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Synergetic Study of Activated Charcoal in Water-Based Drilling Fluid Design for Oil Wells

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Abstract

The importance of oil and gas production in the global economy cannot be over-emphasized thus one of the means to harness this global economy is by drilling and completions operations. However, to achieve successful drilling and completion oil well, a mixture of either polar or non-polar substances with oilfield chemicals referred to as additives will be added for optimum performance. Thus, additives are chosen based on the reservoir conditions. This paper aimed to evaluate the synergetic effect obtained when water-based drilling fluid were formulated using a mutual combination of calcium carbonate and solltex; calcium carbonate and activated charcoal and activated charcoal and soltex. Rheological properties were investigated at temperatures of (80°F – 150 °F) with the aid of Ofite Viscometer and were conducted under API specifications. The results obtained shows that a decrease in rheological properties with an increase in temperature was observed despite the number of different viscosifiers used in the formulation. The fluid loss was achieved with the aid of API Filter Press and was conducted under API specification. The better fluid loss was achieved with activated charcoal and soltex with 5.2 ml/s; followed by calcium carbonate and activated charcoal with fluid loss of 5.4 ml/s and lastly, Calcium carbonate and solltex had a fluid loss of 5.8 ml/s. Furthermore, the study was conducted to identify the chemical compound composition with the aid of X-ray diffraction and these results have shown the reason why a mutual combination of drilling fluid additives has similar fluid loss and rheological trends. Also, elemental compounds and oxide were established in calcium carbonate, activated charcoal, and soltex using X-ray fluorescence (XRF).
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Keywords: Drilling fluid, synergetic, activated charcoal, X-ray Fluorescence, X-ray Diffraction, Fluid Loss.

1. Introduction

Oil and gas are obtained from natural reservoirs deep underground through the process of drilling operations. However, to facilitate the extraction of hydrocarbons from the ground, a deep hole is drilled to form a wellbore[1]. This operation will be impossible without the aid of the drilling fluid which is a mixture of clay, water, and oilfield chemicals are also known as additives. Drilling fluids perform some functions under the American Petroleum Institute (API) specifications. Some of the functions are the removal of cuttings from the wellbore; suspending cuttings and weighting material; control of surface pressures; isolating the fluids from the formation; cooling and lubricating the bits and drill string and providing buoyancy to the weight of the drill and casing string etc. [2, 3]. There are viable chemical additives used in the drilling fluid that have shown the desired features. However, these additives are non-biodegradable and environmentally hazardous[4]. As a result, researchers have sought to identify alternate additives that are environmentally friendly, biodegradable, and sustainable, while also maintaining the properties of efficient drilling fluids[5]. Today's interest in protecting nature is encouraging researchers and the oil and gas industry to move towards more environmentally friendly practices. The environmental regulations introduced by the government motivated the industry to be more efficient in drilling operations in terms of waste management and disposal. To reduce the negative impact on the environment, environmentally friendly drilling fluid additives are used in drilling operations. This results in the formulation of drilling fluids with different properties depending upon the formations to be drilled at different depths and different pressure-temperature (PT) conditions. Such a difference in properties is accomplished by adding different conventional chemical additives[6]. Since drilling fluid encompasses large particles in significant quantities, they do not conform to Newton's law and are non-Newtonian, pseudoplastic. They can range from simple water-based to oil-based to more complex systems like compressed air and synthetic polymers. It thus becomes a careful task of choosing and maintaining the best drilling composition. Many of the commercial chemical additives used in conventional water-based mud (WBM) systems for economic performance are toxic and nonbiodegradable, and if given little or no attention, pose environmental, health, and safety problems. Common commercial chemical additives such as potassium chloride, potassium sulfate, sodium hydroxide, polyamine, chromium compromising thinners, and fluid loss additives, etc., pollute the environment and are too expensive[7]. Compromising the potential of a drilling fluid leads to a disastrous outcome, and the oil company operating incurs a huge cost to repair the damage. Some of the petroleum industry faces challenges while drilling processes. Thus, one of the challenges is how to control filtration loss in drilling operations. The way to reduce filtration loss during the drilling process in water-based mud can be to add additive material into drier mud to produce appropriate mud cake and can control fluid loss[8]. Some materials used as additives to control filtration loss are bentonite, calcium carbonate, boehmite, nanometal oxide, nano zinc oxide, nano silica, and carbon nanostructure[9]. This paperaim to evaluate the rheological properties of synergetic combinations of water-based mud designed with calcium carbonate and soltex, calcium carbonate and activated charcoal, and activated charcoal and soltex; under temperatures of 80^{o}F – 150 ^{o}F; to determine the fluid loss of water-based mud formulated with calcium carbonate and soltex, calcium carbonate and activated charcoal, and activated charcoal and soltex and to characterize chemical compound composition in activated charcoal; soltex and calcium carbonate, and to determine the elemental composition of activated charcoal; soltex and calcium carbonate.

