DOI: 10.31265/atnrs.770

ANNUAL TRANSACTIONS OF THE NORDIC RHEOLOGY SOCIETY, VOL. 32, 2024

EFFECT OF ADDITIVES ON RHEOLOGICAL PROPERTIES AND FLUID LOSS OF OIL BASED DRILLING FLUIDS

Blandine Feneuil[1], Jan David Ytrehus[1], Arild Saasen[2]

[1]SINTEF, NO-7031 Trondheim, Norway
[2]University of Stavanger, NO-4036 Stavanger, Norway

ABSTRACT

Oil-based drilling fluids are often used to drill geothermal or petroleum wells in hot locations. These fluids normally consist of dispersion of organophilic clays in water-in-oil emulsions. If loss of fluid to the formation is expected, fibres or other additives for fluid loss prevention are added.

In the present article results from a study showing the effects of the additions of weight materials and asphaltic resin-based fluid loss prevention additive on rheological properties of the drilling fluids are shown. These results show the complex behaviour of the mixture of these particulate materials into emulsions. Filtration control is measured in a pressure cell where the flow goes through filter paper with 11 and 22 microns opening.

INTRODUCTION

Drilling of hydrocarbon reservoirs and geothermal wells can in some cases have common challenges. Geothermal wells are normally drilled with water-based drilling fluids that are exposed to high temperatures, giving a high risk of polymer degradation and drilling fluid instability[1]. Frequently when drilling petroleum wells and in some situations for the geothermal wells, sections of the well will penetrate reactive formations containing shales and clays, making use of oil-based drilling fluids the best option. Also, if the temperature of the drilling fluids exceeds some 120-140°C oil-based systems may provide a more stable situation. To describe the viscosity of drilling fluids during flow in annular wellbores, the shear stresses at shear rates less than 250 1/s should be considered[2]. For flow into natural fractures the situation is different. A high viscosity at high shear rates has been found to reduce the flow into these natural fractures[3].

In the following it is presented the assessment of the effect of some additives on fluid loss of oil-based drilling fluids. A major effect in prevention of fluid loss, independent of choice of fluid loss material, is the contribution of the water droplets. The impact of water is beyond the scope of the current assessment. In the following the objectives have been to assess the effect of barite as weight material and a commercial asphaltic resin as fluid loss additives. The findings are described, including their effects on viscosity. The fluid loss data was obtained following the industry standard API 13B where the fluid loss filter cake was constructed onto filter paper in a filter press. The filter paper porosity openings were 11 or 20 microns.

RHEOLOGICAL MODEL USED FOR ANALYSING AND COMPARING THE DIFFERENT FLUID COMPOSITIONS

To compare the viscous properties of the tested drilling fluids, the Herschel-Bulkley model is used. The model as initially modified by Nelson and Ewoldt[4] and later by Saasen and Ytrehus[2], is used to be able to compare the results (Equation 1). This model isolates the descriptive parameters into a yield stress (τ_y), a surplus shear stress (τ_s) using a characteristic shear rate ($\dot{\gamma}_s$), and a curvature index (n). These three parameters are independent and can be used for comparing the viscosity parameters.

$$\tau = \tau_y + \tau_s \left(\frac{\dot{\gamma}}{\dot{\gamma}_s}\right)^n \tag{1}$$

The flow curves are generated from measurements conducted in Anton Paar 102 rheometer. The shear rate range are from to 0.01 (1/s) to 1000 (1/s). The yield stress was calculated using a linear extrapolation of the two lowest shear rate measurements, 0.0100 and 0.0126 1/s. A characteristic shear rate is selected based on what is most relevant for the corresponding well situation. Here this is selected as 100 (1/s) which is considered to represent shear rate near the area of a filter cake for bore hole sizes in the deviated sections. For sections higher up, a lower characteristic shear rate may be considered for improved accuracy. The n-value is derived from shear stress curve at 1000 (1/s). This is considered to give sufficient accuracy for the n-value. The viscosity tests were conducted at room temperature of 23°C.

MATERIALS USED FOR TESTING AND TEST PROCEDURES

An oil-based drilling fluid was constructed using the composition shown in **Table 1**. The composition is equal to that of Ofei et al. (2020)[5]. The components were added one by one and mixed with a OFITE constant speed blender at 6000 rpm, mixing time for each component is indicated in the table. To this drilling fluid barite and fluid loss additive was added to provide correct concentration.

