized testing methods for anti-accretion additives across diverse clay types and operational conditions.

Clay Accretion Mechanisms

Clay accretion is primarily driven by the interaction between reactive clays and drilling fluids. Reactive clays, such as smectite and kaolinite, exhibit distinct behaviors that complicate drilling operations. Smectite, with its high cation exchange capacity (CEC) and significant swelling potential, absorbs water, increasing plasticity and adhesion. Kaolinite, lacking CEC and swelling properties, disperses readily in water, forming fine particles that adhere to drilling tools. Both behaviors necessitate tailored fluid formulations to address specific clay characteristics and mitigate operational challenges (Cliffe, 2008; Van Oort, 2003; Van Oort, 2016; Van Oort, 2018). The interaction between clays and fluids is influenced by several factors:

- **Clay Mineralogy:** Different clay types demand specific treatment strategies. Smectite's swelling requires inhibition via potassium ions, while kaolinite’s dispersion necessitates stabilization to prevent adhesion (Cliffe, 2008; Van Oort, 2016; Van Oort, 2018). Studies confirm that kaolinite’s high flocculation and low dispersibility contribute to unique accretion behaviors (Van Oort 2018).
- **Fluid Composition:** Additives like KCl and PHPA significantly affect fluid-clay interactions. KCl lowers water activity, reducing swelling and adhesion in smectite, while encapsulating polymers such as PHPA enhance stability by reducing dispersion (Cliffe, 2008; Van Oort 2018; Khramov, 2023).
- **Operational Parameters:** Downhole conditions, including temperature and pressure, modulate clay-fluid interactions. Thermally stable additives like PHPA maintain performance under elevated temperatures, crucial for high-temperature drilling environments (Van Oort, 2003; Cliffe, 2008; Khramov, 2023).

Cliffe (2008) identified three representative clay types, supported by subsequent studies (Van Oort, 2018; Khramov, 2023), each exhibiting distinct accretion behaviors:

- Oxford Clay: Exhibits intermediate swelling and dispersion behaviors, making it a moderate case for accretion studies.
- London Clay: Displays extreme dispersion and is highly prone to accretion, posing operational challenges.

- Arne Clay: Exhibits rapid surface adhesion, as noted in accretion tests, which may be influenced by its high kaolinite content. However, the specific role of kaolinite in driving this behavior remains an area for further study, particularly through laboratory validation of clay-fluid interactions and field-specific assessments under varying operational conditions.

The understanding of these behaviors underpins this study, which aims to standardize accretion testing protocols and evaluate anti-accretion additives across varied clay types.

Overview of Existing Testing Methods

Laboratory testing methods for evaluating clay accretion and the effectiveness of anti-accretion additives are extensively used in the industry. These methods simulate interactions between clay particles, drilling fluids, and drilling equipment under controlled conditions. Key parameters assessed include clay adhesion, swelling, dispersion, and additive performance in mitigating accretion. Testing approaches commonly used include both static and dynamic methods.

Static methods typically involve immersing clay samples in drilling fluids to observe behaviors like hydration, swelling, or adhesion over time. These methods provide insights into fluid performance in controlled, low-shear conditions, making them suitable for initial evaluations of fluid-clay interactions (Cliffe, 2008; Van Oort, 2015; Van Oort, 2016; Van Oort, 2018). Dynamic methods, such as rolling tests, are designed to simulate downhole conditions by exposing clay samples to fluid movement within a rotating cell. This approach replicates shear and turbulence typical of drilling environments, providing a closer approximation of field conditions (Metwally, 2024; Van Oort, 2016; Van Oort, 2018). Both methods are essential for understanding clay-fluid interactions but serve different objectives depending on the testing conditions.

Environmental factors, such as temperature and pressure, are varied to mimic subsurface conditions. For instance, studies by Van Oort (2015) and Metwally (2024) tested additive performance at elevated temperatures (e.g., 120°F) to evaluate thermal stability and effectiveness. Similarly, Van Oort (2016, 2018) emphasized the importance of simulating downhole conditions during laboratory testing, noting that temperature and pressure significantly influence the accuracy of additive performance evaluations. Replicating these field-like conditions during laboratory testing ensures results are applicable to real-world operations.

