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Evaluation of Kaolin Clay Polymeric Nanoparticles for Improved Water-Based Mud Properties

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Abstract: The work aimed to comprehensively analyze the evaluation of kaolin clay polymeric nanoparticles for the improvement of water-based mud properties. Conventional water-based muds have limitations, including poor rheological properties, low lubricity, and high filtration loss. Recently, nanotechnology has been applied to improve the properties of water-based muds. Kaolin clay nanoparticles have shown great potential as an additive to enhance the performance of water-based muds. This research aimed to analyze how kaolin clay nanoparticles affect drilling fluid rheology and fluid loss control in water-based muds. Five mud samples were formulated, the first mud which was the base mud had no kaolin (LCM), 10g of kaolin was added to the second sample, 20g of kaolin was added to the third sample, 30g of kaolin was added to the fourth sample and the fifth sample contained 40g of kaolin, results showed that increase in the particle size and concentration of LCMs increased the plastic viscosity, apparent viscosity, yield point as well as gel strength, also the ability of the LCMs to seal off fractures in time and reduce fluid loss was affected by particle size of the LCMs. This research showed that the mud sample with the highest concentration of kaolin had a good effect on the rheological properties of the mud had adequate mud cake thickness and was suitable to be used as LCMs.

Keywords: Kaolin Clay, Water-Based Muds, Polymeric Nanoparticles, Rheological Properties, Filtration Loss, Particle Size Distribution, Silicon-Dioxide, Aluminum-Oxide

1. Introduction

Drilling fluids, commonly known as drilling mud, is a crucial component in drilling operations. Water-based muds (WBMs) are commonly used in the drilling industry to control formation pressure and temperature, to prevent formation damage, and to transport drilled cuttings to the surface. The performance of these muds is critical to the overall success of the drilling operation. However, conventional WBMs have limitations, including poor rheological properties, low lubricity, and high filtrate loss. These limitations can result in costly and time-consuming drilling problems, such as stuck pipes, lost circulation, and formation damage. The demand for additives has increased as a result of the current necessity to create more hydrocarbons. Drilling fluid was the most popular oilfield chemical in 2011, according to market research firm Freedonia, accounting for nearly 42% of the $18.2 billion overall cost of oilfield chemical spending [1]. The statistics are shown in Figure 1.

Recently, nanotechnology has been applied to improve the properties of WBMs. Kaolin clay nanoparticles (KCNPs) have shown great potential as an additive to enhance the performance of WBMs. KCNPs have a large surface area, high aspect ratio, and excellent adsorption properties, which can improve the rheological properties, lubricity, and filtration control of WBMs. In recent years, nanotechnology has emerged as the subject of interest in many fields, such as biofuel cells, medical diagnosis devices and wastewater treatment. In the oil and gas industry, nano- materials can enhance the performance of drilling fluids in several applications, such as enhanced oil recovery, cementing, well stimulation and drilling fluids. The main advantages of nanoparticles (N.P.) in drilling fluids application were their relatively small size and the large surface area leading to better physical and chemical properties than other traditional additives. Several studies showed that nanoparticles ameliorate the rheological characteristics of drilling fluid and minimize fluid loss. [2]

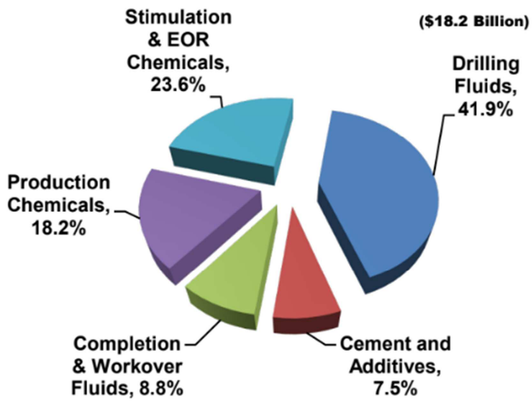

Figure 1. *World Oilfield Chemical Demand.*

Another analysis of improving water-based mud properties using Nanoparticles was done by AlMalki. He carried out an experimental study that showed that nanoparticles-water based drilling fluid could maintain fluid stability in plastic viscosity and yield point and reduce fluid loss at reservoir conditions of temperature and pressure. This is mostly due to the N.P. sizes, surface charges, and surface-to-volume ratio, which can promote colloidal system interaction and seal nanopore throats such as shale. The use of nanotechnology in oil and gas industry has been improved rapidly over last decades. Adding nanoparticles (NPs), because of their very ultrafine size (<100 nm) and high surface area to volume ratio, allow engineers to modify the drilling fluids rheology by changing the composition, type, or size distribution of nanoparticles that suit desired drilling conditions without using other expensive additives. [3]. The benefits include improvement of fluids rheological properties, reductions in filtration loss and friction coefficient, increase of the rate of heat transfer, shale stability improvement, and inhibition of gas hydrate formation.