TABLE 1: Composition of the reference drilling fluid (i.e., without barite nor fluid loss agent)

	Density (g/L)	Mass fraction	Mixing time (min)
Refined mineral oil	814	65.7%	
Emulsifier	950	2.6%	2
Viscosifier (low temp. clay)	1600	1.2%	4
Viscosifier (high temp.)	1700	1.7%	4
Lime	2240	2.6%	5
Calcium chloride brine	1180	26.2%	15

Barite or fluid loss agent was added to the reference drilling fluid. Five different fluids have been studied in total, as indicated in Table 2. Barite was mixed for 25 min and FLA for 10 min with the OFITE blender.

TABLE 2: Composition of the drilling fluids

	Reference	Fluids with barite		Fluids with fluid loss agent	
Barite	0 vol. %	2.4 vol. %	11.7 vol. %	0 vol. %	0 vol. %
FLA	0 vol. %	0 vol. %	0 vol. %	0.4vol. %	0.9 vol. %

Filtration tests were performed with a OFITE HTHP static filtration cell, at room temperature. To prepare the experiments, we first place a filter paper (filtration size 11 or 20 µm) on a base oil-saturated porous disk (porosity 90 µm) at the bottom of the cell. Then, 50 mL of mud are poured in the cell and the pressure at the top of the cell is increased to 35 bar (500 psi). The test starts when the bottom valve of the cell is opened, i.e., the differential pressure is 35 bar. The tests is stopped after 30 min, when the mass of the liquid filtrate is measured.

RESULTS AND DISCUSSIONS

Fluid loss measurements

The barite particle size distribution in accordance with API specifications require maximum 3% larger than 75 micron and maximum 30% less than 6 micron. Based on these requirements, the average particle size, D_{50}, can be anywhere between 15 and 35 microns. In **Fig. 1** it is shown the effect of barite addition on fluid loss. In absence of barite fluid loss is prevented by the water in oil emulsion itself. Typical drop sizes are around 5 microns. As can be seen, the fluid loss is nearly doubled when the filter paper openings are doubled. However, when barite is added, this fluid loss is significantly reduced, and no difference between the tests with different filter paper openings can be observed. This is a result of adding lot of barite particles in the size range of the filter paper openings.

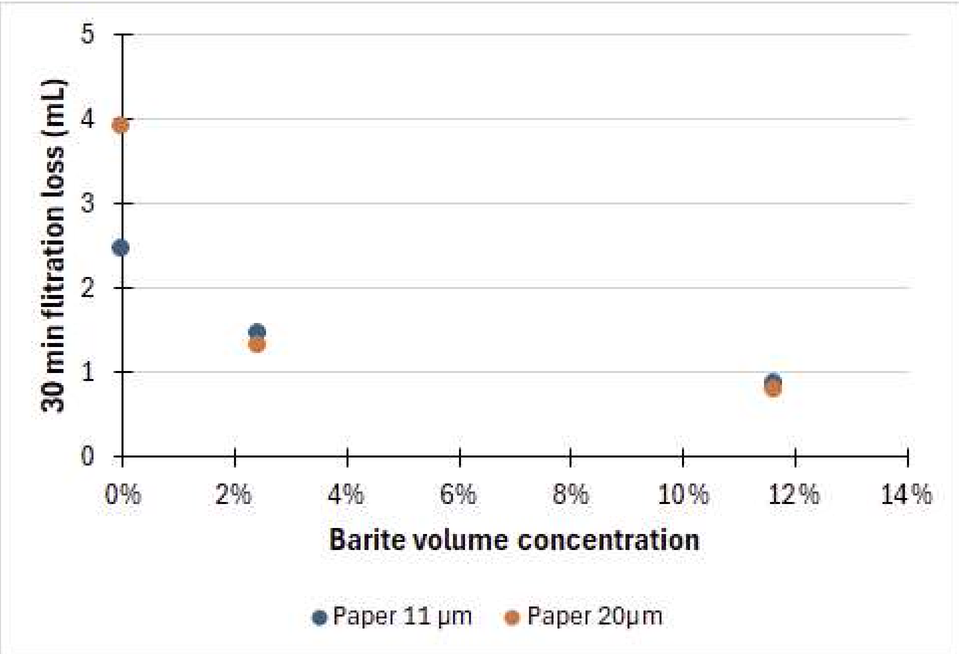

FIGURE 1: Fluid loss as function of barite concentration.