Various additive formulations have been evaluated, including KCl, silicates, polymers such as PHPA, and amine-based inhibitors, for their ability to minimize clay accretion and improve drilling efficiency (Friedheim, 2002; Van Oort, 2003; Iskander, 2009). These comprehensive testing methods and the evaluation of diverse additives are crucial for advancing the effectiveness of WBMs in mitigating clay accretion and enhancing overall drilling performance.

Challenges and Limitations in Current Approaches

Despite advancements in laboratory testing methods for clay accretion, several limitations continue to affect the reliability and applicability of existing tests. Conventional methods, such as atmospheric swelling tests and basic rolling accretion tests, often fail to accurately simulate downhole conditions. Key challenges include inconsistencies in sample preparation, uncontrolled test parameters, and the lack of standardized procedures. For example, tests often fail to replicate the combined effects of temperature, pressure, and shear forces encountered during drilling operations, leading to unreliable results that may overestimate or underestimate the performance of anti-accretion additives (Van Oort, 2016; Van Oort, 2018).

Key Limitations

Variability in Procedures: Accretion tests have shown poor reproducibility and are highly sensitive to how the test is set up. Recent findings (Khramov, 2023) emphasize that accretion testing is generally regarded as a qualitative measurement at best, highlighting the urgent need for procedural standardization to ensure consistent and actionable results across studies (Van Oort, 2016; Van Oort, 2018).

Limited Field Simulations: Laboratory tests often fail to replicate dynamic downhole conditions, such as high pressures, multi-phase interactions, and variable shear rates. While improved rolling accretion tests and dynamic simulation setups have been proposed, their effectiveness has been partially validated. For example, Cliffe (2008) demonstrated that modified rolling accretion cells with enhanced temperature and shear control could better simulate thermal and mechanical stresses encountered in field operations. Similarly, Khramov (2023) highlighted the importance of incorporating variable shear rates into dynamic simulation setups to mimic real-world fluid circulation patterns, noting significant improvements in replicating fluid-clay interaction under operational conditions. However, these methods require further field-specific calibration and validation to ensure their applicability across diverse geological settings.

Narrow Clay Selection: Many studies rely on a limited range of clays, which may not represent the geological diversity encountered in field operations (Cliffe, 2008; Friedheim, 2003).

Inconsistent Performance Metrics: Metrics for evaluating additive performance, such as reductions in clay adhesion or swelling, vary widely, making it difficult to establish industry-wide benchmarks (Van Oort, 2003; Metwally, 2024).

Limitations Toward Standardization

The limitations of existing testing approaches highlight the need for standardized, representative approaches that minimize variability and improve the reliability of laboratory findings. By addressing these challenges, the industry can achieve more consistent evaluations of anti-accretion additives, ultimately enhancing drilling efficiency and operational safety.

Methodology

Building on previous research, this study introduces a standardized testing approach to address the limitations of existing methods. Key elements of this approach include controlled conditions, such as conducting rolling tests at a consistent temperature, an optimized time duration, an optimized fluid formulation, and a standardized cuttings load. To account for various accretion mechanisms, the study incorporates a selection of representative clays, including Arne, London, and Oxford Clays. Additionally, unified performance metrics are established to provide clear and reproducible criteria for evaluating the effectiveness of additives. To enhance the realism of testing environments, the study incorporates dynamic interaction, to better simulate downhole conditions. The proposed standardized approach ensures more reliable, reproducible, and comparable results.

The new methodology was designed with two main goals: optimizing the general drilling fluid formulation to be both simple and accessible for a wide range of lab capabilities, and determining the time at which the maximum amount of accretion occurs on the blank sample before anti-accretion additives are added.

This section outlines the procedures followed to achieve these goals.

1. Materials and Equipment
    - Drilling Fluids: A base drilling fluid formulation was prepared using water, barite, and other common additives. The formulation was designed to be simple and easily accessible for most laboratories. (See Table 1)
    - Anti-Accretion Additives: SLB commercially available anti-accretion additives were tested.
    - Simulated Clay Cuttings: Arne, London, and Oxford clays used at a standardized load (30 grams).
    - Steel Tubes: Standardized hollow, uncapped carbon-steel tubes with the following dimensions: Length 120 mm, OD 35 mm, ID 32 mm.
    - Testing Apparatus: Glass jar.
    - Testing Equipment: Standard laboratory equipment, such as mixers, ovens, and scales, were used to prepare and test the samples.