2. Materials and Method

Activated charcoal was obtained from wood chips; ground, and sieved in a mesh sieve of three different sizes such as fine, medium, and coarse. The activated charcoal was dried at a temperature of 105^{0}F in a far-infrared drying oven and kept in a desiccator to prevent moisture content in the equipment. Water-based drilling fluids were formulated with the ratio of 1:1:1 of the fine, medium, and coarse activated charcoal and calcium carbonate respectively. The experiments were therefore designed to capture these conditions as are often encountered in the wellbore. To achieve the aim of this study, the experiment were performed according to API standard of specifications. Furthermore, experimental analyses were conducted to establish the chemical compound composition and elemental composition of activated charcoal, calcium carbonate, and soltex. Bentonite, Caustic soda, Soda Ash, starch, Polyacrylamide

(Pac L and R), Xanthan Gun (XCD), Potassium Chloride (KCl), and water were used for the formulation and there were added accordingly.

2.1 Formulation of Water-Based Drilling Fluid

Three different sets of water-based drilling fluids were formulated. 95.47g of bentonite was mixed into 216.89ml of water and was mixed in the Hamilton beach mixer and 30mins and thereafter was pre-hydrated for 16hrs to obtain excellent yielding performance. After 16hrs other additives were added by the API specifications. Calcium carbonate was taken from fine, medium, and coarse each and mix vigorously to obtain 15g. 3g of soltex were substituted for activated charcoal. Each of the additives was introduced into the stirring mixture for 5mins. At the end of the last additive, a total of an hour was obtained for a homogenous mixture. The mud density is measured using mud balance, the pH of the mud is measured with the pH indicator, and the viscosity of the mud is also measured with the aid of a viscometer and fluid loss was obtained using the API filter loss cell. The dial reading thereafter of the formulated mud were recorded at 600, 300, 200, 100, 6, and 3rpm with the help of a rheometer. Rheological properties of the various water-based drilling fluids at temperatures between 80^{0}F to 150^{o}F were obtained

2.2 Rheological Test

The rheological measurements were conducted based on API standards. After drilling fluid was prepared, it was transferred into the viscometer cup and subjected to shear in Fann direct-indicating viscometer. The torque response for each rotational speed provided by equipment at (600, 300, 200, 100, 6, and 3 rpm) was recorded. At each rotation speed, the dial reading was taken when the speed of rotation was stabilized.

Rheological values were obtained from the viscometer and various calculations obtained from test results are shown **equation 1** and **equation 2** respectively. Hence, the reference for measuring viscosity and performing calculations according to American Petroleum Institute specifications.

2.3 Calculation of plastic viscosity (PV) and yield point (YP):

Plastic viscosity (PV) and yield point (YP) of cement slurries were calculated using equation (1) and equation (2).

$$PV\ (cP) = (\ \theta_{600} - \theta_{300}) \quad (1)$$

$$YP\ \left(\frac{lb}{100ft^2}\right) = \theta_{300} - PV \quad (2)$$

Where θ = dial reading

Gel strength at 10 seconds and gel strength at 10 minutes were obtained from the viscometer immediately after desired time, at first deflection.

2.4 API Fluid Loss Test

Fluid loss tests were conducted using static filter press assembly at ambient (room) temperature and 100-psi differential pressure. After the drilling fluid was prepared, it was transferred into a filter press consisting of a cylindrical drilling fluid cell having an inside diameter of 3 inches (76.2mm) and a height of 2.5 inches (64 mm). This chamber is made of materials resistant to strongly alkaline solutions and is so fitted that a pressure medium can be conveniently admitted into, and bled from the top. The arrangement is also such that a sheet of 90 mm (3.54 in.), the filter paper was placed at the bottom of the chamber just above a suitable support. The filtration area is (7.1 ± 0.1) in^2 (45.8 ± 0.6) cm^2. Below the support is a drain tube for discharging the filtrate into a graduated cylinder. Sealing is accomplished with gaskets. The entire assembly is supported by a stand. The pressure was applied with any non-hazardous fluids medium, either gas or liquid.