Various processes, most of which are dependent on the continuous phase of drilling fluids and the features of the nanoparticles, can be used by nanoparticles to improve the rheological qualities of drilling fluids. As the continuous phase of drilling fluids [4-6] or as fluids displacing fluids in enhanced oil recovery processes [7] silica nanoparticles can typically increase the apparent viscosity of water. It is generally known that at the same volume concentration of dispersed particles, nanofluid viscosity is significantly higher than that of traditional dispersions. Since internal friction between two layers of a fluid is what is meant by the term "viscosity," once nanoparticles are dispersed in the fluid there is a chance that this friction will increase, increasing the viscosity of the "nanofluid" [8, 9]. Homogeneous solid- fluid interaction models can be used to estimate this increase in nanofluid viscosity. The Einstein model, which is predicated on the premise that the fluid comprises suspensions of spherical forms, served as the foundation for the development of the theoretical formulas now in use for the calculation of the viscosity of nanofluids. His model, however, only functioned at low concentrations of tiny nanoparticles because it was built on basic assumptions. Later, modified models by other investigators have been introduced [10-12] that could be used for larger nanoparticles at higher concentrations, pressure and temperature. Additionally, it has been discovered that the effective viscosity of nanofluids relies on both the size and concentration of the nanoparticles. These findings have been supported by experimental studies [13] as well as molecular dynamics simulations of the hard-sphere potential [14, 15]. It should be mentioned that many additives can be employed in the design of drilling fluids to enhance the rheological properties into a desirable and acceptable range needed for, among other things, hole cleaning, lubricating, and cooling downhole equipment. However, these qualities may not increase past certain thresholds since an improper increase in qualities could have detrimental consequences on fluid circulation in the wellbore, such as increased weight and excessive frictions that impose greater capacity pumps, and sand/cuttings removal issue. Therefore, the aim of using nanoparticles is to attain desirable properties with lower cost and improved efficiencies.

The impact of nanoparticles on filtration control during drilling operations has been the subject of numerous investigations. Commercial NPs did not cause any spurt loss in their sample, showing the presence of a fluid system that does not harm neighboring forms. An extremely thin, evenly distributed, and tight mud cake was created by the drilling fluid. [16, 17] conducted one of the earliest investigations on the impact of silica-based NPs on filtration control. With silica nanoparticles ranging in size from 40 to 130 nm and a concentration of 3 weight percent, they achieved filtrate volume reductions of up to 34%. Similar to this, Cai, utilized 10 weight percent of silica nanoparticles to reduce water incursion, which returned reductions of 58-99% in the shale permeability to water for bentonite muds, and 46- 88% for low solid content muds [18]. They also suggested that the optimal particle size could fall between 7 and 15 nm. Additionally, polymer NPs have been examined as WBF additives for fluid loss management. Kaolin (SIO2) NPs were used in studies by Sadeghalvaad, who found that both the filtrate volume and filter cake thickness decreased by 64% [19]. Jain studied a polyacrylamide/silica NPs drilling fluid and found that at a particle concentration of 1.1 wt%, API fluid loss was reduced by 14% [20]. Round latex particles were evaluated by Liu [21], with size distribution between 80- 345 nm with aluminium complexes, and concluded they had excellent plugging capabilities with a reduction in API filtrate volume by 44%. Riley assessed the usage of silica nanoparticles in a WBF to enhance shale material inhibition and contrasted it with a synthetic based mud that is frequently used for wellbore stability problems in shale formations [22]. Its capacity for sealing micro-pores and micro-fractures was demonstrated by the sample with 3.0 wt% of silica, which resulted in a permeability decrease that was 20.1% higher than the basic sample without silica. According to Akhtarmanesh, a minimum colloidal silica NPs concentration of 10 wt% is required to minimize permeability and fluid invasion. The 35 nm sized NPs also demonstrated higher plugging efficacy than the 50 nm sized NPs [23]. To improve shale inhibition, Taraghikhah, investigated silica NPs in WBFs at a concentration of 1.0 wt% and compared the outcomes to a WBF containing shale inhibitors. It demonstrates that even with the shale inhibitor present in the advanced polymer drilling fluid, swelling can still happen whereas the shale formation is successfully prevented from swelling by the nano-drilling fluid.

Kaolin appears as odorless white to yellowish or grayish powder. Contains mainly the clay mineral kaolinite ($Al_2O_3(Sio_2)_2(H_2O)_2$), a hydrous aluminosilicate. Kaolinite has mp 740-1785°C and density 2.65g/cm3. Kaoline is insoluble in water but darkens and develops an earthy odor when wet.