2. Experimental Design

2.1 Preparation of Drilling Fluids
- The base drilling fluid formulation was prepared by mixing water, additives and barite in specific order and loading.
- Control and Test samples: Anti-accretion additives were then added to the base fluid at predetermined concentrations.

2.2 Preparation of Simulated Clay Cuttings
- Simulated clay cuttings were prepared by grinding and sieving natural clay samples to obtain particles of uniform size. Clays are sized between 4mm-6mm.
- Different types of clay cuttings (Arne, London, Oxford) were prepared to evaluate the performance of anti-accretion additives with various clay mineralogy.

2.3 Accretion Testing Procedure
- Carbon-steel tubes were cleaned and weighed before each test to ensure accurate measurement of accretion.
- Testing apparatus consists of a steel tube inserted into glass jar with specified amount of drilling fluids, and then placed into a roller oven at 150°F.
- Cuttings added to testing apparatus. (See section 2.2)
- The testing apparatus was operated under controlled conditions, temperature and rotation speed to simulate drilling operations.
- The steel tubes were removed from the apparatus after an optimized time period, cleaned, and weighed again to measure the amount of clay accretion. (See section 2.4)

2.4 Optimization of Testing Parameters
- Using the blank fluid (no Anti-accretion additive), the accretion values were taken at iterative time increments from 0 up to 45 minutes, depending on the clay type.
- Analysis was done on accretion data to determine the time corresponding to the highest accretion value (maximum accretion value).
- The optimized time is dependent on clay type, testing apparatus, fluid, and laboratory equipment.
- Variations in the testing procedure, such as fluid composition and temperature, were systematically controlled.

2.5 Optimizing the Fluid Formulation (See Table 1)
- KCL brine was introduced to reduce immediate hydration of clays and give longer clay/fluid interaction time.
- Xanthan Gum used for viscosity profile.
- PHPA used to increase the clay/fluid interaction time and simulate technology used in field setting.
- Barite added to simulate technology used in field setting.

Steps	Items	Concentration
1	20% KCl Brine	90-95%
2	Dry Xanthan Gum	1-5%
3	Dry PHPA	1-5%
4	NaOH solution 5N	Adjust pH to 10
5	API Standard Barite	5-7%

Table 1: 11.0 ppg Aqueous Baseline Drilling Fluid

During the design process, the fluid parameters outlined for success included a greater than 50% maximum accretion value using the blank fluid, and a greater than 50% accretion reduction comparing the blank versus the test fluid (fluid with anti-accretion additive). Please see the Results section for optimized times corresponding to maximum accretion values by cuttings type. Keep in mind this procedure was designed using SLB specific products for SLB specific purpose, and other products may not have the same level of accretion reduction using this formulation.

Results

Using the procedure discussed in the Methodology section and the formulation given in Table 1, accretion values were collected over 16 repeated iterations in two different lab locations, Houston and Qingdao. This repeated testing was conducted in two stages: the development stage, during which the procedure was optimized, and the validation stage, during which the procedure was actively used for performance evaluation. The 16 iterations included 8 tests using the formulation with no anti-accretion additive (blank) and 8 tests using the SLB flagship anti-accretion additive (control). The results are presented in Table 2.

For table 2 and 3, data in the top row is % accretion and bottom row is % accretion reduction. From Table 2, it is evident that all blank accretion values are greater than 50%. In contrast, the control accretion values average less than 10%, with the percent accretion reduction significantly exceeding the parameter of 50% accretion reduction.

Development							
Series 1		Series 2		Series 3		Series 4	
UT	TR	UT	TR	UT	TR	UT	TR
61%	7.60%	80%	2%	68%	5.60%	74%	6%
-	88%	-	98%	-	92%	-	92%

Table 2: Development Test Series of Treatment with ROP Enhancers Untreated (UT) VS Treated (TR) Samples

Validation							
Series 5		Series 6		Series 7		Series 8	
UT	TR	UT	TR	UT	TR	UT	TR
61%	8%	85%	14%	74%	2%	79%	1%
	87%		84%		98%		99%

Table 3: Validation Test Series of Treatment with ROP Enhancers Untreated (UT) VS Treated (TR) Samples

The blank average accretion through both the development and validation stages is 73%, well above parameter of 50% accretion. The control average accretion is 6%, and the accretion reduction of the control average is 92%, far surpassing the parameter of success of a 50% reduction. Figure 1 is a graphical representation to show the disparity between accretion values on the blank sample versus the control samples, using the optimized formulation.