3. Results Analysis

Comparative analyses of activated charcoal and calcium carbonate; activated charcoal and soltex were carried out to ascertain their reduction in filtration loss; and their effect on rheological properties to temperature in water-based drilling fluids.

Figure 1 to **Figure 3** shows the results of the rheological properties of water-based drilling fluids formulated with activated charcoal, calcium carbonate and soltex. From the Figures (**Figure 1** to **Figure 3**), it is observed that the viscosity of activated charcoal, calcium carbonate and soltex were affected by rotational speed to temperature. As temperature increases, there is a corresponding decrease in the viscosity of samples as temperature increases. This decrease in viscosity is in agreement with the concept of dilatant (thixotropic) fluid condition in which viscosity increases with an increase in shear rate, thus obeying the non-Newtonian behaviour of fluid flow.

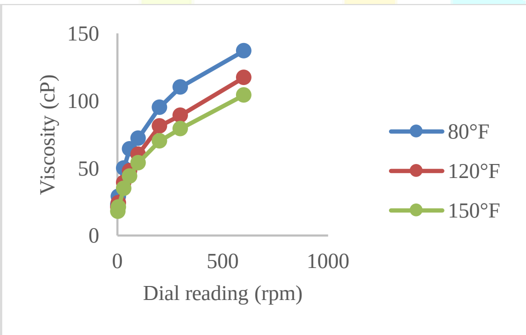

Fig. 1. Viscosity as a function of dial reading of calcium carbonate and soltex of water based drilling fluid at different temperatures

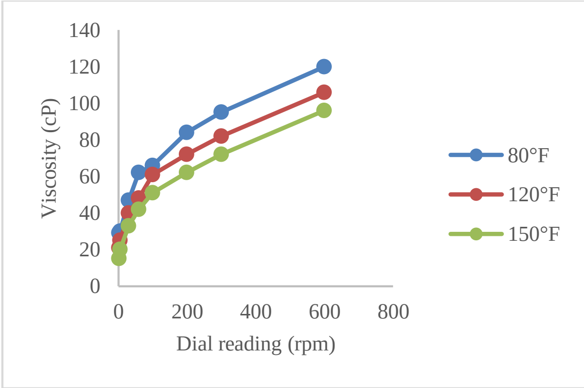

Fig. 2. Viscosity as a function of dial reading of calcium carbonate and activated charcoal of water-based drilling fluid at different temperatures

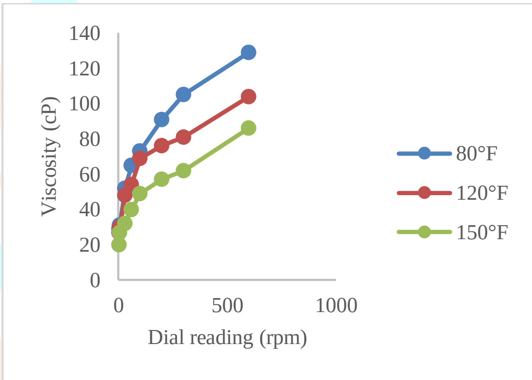

Fig. 3. Viscosity as a function of dial reading of activated charcoal and soltex water-based drilling fluid at different temperatures

Similarly, **Figure 4** to **Figure 6** shows the effect of plastic viscosity of the water-based drilling fluid with activated charcoal, calcium carbonate and soltex. As can be seen, there is a decrease in plastic viscosity with a corresponding increase in temperature of the water-based drilling fluid formulated with mutual combinations of calcium carbonate and soltex, calcium carbonate and activated charcoal. From the Figures, (**Figure 4** to **Figure 6**), it is noted that at different temperatures of 80ºF, 120ºF and 150ºF, there were a corresponding plastic viscosities of water-based drilling fluid with calcium carbonate and soltex values of 27cP, 28cP, and 25cP; 25cP, 24cP, and 24cP; 24cP, 23cP, and 21cP respectively. These results have shown that most of the fluid loss additive have an effect on the rheological properties of water-based drilling fluids at higher temperatures despite the number of viscosifiers present in the design of the drilling fluids.

