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The Application of Borax as a Fresh Water-Based Drilling Fluid Additive at Different Temperature and Clay Contamination Conditions

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INFORMATION

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ABSTRACT

To be able to provide stability for fresh water-based drilling fluids systems is still a considerable controversy in high-temperature and high clay-bearing environments. It is a well-known fact that fresh water-based drilling fluids are losing their stability in high-temperature environments. The viscosity and the water loss of these muds are increasing. It is even getting worse coupling with shale contamination. In order to get over these problems, different types of polymers are used as additives, which in the end might cause additional drilling-related issues and also an additional cost to overall drilling operations. The usage of borax as an additive is not that common in the drilling industry. Its effect on rheological and water loss properties is not very well-defined, especially at high temperatures and in a contaminated environment. The main goal of this study is to test borax as a fresh water-based drilling fluid additive under elevated temperature and contamination conditions. The variation of rheological properties is investigated with a conventional viscometer. The water loss properties are examined using a high-temperature, high-pressure (HTHP) water loss testing apparatus. Numerous tests were performed at temperature conditions ranging from room temperature to 200 0F (93 °C) and a filtration pressure of 100 psi (0.7 MPa). The experiments were also repeated using OCMA (Oil Company Materials Association) clay to mimic shale contamination. The experiments have resulted in acceptable rheological properties and filtration rates for the fresh water-based mud at high temperatures. The experimental results promise that properly formulated fresh water-based drilling fluids with borax might be a potential choice in wells expecting high temperature and shale contamination besides their low-cost advantages.

1. Introduction

Drilling is the process of making a circular hole in the earth with the help of a drill bit. Cuttings need to be brought to the surface. The process of transporting the cuttings to the surface is provided by a fluid called the drilling fluid (drilling mud), which consists of various chemicals. This process constitutes a major part of the drilling cost. In addition, drilling fluid has some crucial functions, such as applying hydrostatic pressure against formations to prevent formation fluids from flowing into the well, cooling, and lubricating the drill bit (Bourgoyne et al., 1991).

The drilling fluid can vary according to the type, temperature, strength, permeability, and porosity of the formation to be drilled. The drilling fluid can be determined by trial and error to minimize the drilling cost. Drilling fluid types are divided into three main groups water-based, petroleum-based, and organic-based.

The most commonly used drilling fluids are water-based. Water-based drilling fluids are less costly and require fewer contamination procedures than petroleum-based ones. The uses of petroleum-based drilling fluid are limited. It can be used in extremely hot formations where water-based drilling fluids are adversely affected. In impermeable formations, gases can be used as drilling fluid (Bourgoyne et al., 1991).

While performing the functions of drilling fluids in the wellbore, it is essential to maintain its stability against the temperature and pressure conditions at the bottom of the well and to prevent the effect of contamination originating from the formation solids and fluids. For this purpose, various chemical additives are used in drilling fluids in different sizes and compositions for weighting agents, dilution, fluid loss control, corrosion inhibitors, and pH control agents. In this study, borax (a type of boron) is used as an additive to provide stability for high temperature and high clay content-bearing environments.

Boron is an element in group IIIA of the periodic table with atomic number 5. The use of boron, known as the hardest element after diamond, is increasing day by day in industries such as glass, ceramics, agriculture, and cleaning (Werheit et al., 2010). The element boron forms strong bonds with oxygen, forming boron oxides and borates. Borates also have current uses in the oil and gas exploration and production industry. These uses are shown in Table 1 (Greenhill-Hooper, 2012).

In the petroleum and natural gas exploration and production industry, borates are used for many purposes such as polymer breaker in hydraulic fracturing, fluid gelation in mud leaks, additive in well completion operations, and cement setting time retarder in cementing operations (Greenhill-Hooper, 2012). There are studies in which borates are used as a crosslinker in hydraulic cracking operations (Harris and Services, 1993; Harris and van Batenburg, 1999; Ainley et al., 1993). Borates are also used as set retarders in cementing processes in the oil and natural gas industry (Bensted et al., 1991). It contains fluid loss additives to prevent fluid loss of cement in cementing operations. The use of borates as cement fluid loss additives has also been suggested (Szymanski et al., 2008; Ozdemir et al., 2022).