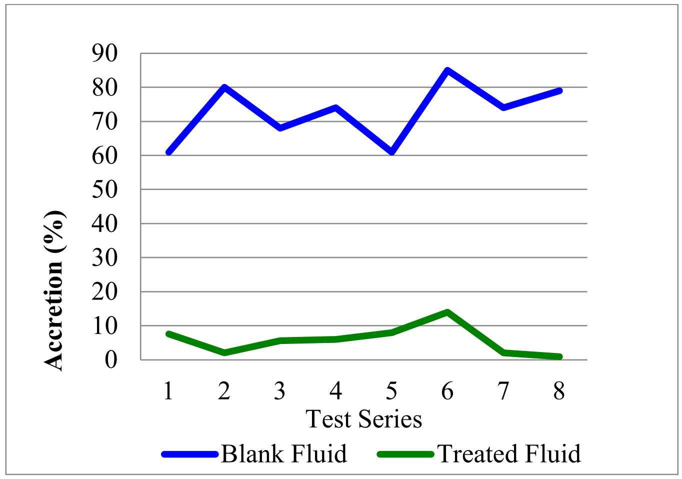

Figure 1: Sample-wise Comparison of Blank and Control Accretion Values

To evaluate the consistency of accretion reduction, statistical metrics were calculated. The mean reduction across all samples was 91.89%, with a standard deviation of 5.62% and a coefficient of variation (CV) of 6.12%. These values indicate a high level of consistency in the reduction performance of the SLB flagship anti-accretion additive. The range of reduction values was 15.20%, demonstrating limited variability across the samples. These results confirm that the additive provides reliable and reproducible performance in mitigating accretion.

During the validation stage, data was collected using the new accretion procedure at the SLB lab in Qingdao, China. The results are shown in Table 4. This table displays blank and control testing completed in a different lab using the same base clay (Arne), the same steel tubes, different ovens, and different personnel. The maximum time for blank accretions was 20 minutes, consistent with the maximum time used in Houston during the development stage.

Total Time Rolled (min)	Total Weight of Bar and Retained Cuttings (g) Measured at Various Time Increments			
	UT		TR	
	Test 1	Test 2	Test 1	Test 2
0	133.89	133.86	124.14	124.08
2	168.22	167.72	132.81	131.89
5	174.85	172.13	132.14	132.96
10	181.17	176.81	133	133.21
15	180.85	184.62	133.15	132.95
20	184.18	185.8	132.56	132.62
25	184.07	183.14	132.47	131.8
30	182.28	181.72	131.66	131.99

Table 4: Validation Data in Qingdao Lab

Figure 2 provides a graphical representation of accretion vs. time using Arne clay. The maximum accretion on the blank formulation occurs at 20 minutes for both Test 1 and its repeat, Test 2. The results from the Qingdao Laboratory confirm the findings from Houston.

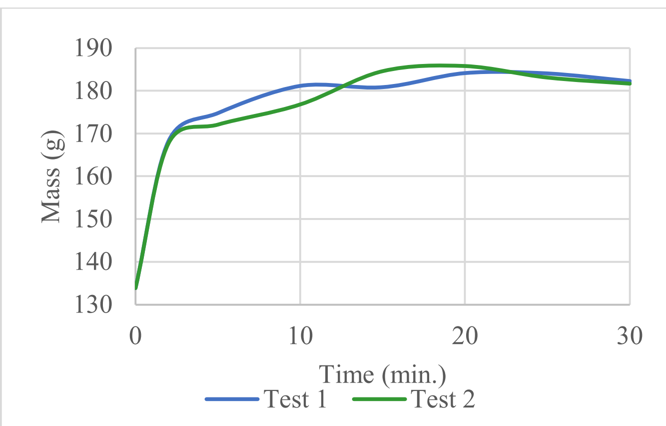

Figure 2: Arne Clay Max Accretion Curve

After the methodology using similar variables (formulation, cuttings, equipment) was validated, the next step was to use the new methodology and change the cuttings variable. For this simulated drill cuttings were sized (See Methodology section) from both London and Oxford clay types. Optimum accretion times (See Section 2.4) were determined, holding all other variables the same. Please note, this testing was completed in the Houston lab.