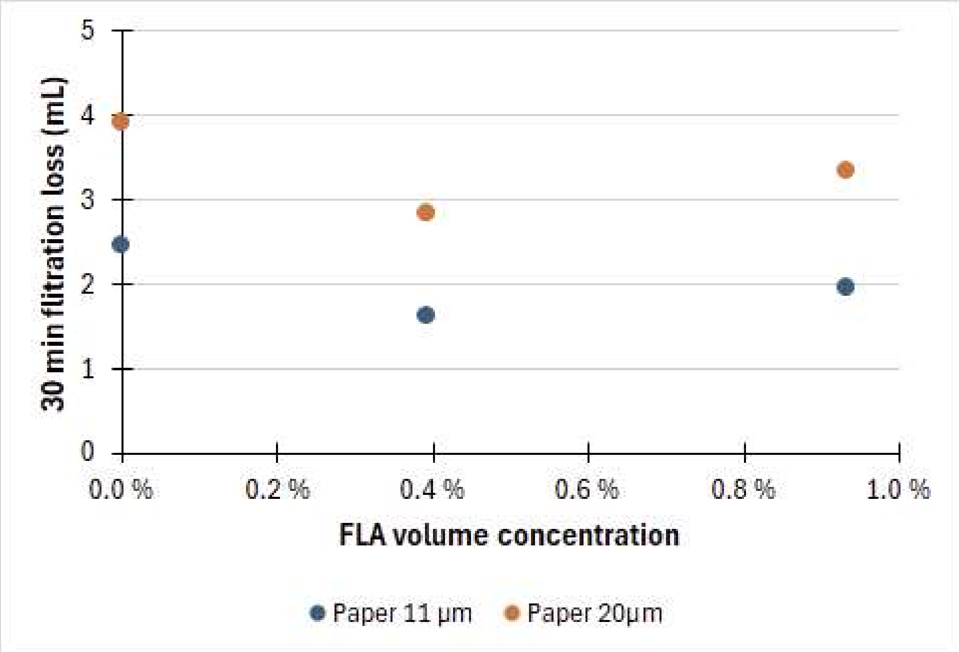

FIGURE 2: Fluid loss as function of Fluid Loss Additive (FLA) concentration. This FLA is a commercially available asphaltic resin.

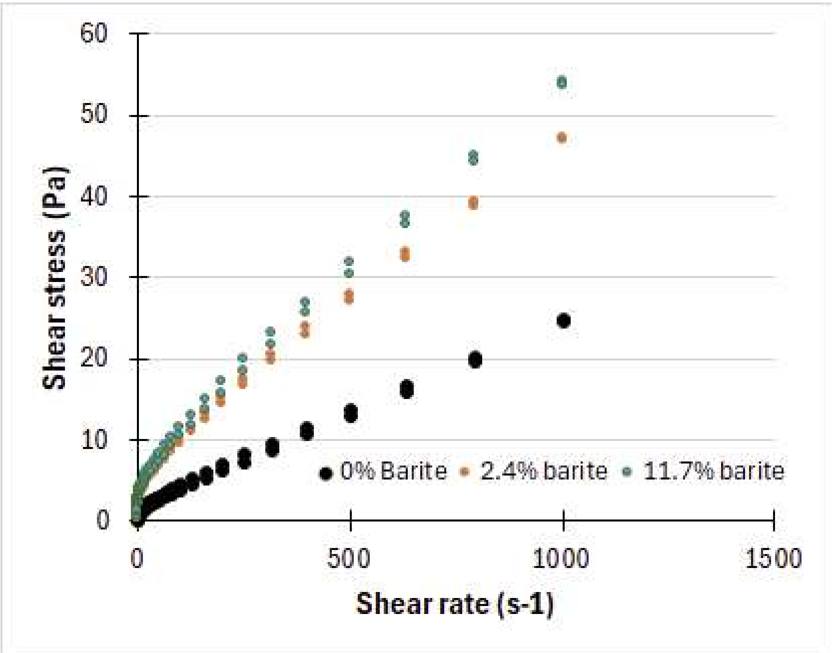

FIGURE 3: Plot of flow curves for fluid with 3 barite concentrations. No Fluid Loss Agent is present.

Viscosity of additions

The viscosity measurements are presented in **Figs. 3 and 4**. The Herschel-Bulkley parameters for these tests are shown in **Table 3**. The addition of barite increases the yield stress. Similarly, the surplus stress is increased, and the curvature exponent is slightly reduced. Addition of resin at these concentrations does not seem to give any significant changes in any of the properties.