Table 1. Chemical applications of borates in major existing oilfields (Greenhill-Hooper, 2012)

Activity	Function	Borate Property
Hydraulic fracturing	Fluid gelation Polymer breaker	Borate ester formation Oxidizing function of perborate
Lost circulation prevention	Fluid gelation	Borate ester formation
Completion and workover	"Nondamaging" fluid additive	Sparingly soluble borates
Oil well cementing	Cement set retardant	Sparingly soluble borates
Reservoir logging	Chemical tracer	High neutron capture cross-section

Toka (2008) used sodium borate instead of sodium carbonate (Na_2CO_3), which is widely used in the activation of bentonites, considering that sodium borate, known as borax, can prevent the decomposition of doped bentonites. The effects of sodium borate on rheological and filtration properties were investigated by using two different types of bentonite, Edirne bentonite (E-Ben) and Çankırı bentonite (C-Ben). In this study, the effect of borates on the rheological properties of drilling muds under high temperature and pressure was not investigated. At the same time, the effects of borates on the rheological properties of drilling muds in the presence of polymers were not mentioned.

Krishnan et al. (2016) tested the fluid loss and stability at 302 °F temperature and 500 psi pressure values using boron nanoparticles in water-based fluids. With this study, they showed that premature degradation of polymers in water-based fluids can be prevented under HPHT conditions. However, the use of nanoparticles in the drilling fluid may cause rheological stability problems.

Korzilius and Minks (2001) studied the effect of drilling fluid on the corrosion of metallic materials by adding boron compounds to drilling fluids containing alkali metal carboxylate. As a result of this study, it was found that drilling fluid containing alkali metal carboxylate mixed with boron compounds significantly reduces the corrosive effects of metallic materials.

Ozkan and Kaplan (2019) investigated the effects of boron minerals added to water-based drilling fluid at various concentrations on the rheological and filtration properties of the drilling fluid. In this study, it has been observed that boron added drilling fluid positively affects the rheological and filtration properties.

This study focuses on experimental work. The primary purpose is to investigate the usage of borax as a fresh water-based drilling fluid additive for different temperature conditions. The rheological and water loss measurements of a drilling mud having a proposed composition are introduced. Such properties are also tested for clay-contaminated conditions by adding OCMA clay to the mud samples.

2. Methods and Materials

In this experimental work, a fresh water-based mud system is proposed. In the mud, bentonite clay is used as the colloidal component. Also, to obtain a certain density, API barite was added to the fresh water-based mud. For the contaminated mud samples, OCMA clay was also added. The ingredients of the muds are tabulated in Table 2.

API RP-13B (American Petroleum Institute Recommended Practice 13 B) Standard procedures are employed throughout the laboratory study to observe the rheological and fluid loss properties.

The Five-Spindle Multi-Mixer® Model 9B mixer is used to mix the ingredients of the drilling fluids samples in the preparation stages for laboratory tests. Drilling fluid aging is a required procedure in which a drilling fluid sample is allowed to completely develop its rheological and filtration properties. The prepared mud samples were poured into the aging cells and were put in a rolling oven. The period needed to fully develop properties is usually 16 hours. During these 16 hours of aging periods, samples were subjected to the test temperature.

The tests and aging period were repeated for four different temperature conditions [room temperature ~68 °F (~20 °C), 100 °F (~38 °C), 150 °F (~66 °C), and 200 °F (93 °C)].

Table 2. Ingredients of the mud samples

Ingredient	Amount
Fresh water	350 ml
Bentonite	25 g
Barite	10 g
Borax	10 g
OCMA	30 g

After 16 hours of aging periods, the samples were taken out of the aging cells, and tested firstly for rheological properties, then tested for water loss properties. To observe the rheological properties, Fann Model 35 viscometer was used. Different reading values were obtained for different shear rates (revolutions per minute). Besides, the gel strength properties were obtained using the same apparatus for three different periods (10 sec., 1 min., and 10 min.) to observe the gel strength development of the samples with time.

Once the rheological measurements were completed, the samples were tested for their water loss properties. An HTHP (high-temperature, high-pressure) apparatus was used to obtain water loss data. The tests were carried out for different temperature conditions. During these filtration processes, the HTHP cells were pressurized at 100 psi (0.7 MPA). For all the samples, the HTHP tests lasted 30 minutes. The obtained values are converted to API equivalent water loss values. All tests were repeated at least three times. The following experimental results section covers the averaged values of the repeated experiments for both rheological and water loss properties.

