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THE EFFECT OF NANO-SILICA ON DRILLING MUD

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KeyWords

Drilling fluid, Mud density, Fluid loss, Nano-silica and Rheology.

ABSTRACT

This study investigated the effectiveness of nano-particles, mainly silica, as an additive to water based muds to the extent of High Pressure, High Temperature (HPHT) conditions. Specifically, the study ascertained the impact of silica nano-particles in improving performance of water based mud, the study also investigated the effect of nano-silica on mud density and also investigated the quality of silica nano-particles as a fluid loss agent and rheology modifier. The laboratory study was divided into four parts: viscosity determination, fluid loss test, sand content determination, and density determination. All these studies were conducted using water-based mud with and without silica nanoparticles. In the course of the study, the rheological, fluid loss properties, the rheological behaviour of the mud, and the cuttings transportation efficiency were directly and indirectly ascertained. From the findings, it was ascertained that nano silica improves mud viscosity for plastic viscosity by 87.5%, the apparent viscosity of the mud by 6.8%, and mud density by 1.92%, and also reduces yield point by 2.9%, and fluid loss between 17.5% and 42.9% for time intervals of between 5 – 50 minutes in which the experiment was conducted for which harmonises and complements previous standardized researches done.

1. INTRODUCTION:

Drilling fluids, also known as drilling mud, functions to suspend cuttings, control pressure, stabilize exposed rock, provide buoyancy, cool and lubricate the drill in the well (Chang et al, 2011). During the third century BC, the Chinese had already been using drilling fluids (ASTM, 2000). This is a complication as the cuttings are not being circulating, and will fill the hole again. Drilling fluids function as a

suspension tool to prevent such situations (Nazari et al, 2010 Another factor for using drilling fluids is rock stabilization. Certain fluid additives are used so that fluid will not be lost to formation pores and clog pores (Jauhari et al, 2013). The drilling fluid should have an optimum viscosity to transport the cuttings, so that the cuttings will fall back to the annulus (Egenti, 2014; Fakoya and Subhash, 2013; Chang et al., 2011). Recently, the application of nanoparticles in drilling fluids has shown promising solutions to inherent drilling fluids problem (Abimbola et al., 2017; Bland et al., 2006; Fedele et al., 2011). Due to the ultrafine size and high surface area to volume ratio of nanoparticles, mud engineers are able adjust the drilling fluid rheology by modifying the composition, type or size distribution in drilling fluids to accommodate any special situation when nanoparticles are used as additives (Smith et al., 2018). Recent investigation by (Amanullah and Al-Tahini, 2009; Ragab and Noah, 2014; Noah et al., 2017; Noah et al., 2017a) stated that nanoparticles offers benefits such as reduction in filtration loss and friction coefficient, improvement of drilling fluids rheological properties, inhibition of gas hydrates and improvement of shale stability. Several experimental investigations have analyzed Nano-silica as a drilling fluid additive because Silica (SiO2) nanoparticles are highly stable, highly efficient, and can work effectively in the presen effectiveness of nano-particles, mainly silica, as an additive to water based muds to the extent of HPHT conditions. Drilling fluids are typically formulated with loss circulation materials (LCMs). LCM forms a barrier which limits the amount of drilling fluid penetrating the formation and prevents loss (Chang *et al*., 2011). nanoparticles (NPs) as a loss circulation material could fulfill the specific requirements by virtue of their size domain, hydrodynamic properties and interaction potential with the formation (Amanullah *et al*., 2009; Srivatsa, 2010; Abdo & Haneef, 2010). Kang *et al*. (2016) suggested that small particles of high concentrations might bridge across the pore throat. Again, smaller particles aggregate around larger ones to fill the tinier spaces and hence effectively plug the pore opening spaces.