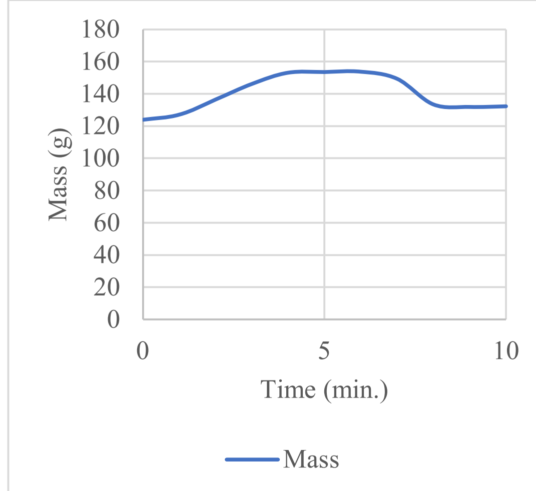

Figure 3: London Clay Max Accretion Curve

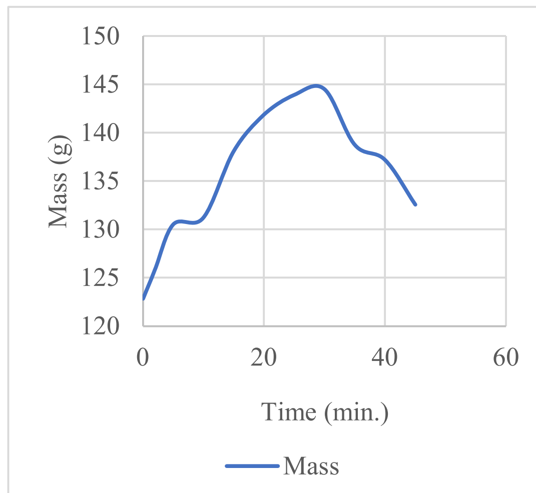

Figure 4: Oxford Clay Max Accretion Curve

Figures 3 and 4 illustrate the trends of accretion values over time for London clay and Oxford clay, respectively. The experimental results reveal significant differences in the accretion behavior of the two clay types:

- London Clay: The maximum accretion value was observed at 6 minutes, highlighting its rapid dispersion and accretion characteristics. The blank accretion value on London clay was achieved greater than our target, at 55% accretion. The % reduction value achieved in this testing was 61%. However, please note the load of the anti-accretion additive was adjusted to 6%vol to increase the % accretion reduction from the initial 33% to 61%.

- Oxford Clay: The maximum accretion value occurred at 30 minutes, indicating that its accretion behavior requires a longer duration to fully develop. The blank accretion value on Oxford clay was achieved greater than our target, at 68% accretion. The % reduction value achieved from this testing was 69%.

These findings emphasize the importance of developing a normalized approach to determine the optimal aging time during accretion testing. The distinct accretion characteristics of each clay type provide a robust basis for further discussions on the applicability and flexibility of the proposed procedure.

Moreover, the comprehensive testing and validation performed across different laboratories and under varied conditions demonstrate the robustness and reliability of the new standardized procedure. These results ensure consistent and accurate evaluation of anti-accretion additives in drilling operations.

Discussion

By standardizing the existing clay accretion testing protocols and optimizing the formulations used to test anti-accretion additives, this study successfully achieved consistent and verifiable results across different laboratories and multiple personnel. The data indicate that accretion values were reduced by more than 90% when anti-accretion additives were introduced, while the blank samples demonstrated a maximum accretion value of 72% at 20 minutes. This 20-minute duration was identified as optimal, allowing sufficient fluid-clay interaction within a reasonable timeframe, avoiding insufficient data from shorter durations and preventing accretion values from declining toward zero during longer durations.

Standardization of Testing Parameters

A major accomplishment of this study is the development of a unified approach to accretion testing, particularly in standardizing a method to optimize testing time by location. The validation data revealed that the 20-minute maximum accretion time for Arne clay was consistent between the Houston and Qingdao laboratories, despite variations in equipment, personnel, and other conditions. This consistency demonstrates the robustness of the procedure and highlights its ability to produce reliable and reproducible results under different operational conditions. Furthermore, the results validate the procedure’s applicability to other clay types, such as London and Oxford clays, which displayed unique accretion characteristics in line with their expected behaviors.