3. Experimental Results and Discussions

Rheological measurements are performed using a conventional viscometer. Reading values are obtained for 600, 300, 200, 100, 6, and 3 rpm. The well-known optimum dial reading value of 30 at 600 rpm is used to compare the mud samples at different temperatures. Firstly, the mud samples with borax are analyzed. Then the contaminated mud samples are compared with each other.

In Fig. 1, 600 rpm reading values of the samples at different temperatures are given in the blue columns. As seen from the figure, the rheological measurements are constant up to 150 ^{0}F and increased slightly at 200 ^{0}F measurements. All reading values are below the value of 30. It is a fact that the rheological properties deteriorate with temperature and mostly temperature causes firstly a decrease, then after a certain temperature, an increase in these readings. Such a situation is undesired as it affects the stability of the mud. It indicates that the existence of borax in the solution provides to keep stability in terms of rheology at elevated temperatures.

Furthermore, 600 rpm reading values of the samples contaminated with OCMA clay at different temperatures are given in the orange columns in Fig. 1. The reading values increase with the contamination as expected whereas they decrease with increasing temperature. All the reading values are also below the value of 30. The effect of the contamination on rheology was eliminated.

Moreover, it is getting even better for the samples tested at higher temperatures. It is evidence showing that the borax provides its duty of maintaining the stability of the mud samples with temperature and even coupled with contamination. Such a trend can be considered a characteristic behavior for inhibitive drilling fluids.

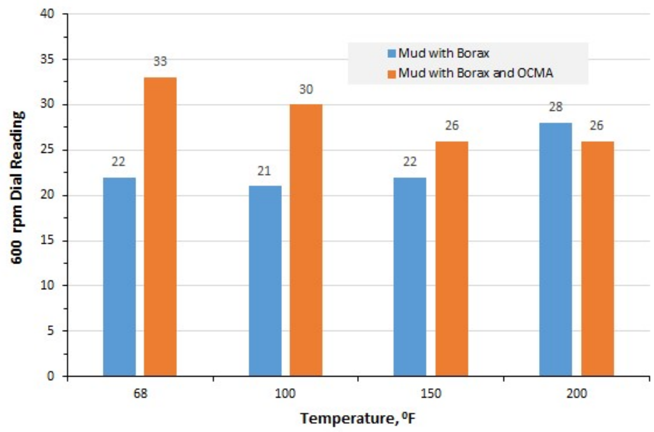

Fig. 1. 600 rpm reading values of the mud samples with borax (blue) and OCMA contaminated samples (orange)

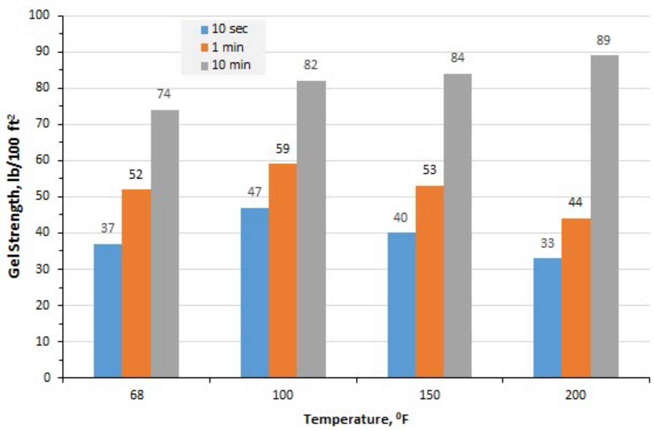

Fig. 2. Gel strength values of the mud samples with borax

The gel strength development of the mud samples was also investigated. Fig. 2 depicts the mud samples' gel strength values for 10 seconds, 1 minute and 10 minutes. On the x-axis, these values are given for different temperatures. The gel strength values, which are high, are increasing with time as expected. However, the gel strength values are slightly affected by increasing temperatures.

The gel strength development of the mud samples contaminated with OCMA clay was examined as well. In

Fig. 3, the mud samples' gel strength values for 10 seconds, 1 minute and 10 minutes are illustrated. Similarly, on the x-axis, these values are given for different temperatures. The gel strength values are increasing with time as usual again. The values are higher compared to those of the uncontaminated samples. Nevertheless, it can be seen that the increases in gel strength development are more noticeable than those of the uncontaminated samples. In order to decrease the gel strength, another additive might be used if needed.