Kaolinite, dickite, nacrite, and halloysite are the many minerals that make up kaolin. The most prevalent kaolin mineral is kaolinite ($Al_2Si_2O_5(OH)_4$), which has the following chemical formula: 46.54% SiO_2, 39.50% Al_2O_3, and 13.96% H_2O. Tetrahedral and octahedral layers in kaolinite are continuous in the z- and x-axes, respectively, and are layered on top of one another in the y-direction. The structural arrangement of kaolinite has a significant impact on both its physical and chemical properties. Numerous stacking faults that may develop during the development and expansion of kaolinite have been linked to structural flaws in its crystal structure. Understanding the differences in the kaolinite structure is crucial for determining how plasticity, brightness, and viscosity are related. In order to examine the structural disorder or crystallinity of kaolinite based on XRD-derived crystallinity indices like Hinckley indices, the X-ray diffractometry (XRD) technique has been extensively used. An additional technique for assessing the degree of kaolinite disorder is Fourier transform infrared (FTIR) spectroscopy, which relies on variations in the location and relative strength of OH stretching and bending bands in the IR-spectrum. Vaculikova presented the empirical technique (IR-E) and the numerical approach (IR-N) as two methods for assessing the degree of structural disorder of kaolinites from IR spectra. While IR-N is based on crystallinity indices (CI) determined from the intensities of chosen vibration models and structural OH bands, IR-E is based on resolution and relative intensities of bands in the OH stretching and bending region. [24]

2. Materials and Methods

This section covers detailed description of the experimental procedures, as well as apparatus and materials used. During this research, the following outlined activities are carried;

1) Preparation of kaolin clay material - Process of collecting kaolin clay sample, process of cracking kaolin clay into nano sizes.
2) Sieve analysis of kaolin clay nanoparticles into mesh sizes of 250.
3) Formulation of mud and rheology measurement to characterize the drilling fluid.
4) Determination of filtrate volume and mud cake thickness.

The experiments were conducted in accordance with the standard stipulated in API RP13B-1; recommended Practice Standard Procedure for Field Testing Water-Based Drilling Fluids. Water- based drilling fluid was used as the base fluid throughout the study. The sieving Analysis, Rheology and filtration test was conducted at Department of Petroleum Engineering Laboratory, Federal University of Technology, Owerri, Nigeria.

2.1. Preparation and Experimental Procedure

2.1.1. Preparation of Kaolin Clay and Cracking of Kaolin Clay into Nanoparticles

Kaolin clay was cracked into nanoparticles (basically silica and aluminum nanoparticles, and dried under the sun to remove mixture from it).

2.1.2. Sieve Analysis

A sieve analysis is a practice or procedure used to assess the particle size distribution of mostly a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh sizes and weighing the amount of material that is stopped by each sieve as fraction of the whole mass.

Procedure:

1) Sieves with sieve aperture of 250 microns were used during the sieve analysis.
2) The sieves were washed, cleaned using clean brush to remove any particles that was stuck in them.
3) The sieves were arranged as in order of the smaller openings to the bottom and the sieves with larger openings to the top.
4) The weight of each sieve and receiving pan was recorded.

2.1.3. Preparation of Mud Sample

Drilling fluids from appropriately measured sample amounts were used for the test.

Based on the fact that 1gm/350cm^3 of the sample is equal to 11b/bbl (42gal) of the actual mud system, the calculation was made. Agal/bbl (42gal) of the actual mud system is comparable to 8.33cm^3/350, or 8.33 cm^3/350.

1lab barrel is equal to 350cm^3 (1gm = 1b, 1gallon = 8.33cm^3) in final volume.

In order to create 1bbl (350ml) of the water-based mud with a specified mass, the additives were added to the base fluid (water) at the proper concentrations. To create a homogeneous mixture, a Hamilton Beach mixer was employed. To compare with the base case, the LCMs (kaolin clay) were then introduced to additional mud samples.

***Table 1.** Additives used in drilling fluid formulation.*

S/N	ADDITIVES	MASS (grammes)	MIXING TIME (min)
1	Water	334.25	1
2	Caustic soda	0.5	2
3	Bentonite	15	15
4	Barite	30	10
5	Kaolin (LCM)		

***Table 2.** Weight of kaolin added to the Water Based drilling mud.*

Mud Sample	Mud Sample A	Mud Sample B	Mud Sample C	Mud Sample D	Mud Sample E
Weight of kaolin (g)	No kaolin	10	20	30	40

2.1.4. Determination of Mud Density

Mud density can be monitored with a mud balance that has an accuracy of +0.1 lb/gal in order to manage subsurface pressures and stabilize well bores. When calibrated with fresh water at 700 + 50, a mud balance should read 8.3 lb/gal. We swap out a rock cylinder for a mud cylinder when drilling the wellbore. Establishing the mud weight necessary to give the proper level of borehole pressure support is a crucial first step in creating a drilling fluid. The tool used to determine the density of drilling fluid is a mud balance. The mud balance is designed such that the drilling fluid holding cup at one end of the beam is balanced by a fixed counter weight at the other end with a sliding weight rider free to move along a graduated scale.