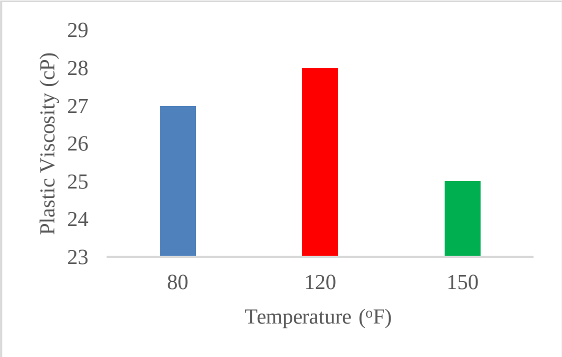

Fig. 4. Plastic Viscosity as a function of Temperature of calcium carbonate and soltex of water-based drilling fluid

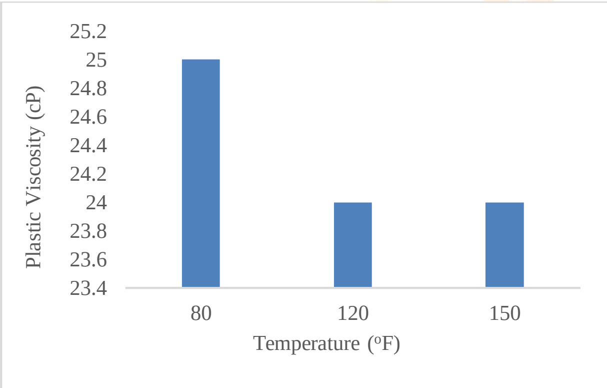

Fig. 5. Plastic Viscosity as a function of Temperature of calcium carbonate and activated charcoal of water-based drilling fluid

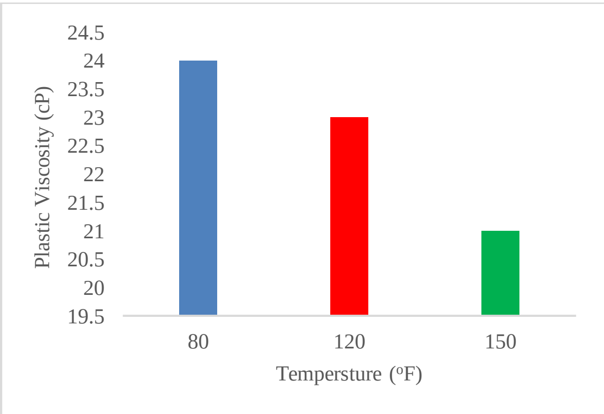

Fig. 6. Plastic Viscosity as a function of Temperature of soltex and activated charcoal of water-based drilling fluid.

Figure 7 shows the effect of fluid loss of water-based mud formulated with activated charcoal, calcium carbonate and soltex at temperature of 80ºC. Fluid loss control in drilling mud is essential for drilling operations, especially to prevent fluid migration fluid segregation in an unconsolidated or fracture formation. From **Figure 7**, it is observed that at 80ºC, there was a fluid loss of 5.8ml/s, 5.4ml/s and 5.2ml/s for mutual combinations of calcium carbonate and soltex, calcium carbonate and activated charcoal and activated charcoal and soltex respectively. Comparatively, activated charcoal and soltex had an appreciable decrease in fluid loss to calcium carbonate and soltex, and calcium carbonate and activated charcoal. This results confirmed that to achieve better fluid loss reduction, mutual combinations of activated charcoal and soltex will be preferable in water-based drilling fluid design.

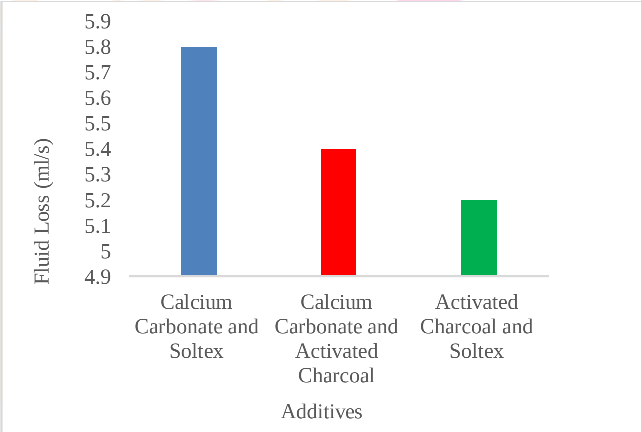

Fig. 7. Fluid Loss as a function of additives of water-based drilling fluid at ambient Temperature

4. Conclusion

Based on the experimental work done and results obtained, it is well noted that mutual combination of activated charcoal and soltex yield a better reduction in fluid loss.There was an incremental decrease in rheological properties with an increase in temperature despite the amount of Viscosifiers used in the water-based drilling fluids formulated in the presence of fluid loss additives.The chemical compound compositions and the elemental compound obtained in activated charcoal attributed to its optimal performance as a fluid loss reducer in the water-based drilling fluid.

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Conflict of Interest Disclosure

The authors declare that they have no conflict of interests.

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