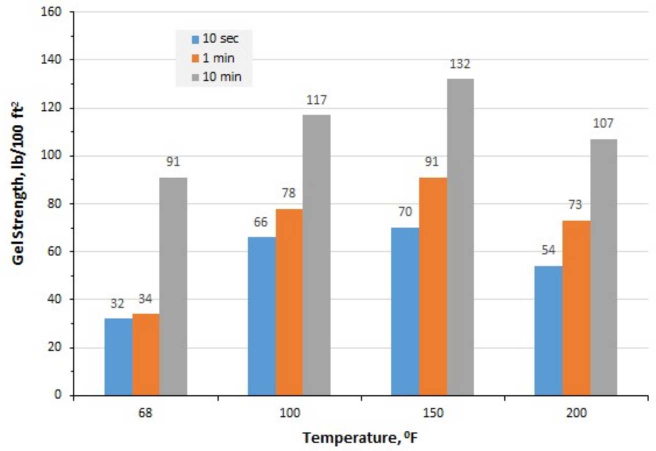

Fig. 3. Gel strength values of the OCMA contaminated mud samples

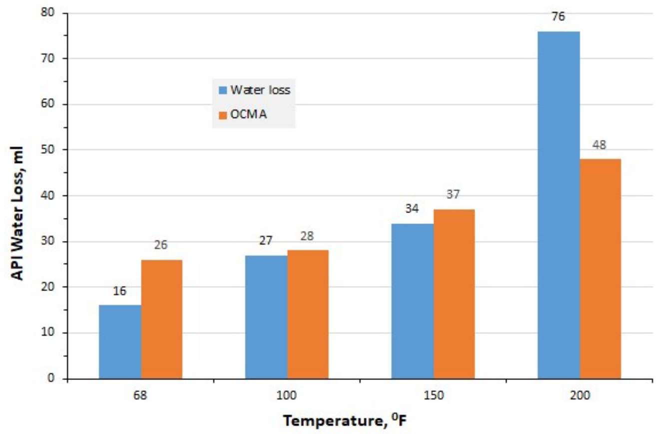

Fig. 4. API water loss data of the mud samples with borax (blue) and OCMA contaminated samples (orange)

The samples were also tested in terms of their water loss properties, as previously stated. An HTHP apparatus was used to measure water loss data. The tests were also conducted at different temperature conditions. During these filtration processes, the HTHP cells were pressurized at 100 psi (0.7 MPA) similar to the previous cases. For all the samples, the HTHP tests lasted 30 minutes. The obtained values are converted to API equivalent water loss values by multiplying them by 2 as indicated in API RP-13. API recommends 15 ml of water loss for laboratory applications. However, in-field applications, the water loss can be tolerable up to 40-50 ml.

In Fig. 4, water loss data of the samples at different temperatures are given in the blue columns. On the x-axis, these values are given for different temperatures. As seen from the figure, the water loss values are increasing with temperature. This is an expected behavior for water-based drilling fluids. Up to 100 ^{0}F conditions, the values are almost in an acceptable range. Over 100 ^{0}F, the water loss values are increasing.

Similar behavior can be observed for the samples with OCMA contamination given in Fig. 4 as orange columns. However, the increase is less compared with the ones of uncontaminated samples. Such a situation is once more a characteristic behavior for inhibitive drilling fluids. Although the water loss data are over 15 ml values, it is considered suitable for field applications. If needed, water loss control additives might be used to decrease the water loss values.

4. Conclusions

In this experimental study, borax has been used as an additive in a formulated drilling mud. The samples are tested to investigate their rheological and water loss behaviors. The existence of borax in the mud solutions has provided to control the rheological values for high-temperature environments, even coupled with clay contamination. It can be said that gel strength values are high; however, again the presence of borax delivered less increase in gel strength. Besides, even though the water loss data are a little bit high, it can be considered appropriate for field applications. The obtained results show that the proposed mud with borax additive has properties similar to inhibitive drilling fluids. A fresh water-based drilling fluid with borax as an additive may be a promising alternate drilling fluid for high-temperature and shale-contaminated environments since it seems to be a cost-effective material compared to currently used inhibitive drilling fluid systems.

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