Procedure:

1) Fill the cup of the mud balance to the brim.
2) Cover with the cap to allow excess mud and air out of the cup.
3) Clean the mud balance of any excess mud while holding the cup tightly to the cup.
4) Balance the mud balance on the provide knife edge using the rider.
5) When balanced, record the reading on the scale as indicated by the arrow.

2.1.5. Determination of Water Based Mud (WBM) Rheology

The yield point, apparent viscosity, plastic viscosity, and gel strength were all measured using the fan viscometer. Rotational viscometer measurements of rheological characteristics are frequently used to determine drilling fluid hydraulics, lift and suspend capacities, and solid buildup flocculation or de-flocculation of solids. The plastic viscosity (PV) and yield point (YP) of drilling fluid are easily determined from the shear rate or shear stress measurements made with a rotational viscometer. the device now being used to gauge gel strengths. The physical dimensions and existence of any particles or emulsified droplets in the fluid contribute to the plastic viscosity. The PV should be as low as feasible, and in order to lower the PV, we must also lower the solids. In order to raise the yield point, attraforce-containing items must be added. The yield point is the viscosity caused by the chemical attraction between the particles. The increase in viscosity at zero shear rates is referred to as the gel strengths. It serves as a gauge for attractive forces in static situations. The equations to calculate the rheological properties, plastic viscosity, apparent viscosity, yield point was stated in equations (1), (2) and (3) respectively, the gel strength was read directly from the viscometer.

$$\text{Plastic viscosity (YP)} = \Theta 600 - \Theta 300 \quad (1)$$

$$\text{Apparent Viscosity (AV)} = \Theta\ 600/2 \quad (2)$$

$$\text{Yield point (YP)} = \Theta 300 - PV. \quad (3)$$

Procedure:

Set the VG Meter cup with the sample on the platform and lift it until the mud level reaches the line shown around the VG Meter sleeve.

1) To keep the platform in place when using the VG Meter tighten the screw.
2) Only move the red knob up or down while the meter is running.
3) Toggle the switch to the high-speed setting, and the sleeve will start to rotate at 600 rpm. At 600 rpm, the initial reading will be taken. Keep a reading log.
4) While the red knob is still all the way down, flip the switch to the low- speed position. When the sleeve reaches 300 rpm, the second reading is obtained. Keep a reading log.
5) Toggle the switch off and hold it for 10 seconds. Push the switch back to the low-speed position after 10 seconds while keeping an eye on the dial. The dial briefly reached a high value before reverting to a lower one. Prior to being reset to the 10sec Gel strength, the highest dial value is taken.
6) The VG meter cup is turned off once more for 10 minutes without moving the red knob. The toggle switch is depressed when the dial is being watched after 10 minutes. The 10mins Gel strength is determined by the maximum value attained before the dial drops back.
7) LCM samples are used to repeat the process.

2.1.6. Determination of Filtrate Volume and Mud Cake Thickness

This test measures how quickly fluid passes through the filter paper under a set of time, temperature, and pressure parameters.

The test is run at 100 psi, and water readings in (ms-1) are taken after 7.5mins, 15mins, 22.5mins and 30 minutes. After the test, the thickness of the solid filter cake that was deposited in a 32nd of an inch is measured.

PROCEDURE:

1) Install the API filter press device on the work surface.
2) If the cell hasn't previously been taken apart, remove it from the rack.
3) Add mud sample to the cell until it is 3–4 cm from the top.
4) Place the assembly into the filter press stand and cover the cell body with the regulator cap.
5) Completely back off the T-screw on the regulator without removing it. In order to prevent CO2 leaking, insert the CO2 cartridge into the barrel of the cartridge and tighten.
6) Set a graduated cylinder measuring 25ml under the cell to catch the filtrate.
7) Turn the T-screw clockwise and push the red knob in to pressurize the cell to 100 psi.
8) Start the timer and run the test for 30mins. Values of mud filtrate were taken at 7.5mins, 15mins, 22.5mins and 30mins.
9) Record the filtrate value and observe the filter cake thickness.

3. Results and Discussion

This contains results of various experiments carried out during this research.

Analysis of Water Based Mud

Drilling muds were formulated according to standard API procedure, blank mud was used, which was the base mud for the experiment. Four other muds were formulated and additives added according to particle size distribution, the blend mud was mixed with kaolin at different grams. The change in rheological properties such as density, plastic viscosity, apparent viscosity, yield point, and gel strength was compared to the base case.

Mud Density

Fluids in the formations can be controlled by mud density. Freshwater has an 8.34 ppg density, or a 0.433 psi/ft pressure gradient. The majority of the formation has a pressure gradient that is higher than the freshwater property at 0.466 psi/ft.