Clay-Specific Observations

The experimental results validated the descriptions of different clay characteristics mentioned in the introduction and further demonstrated the applicability of the procedure:

- Arne Clay: The maximum accretion time of 20 minutes was consistent with results from the Houston laboratory, confirming the reliability of the procedure under different experimental conditions.
- London Clay and Oxford Clay: The maximum accretion times for these clays were 6 minutes and 30 minutes, respectively. This variation further highlights the procedure's ability to adapt to diverse clay characteristics and supports its applicability to a range of real-world formation conditions.

Through these validations, the standardized procedure proposed in this study not only demonstrated consistency across different laboratories but also proved its adaptability to a variety of clay types. This ensures that it meets the dual standards of laboratory testing and field application.

Flexibility and Adaptability of the Method

The proposed method has been validated for various clay types, including London Clay, Oxford Clay, and Arne Clay, demonstrating its scalability and adaptability. Results indicate that the procedure does not depend on any specific clay type and may also be applicable to local field cuttings. This flexibility enhances the method’s relevance, allowing laboratories to tailor testing to meet specific needs while maintaining reliable outcomes.

Further Work and Limitations

While the method described in this paper has been verified in the laboratories discussed here, including the SLB lab in Qingdao, China, further validation is ongoing in other laboratories, including an SLB lab in the UAE. Additional data beyond the 16 data sets discussed here could be incorporated to strengthen the study. Testing this procedure outside of the two initial labs will necessitate reviewing other types of clays on a local level, including field cuttings. Gathering more data from additional laboratories and personnel will enhance the study's validity and robustness.

Overall, this study has successfully shown that standardizing accretion testing protocols and optimizing formulations can lead to consistent and reliable evaluation of anti-accretion additives. Continued validation and data collection will further solidify these findings, contributing to improved efficiency and success in drilling operations.

Conclusions

In conclusion, this study has successfully addressed the significant challenge of variability in laboratory accretion testing for anti-accretion additives in drilling operations. By developing and implementing a standardized testing procedure, we have demonstrated that it is possible to achieve consistent and reliable results across multiple laboratories. This new universal procedure, which controls for key variables such as fluid composition, steel tube characteristics, clay mineralogy, temperature, and test duration, offers a robust framework for evaluating the performance of anti-accretion additives.

The findings from this multi-laboratory study highlight the importance of standardization in obtaining reproducible data, which is crucial for making informed decisions about the selection and optimization of drilling fluids. Optimizing the general drilling fluid formulation to be both simple and accessible, and by determining the optimal time for maximum accretion normalized to individual lab equipment, has provided the industry with performance parameters that can enhance the efficiency and success of drilling operations.

Moreover, this study builds on previous research by further elucidating the relationship between clay mineralogy and accretion, contributing to a deeper understanding of the mechanisms involved. The standardized method developed here not only reduces the variability in testing but also sets a benchmark for future research and development in the field of drilling fluid additives.

Future work should focus on further refining this standardized procedure and exploring its application to a broader range of drilling conditions and fluid formulations. Additionally, continued collaboration between laboratories and industry stakeholders will be essential in ensuring the widespread adoption and continuous improvement of accretion testing methods.

By addressing the complexities and inconsistencies of traditional accretion testing, this study lays the groundwork for a more systematic and reliable approach to evaluating anti-accretion additives, ultimately contributing to the advancement of drilling technology and practices.

Nomenclature

UT = Untreated Base Fluid
TR = Base Fluid Treated with ROP Enhancer
PPG = Pounds Per Gallon

References

Bailey, L., Stamatakis, E., & Bland, R. G. (1996). Silicate-Based Drilling Fluids: A Versatile Option for Shale Stabilization. Presented at the SPE/IADC Drilling Conference, New Orleans, Louisiana, March 12–15. SPE-35059-MS.

Bland, R. G., Jones, T. A., and Tibbitts, G. A. (1997). Reducing Drilling Costs by Drilling Faster. Presented at the SPE Annual Technical Conference and Exhibition, San Antonio, Texas, October 5–8. SPE-38616-MS. DOI: 10.2118/38616-MS.

Bland, R. G., Waughman, R. R., Tomkins, P. G., Halliday, W. S., Pessier, R., and Isbell, M. R. (2002). Water-Based Alternatives to Oil-Based Muds: Do They Actually Exist? Presented at the IADC/SPE Drilling Conference, Dallas, Texas, February 26–28. IADC/SPE-74542-MS. DOI: 10.2118/74542-MS

Cliffe, S., and Young, S. (2008). Agglomeration and Accretion of Drill Cuttings in Water-Based Fluids. Presented at the 2008 AADE Fluids Conference and Exhibition, Houston, Texas, April 8–9. AADE-08-DF-HO-10.