The effect of barite on viscosity is significantly higher than the effect of FLA. However, the volume concentration of barite is higher by an order of magnitude than for FLA. The concentration of barite was required to reach a density for the fluid corresponding to a sg of 1.30.
It was expected that the both the fluid loss and the viscosity of the fluid with 0.4% resin were lower than that of the fluid with 0.9% resin. However, inaccuracies are expected for the the fluid with 0.4% resin. This fluid was difficult to mix into a homogeneous fluid. After conducting all the tests there was not sufficient fluid to repeat that test, leaving this measurement point as the recorded one.

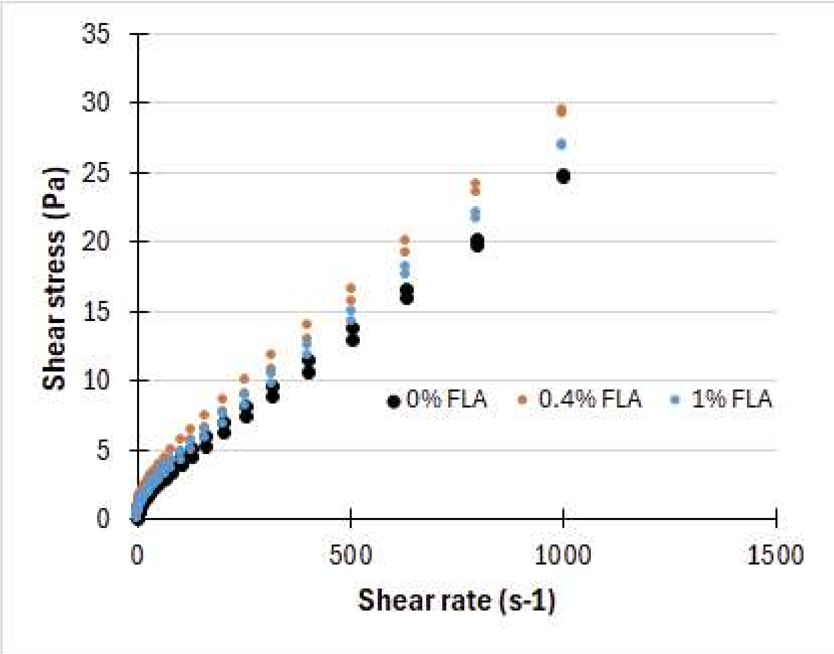

FIGURE 4: Plot of flow curves for 3 concentrations of Fluid Loss Agent. No barite was added.

TABLE 3: Herschel-Bulkley parameters for the tested fluid compositions.

Barite %	Ty	Ts	n
0	0.27	3.67	0.822
2.4	0.67	8.95	0.712
11.7	1.04	9.35	0.751

Resin %	Ty	Ts	n
0	0.27	3.67	0.822
0.4	0.37	4.52	0.805
0.9	0.36	3.93	0.829

CONCLUSIONS

A study of an oil-based drilling fluid with and without barite and fluid loss material is conducted. Filter cake has been evaluated using filter press with filter paper of 11 and 20 microns. Some observations include:

- Barite has a significant effect to prevent fluid loss in the applied laboratory setup. This is valid both for filter paper with 11 and 20 microns.
- The Fluid Loss Agent has some effect in reducing fluid loss.
- It is verified that the oil-based drilling fluid without fluid loss agents nor barite will still create an efficient filter cake.

REFERENCES

1. Mohamed, A.; Salehi, S.; Ahmed, R. Significance and complications of drilling fluid rheology in geothermal drilling: A review, *Geothermics*, **2021**, *93*, 102066, https://doi.org/10.1016/j.geothermics.2021.102066.
2. Saasen, A.; Ytrehus, J.D., Rheological properties of drilling fluids: Use of dimensionless shear rates in Herschel-Bulkley and Power-law models, *Applied Rheology*, **2018**, *28*, https://doi.org/10.3933/APPLRHEOL-28-54515
3. Sun, Y.; Huang, H. Effect of Rheology on Drilling Mud Loss in a Natural Fracture, 49th US Rock Mechanics / Geomechanics Symposium 28 June- 1 July, 2015. Paper ARMA-2015-345, San Francisco, CA, USA
4. Nelson, A.Z., Ewoldt, R.H., Design of yield stress fluids: A rheology-to-structure inverse problem, *Soft Matter*, **2017**, *13*, 7578 – 7594
5. Ofei, T.N., Cheng, I., Lund, B., Saasen, A. and Sangesland, S., "On the Stability of Oil-Based Drilling Fluid: Effect of Oil Water Ratio", Paper OMAE2020-19071**,** the ASME 2020 39th International Conference on Ocean, Offshore and Arctic Engineering, 3-7 August, 2020, Online