Table 3. *Mud Weight of Samples.*

Mud sample	Mud 1 (no kaolin)	Mud 2 (kaolin 10g)	Mud 3 (kaolin 20g)	Mud 4 (kaolin 30g)	Mud 5 (kaolin 40g)
Mud density (ppg)	9.0	9.2	9.3	9.5	9.6

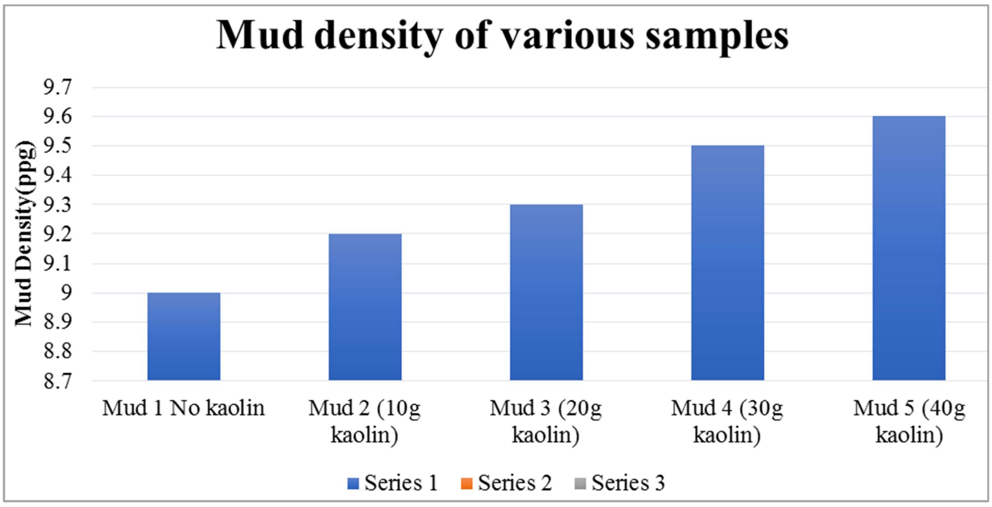

Figure 2. *Mud weight of Various samples.*

Effects Of Kaolin Clay Nanoparticles On Rheological Properties Of Water Based Mud.

Table 4. *Results from Mud Rheology test.*

Parameters	Dial reading Mud 1 (no kaolin)	Dial reading Mud 2 (kaolin 10g)	Dial reading Mud 3 (kaolin 20g)	Dial reading Mud 4 (kaolin 30g)	Dial reading Mud 5 (kaolin 40g)
Θ_{600}	17	21	27	34	40
Θ_{300}	14	17	23	29	35
Plastic viscosity	3	4	4	5	5
Apparent viscosity	8.5	10.5	13.5	17	20
Yield point	11	13	19	24	30
Gel strength 10secs	24	30	32	35	37
Gel strength 10mins	30	39	42	44	47

Plastic Viscosity

Plastic viscosity PV is a part of resistance to flow caused by the friction between the suspended particles and influenced by the viscosity of the based fluid, high PV is caused by viscous base fluid and excess solids. The highest PV was attained by the mud containing 40g of LCM, because of the greater percentage of nano-sized particles of the kaolin.