Friedheim, J., Sartor, G., and Malik, I. (2003). WBM With Triple-Inhibition Mechanism Demonstrates Near OBM Performance in Deepwater Gulf of Mexico. Presented at the Offshore Mediterranean Conference and Exhibition, Ravenna, Italy, March 26–28. OMC-2003-061.

Hegazy, M., Sharma, S., Fares, K., and ElBatran, A. (2018). High Performance Water-Based System Proved an Environmentally-Friendly Alternative for Time-Sensitive Shales in Saudi Arabia. Presented at the SPE Kingdom of Saudi Arabia Annual Technical Symposium and Exhibition, Dammam, Saudi Arabia, April 23–26. SPE-192270-MS.

Iskander, G. R., Young, S., and El Mokadem, S. (2009). The Use of Water-Based Fluids to Replace Invert Fluids in Egypt. Presented at the Offshore Mediterranean Conference and Exhibition, Ravenna, Italy, March 25–27. OMC-2009-108.

Khramov, D., Panamarathupalayam, B., and Barmatov, E. (2023). Evaluation of Laboratory Performance Tests for Drilling Fluids. Presented at the AADE Fluids Technical Conference and Exhibition, Midland, Texas, April 4–5. AADE-23-FTCE-012.

Mettath, S., Stamatakis, E., Young, S., and De Stefano, G. (2011). The Prevention and Cure of Bit Balling in Water-Based Drilling Fluids. Presented at the AADE Fluids Conference and Exhibition, Houston, Texas, April 7–9. AADE-11-NTCE-28.

Metwally, M., Gyimah, E., and Koray, A. M. (2024). An Efficient Coupled Hydro-Geomechanical Model for Determination of Open Hole Extended Limit of Drilling Horizontal Wells in the Permian Basin by Using Developed Environmentally Friendly High Performance Water-Based Mud. Presented at the 58th U.S. Rock Mechanics/Geomechanics Symposium, Golden, Colorado, USA, June 23–26. ARMA 24–149.

Patel, A., Stamatakis, E., Young, S., and Cliffe, S. (2002). Designing for the Future – A Review of the Design, Development, and Testing of a Novel, Inhibitive Water-Based Drilling Fluid. Presented at the AADE 2002 Technical Conference, Houston, Texas, April 2–3. AADE-02-DFWM-HO-33.

Patel, A., Stamatakis, E., Young, S., and Friedheim, J. (2007). Advances in Inhibitive Water-Based Drilling Fluids—Can They Replace Oil-Based Muds? Presented at the SPE International Symposium on Oilfield Chemistry, Houston, Texas, February 28–March 2. SPE-106476-MS. DOI: 10.2118/106476-MS.

Pinartjojo, D., Hutahaean, E. T. T., McManus, I., Nerwan, A. S. I., and Hansen, R. (2021). A Customized High Performance Water-Based Mud Solved the Challenge to Drill Reactive Shale Formation and Simplify the Logistic Challenge in an Exploration Well in Offshore East Kalimantan, Indonesia. Presented at the Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, UAE, November 15–18. SPE-208199-MS.

Van Oort, E. (2003). On the Physical and Chemical Stability of Shales. Journal of Petroleum Science and Engineering, 38:213–235. DOI: 10.1016/S0920-4105(03)00034-2.

Van Oort, E., Ahmad, M., Spencer, R., and Legacy, N. (2015). ROP Enhancement in Shales Through Osmotic Processes. Presented at the SPE/IADC Drilling Conference and Exhibition, London, United Kingdom, March 17–19. SPE/IADC-173138-MS. DOI: 10.2118/173138-MS.

Van Oort, E., Hoxha, B. B., Hale, A. H., Aldin, M., and Patterson, R. (2016). How to Test Fluids for Shale Compatibility. Presented at the AADE Fluids Technical Conference and Exhibition, Houston, Texas, April 12–13. AADE-16-FTCE-77

Van Oort, E., Hoxha, B. B., Hale, A. H., Aldin, M., and Patterson, R. (2018). How to Test for Compatibility Between Fluids and Shales. Presented at the IADC/SPE Drilling Conference and Exhibition, Fort Worth, Texas, March 6–8. IADC/SPE-189633-MS.