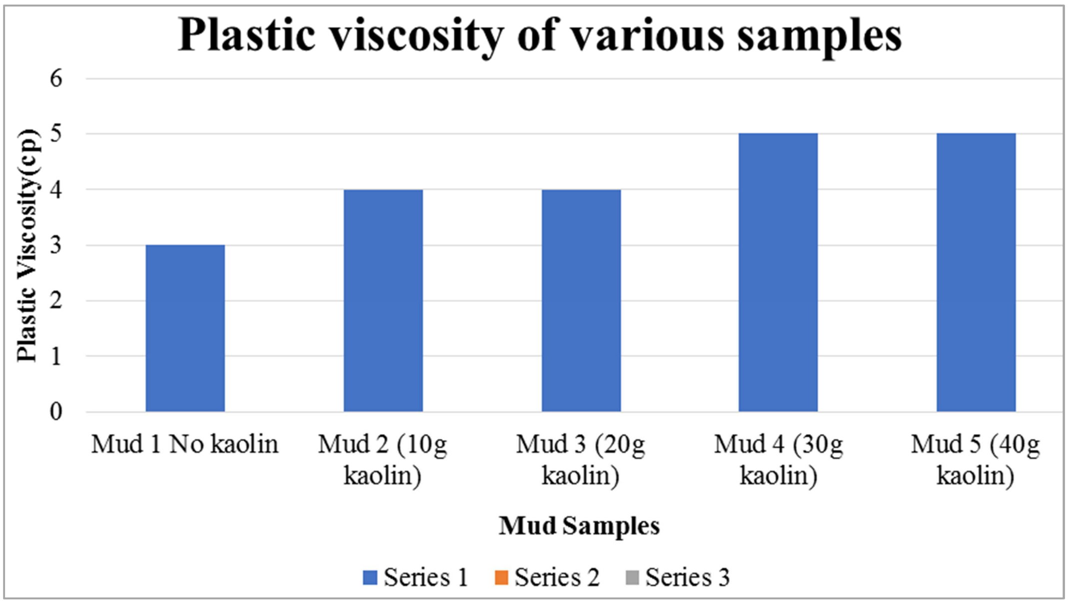

Figure 3. *Plastic viscosity of various samples.*

Apparent Viscosity

Apparent viscosity quantifies the flowability of the drilling fluids and is related to rate of penetration. The values of apparent viscosity were increased when kaolin was added to the mud sample, with the blend mud having the highest AV as it had the highest concentration of Kaolin.

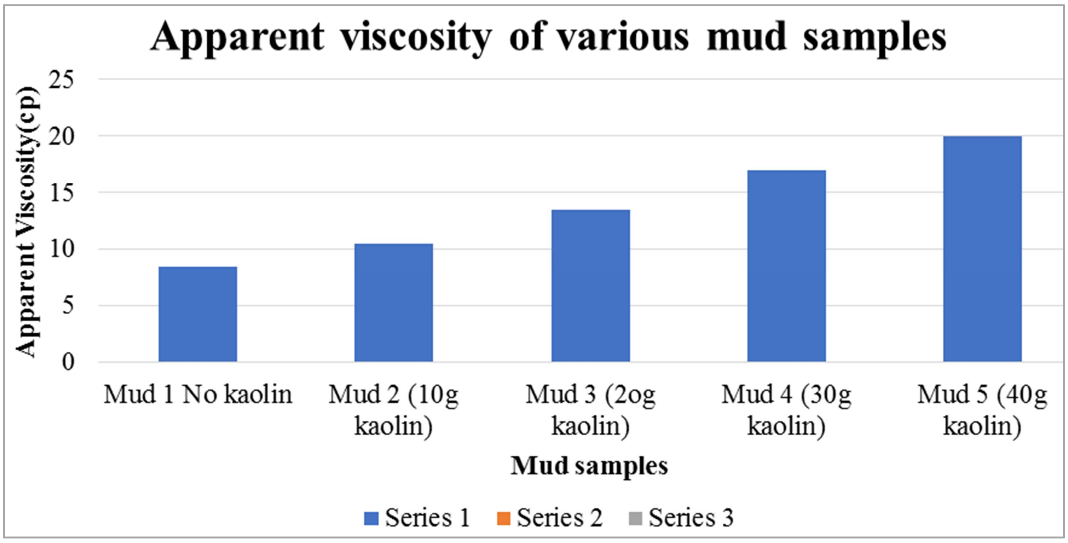

Figure 4. *Apparent viscosity of various mud samples.*

Yield Point

The mud's yield point dictates how well it can move cuttings out of the hole. It displays the initial flow resistance or the stress needed to start fluid movement. Compared to a fluid with the same density but a lower yield point, a high YP fluid is better able to move cuttings out of the hole. The yield points also increased when the kaolin nanoparticles was added to the mud, with the blend mud having the highest concentration of kaolin having the highest yield point. The concentration and sizes of the kaolin had an effect on the YP.

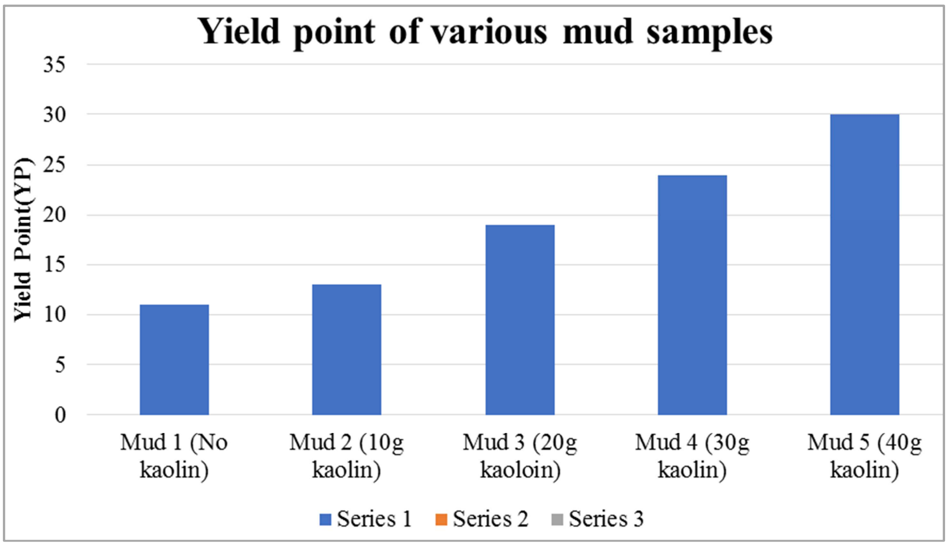

Figure 5. *Yield point of various mud samples.*

Gel Strength

This rheological property indicates if the mud can suspend drill cuttings. Gel strength is a property with that ensures the cuttings do not set in the hole. It measures the attractive forces of mud particles under static conditions for 10 seconds and 10 minutes. Effective solids control is necessary to keep the gel strength at the right level. The way gel strength is treated depends on the mud system being used. Viscosifiers and flocculants can be used to accomplish this.

As LCMs of various concentrations were added to the mud, the gel strength considerably increased. Additionally, gel strength rose as viscosity rose.

A moderate gel strength is necessary to stop solids from settling immediately after circulation has ceased; a high gel strength of (35–40 1b/100 ft2) may delay cuttings separation and necessitate considerable pumping pressure to halt circulation (Ghazali 2017).

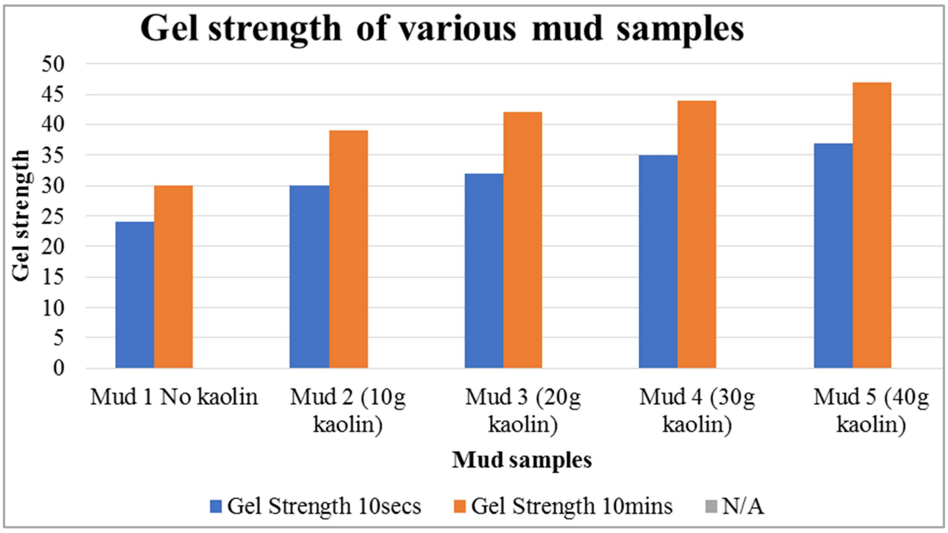

Figure 6. *Gel strength of various mud samples.*

Filtration Test and Mud Cake Thickness

Table 5. *Results from Filtration test.*

Time (mins)	Mud 1 No LCM	Mud 2 (10g LCM)	Mud 3 (20g LCM)	Mud 4 (30g LCM)	Mud 5 (40g LCM)
7.5	15.0ml	12ml	11ml	9.0ml	8.0ml
15.0	4.0ml	2.5ml	2.5ml	2.3ml	2.1ml
22.5	3.7ml	2.1ml	2.1ml	2.0ml	1.9ml
30	3.2ml	1.9ml	1.9ml	1.8ml	1.8ml
Cumm	25.9ml	17.5ml	17.5ml	15.1ml	13.8ml

Table 6. *Results from Mud cake thickness.*

Mud sample	Mud 1 No LCM	Mud 2 (10g LCM)	Mud 3 (20g LCM)	Mud 4 (30g LCM)	Mud 5 (40g LCM)
Thickness (inches)	0.09375	0.125	0.125	0.125	0.125

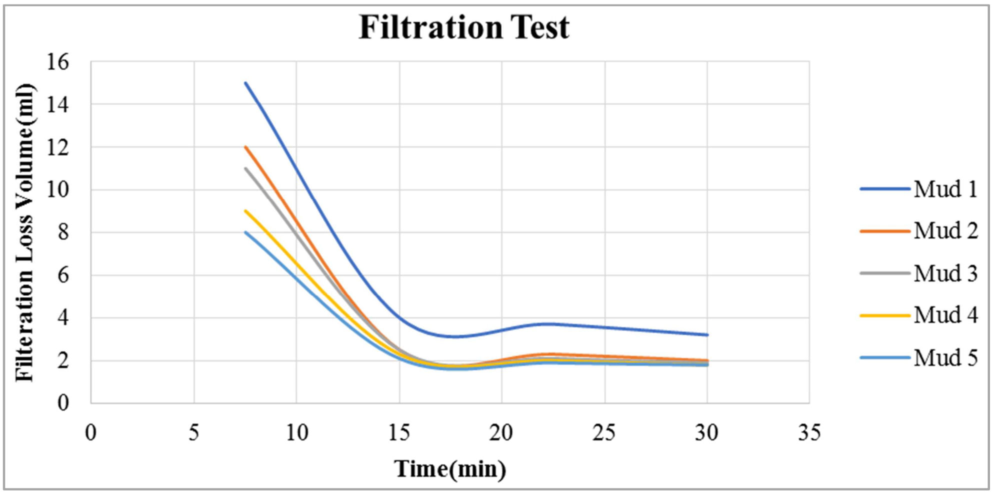

Figure 7. *Filtration loss volume for various mud samples against time.*

From Table 5 results showed that mud with highest concentration of kaolin as LCM has the lowest filtration volume. It can be deduced that the mud sample that has the largest volume of fine particle size has the highest ability to perform better as seals in lost circulation zones, this result was proceeded by the mud with the highest concentration of kaolin. The blank mud had no LCM concentration so it had the highest filtration volume.

Figure 7 demonstrated the relationship between the volume of filtrate lost over time for the fluid volumes collected using the graduated cylinder at 100 psi of pressure. For all mud samples, the amount of filtrate loss reduced with passing time. This is because the LCM particles have created a thicker cake by filling the pore gaps and blocking fluid loss through the filter paper.

Table 6 shows the results for mud cake thickness after the filtration test for the various mud samples. Mud sample 2, 3, 4 and 5 had the same mud thickness while the blank mud with no LCM showed the thinnest cake thickness. This occurred because the particle sizes were finely distributed. Thin mud cake is desired because thick mud cake increases torque, drag and the tendency to become differentially stuck.

4. Conclusions

The study looked at the effect of Kaolin clay nanoparticles on water-based drilling fluid Rheology in water-based muds. Experiments were carried out to see how the Rheology of the water-based muds was affected by kaolin clay nanoparticles, also the mud weight of the various mud samples were measured with the mud weight balance. To determine the ability of the kaolin clay nanoparticles to act as seals or bridges when they encounter fractures was looked at by carrying out experiments with the API filter press assembly, which also measured the volumes of fluid lost before the LCMs plugged the fractures. The results obtained were analyzed to see how effective this kaolin clay nanoparticles were in sealing fractures and their effect in water-based mud.

Polymeric nanoparticles when compared with these commercial LCMs (cyber seal and new bridge, polyurethane) which have been also tested in laboratories in high temperature and high-pressure conditions have also been successful. Tschoepe, 1982), also (Mansure, 2002) reviewed polyurethane as the material of choice for sealing boreholes with large fractures. Polymeric nanoparticles have also shown a high degree of success in sealing fractures, with local materials easy to source and are less expensive.

Conclusion drawn from Rheology:

The 40g kaolin mud sample had the highest values for all rheological properties due to the use of the medium sized particles and also high concentration of kaolin. It can be said that increase in particle size and concentration of LCM increases the rheological properties of water-based muds.

Conclusion drawn from Filtrate loss volume;

From recent researches it has been found that mud sample with high concentration of kaolin has the least fluid loss volume and seal the fractures faster as well as the experiment carried out the mud sample with the highest concentration of kaolin had the least filtration volume, therefore it can be deduced that use of more of the fine particles of LCMs does a better job in sealing fractures.

5. Recommendations

Kaolin clay nanoparticles can be used as additives in water-based muds due to its ability to enhance rheological properties, improve fluid loss control, increase stability as well as reduce filtration rates and help with well-bore stability.

For further research in this area the following should be considered

1) The effects of kaolin nanoparticles can vary based on concentration, particle size and the overall mud composition, so it's essential to conduct thorough testing to determine optimal conditions for your specific application.
2) Kaolin clay polymeric nanoparticles should be considered as LCMs because they have good performance and also less expensive.
3) Use of kaolin LCMs with fine additives such as PAC L (poly-anionic Cellulose low viscosity additives) should be considered. Due to its ability to control filtration loss and maintain well stability.
4) The mud samples should be increased to analyze the effect of blend LCMs on mud rheology when the LCMs are added to the mud samples in different concentrations and the base fluid blended with commercial LCM additives such as PAC L should be of the same weight concentration as the mud sample blended with kaolin nanoparticles at different concentrations to achieve an effective compare.

Abbreviations

API: American Petroleum INSTITUTE
LCM: Lost Circulation Material
XRD: X-ray Diffraction
WBDF: Water-based Drilling Fluid
VG: Viscosity-gel
PAC L: Poly-Anionic Cellulose Low Viscosity Additives
FT-IR: Fourier Transform Infrared Spectroscopy
KCNPs: Kaolin Clay Nanoparticles

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Conflicts of Interest

The authors declare no known competing interests that could have influenced this report.

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