Selection of nanoparticles is dependent on its properties and particle size. There are different methods for nanoparticles synthesis which are categorized as dry and wet methods. Dry methods consist of jet and ball milling, micronizer whereas wet synthesis consist of solvent evaporation, chemical precipitation, spray drying and emulsion method.

Nanoparticles have an extensive range of unique characteristics for varied functionalities such as surface plasmon resonance, superior catalytic activity, intrinsic reactivity, great adsorption affinity and dispersibility (Hashemi *et al.*, 2014).

Lee *et al.*, (1999) reported that nanoparticle based fluids exhibit higher thermal conductivity with great dependency on factors such as the material type, size, shape, surface area, particle volume fraction, base fluid material and temperature.

Nanoparticles are defined as object with a diameter less than 100nm (Riley, *et al.*, 2012). High solids content in drilling fluids is one of the factors that attributes to wellbore instability, reduces productivity index and decreases penetration rates.

Silica, also known as, silicon dioxide is found in many different forms; amorphous/crystalline, porous and non-porous, anhydrous and hydroxylated.

It is synthesized either by dissociating monomeric silic acid or from the vapor of a silicon compound, from aqueous solutions. Nano silica solutions are widely used, and come in sizes ranging from 5 to 100nm (Hendraningat *et al.*, 2013) (Long *et al.*, 2013).

Amanullah *et al*. (2011) disclosed a WBM with less than 1 wt% NPs, resulting in no mud spurt loss. High potential for reducing differential pressure sticking problems while drilling, reduce torque and drag ce of other molecules (Jauhari et al., 2011; Strambeaunu et al., 2015). The main aim of this study is to study the problems in deviated, horizontal extended reach and multi-lateral drilling operations.

2. MATERIALS AND METHODS:

Items used in this study includes nanoparticle (SiO2), fresh water at 21°C, Tap water (H2O),
distilled water, caustic soda (NaOH), soda ash (Na2CO3), polyanionic cellulose (PAC) UL, calcium carbonate fine (10μ), xanthan gum, bentonite, octyl alcohol deformer, fresh water at
21℃ = 1kg/l, 1/4 gallon = 26(+/- 0.5) secs, Silver nitrate solution with known titration
Potassium chromate indicator solution, Sulphuric acid:N/50 and 0.1 regular (N/10), Phenolphthalein indicator solutions, Xylene/Hysopropanole mixture: 50/50, etc

2.1 Materials

The materials used includes Air-dry Oven (type 48 BE Apex Tray Drier), weighing balance, measuring cylinder (10 or 25cc graduated cylinder), beakers (100-150cc beaker or a white vessel), Hamilton beach mixer and cup, pH Indicator Paper or strip (paper test stripsor pH Paper), thermometer, knife, sieving mesh, bucket, bowl and stop watch/clock (30min timer, etc), Rotational Fann viscometer (V-G Meter), API filter press, mud balance and sieves,
spatula, mixing cups, Baroid Mud balance, Thermometer 0-105℃ Calibration, Faan V-G
Meter, Marsh Funnel, Sand screen set consisting of a 200 mesh sieve of 2.5" diameter, a funnel

to fit the screen, a glass measuring tube with indicated marks relating to the quantity of fluid and water to be reached and graduations from 0% to 20% which immediately allows the reading of sand percentage, 1cc pipette, 1cc serological (graduated) pipette, glass stirring rod, Half liter glass jar with lid, 5cc syringe, 5cc graduated pipette, magnetic stirrer with 38mm stirring bar (1.5in), Thermostatic cup, Chronometer, fluids of known viscosity (Silicon Oils), a suitable mechanical calibration kit, Filter press with internal diameter of 3", filter area of 7.1 +/- 0.1 in2, Paper filter, Whatman No 50 or S&S No 576 diameter 90mm, Atmospheric filter press, CO_2 cartridge, Press cup, Wash bottle, etc.

2.2 Mud Formulation:

The American Petroleum Institute (API) standard of 8.0g of conventional bentonite per 1 lab barrel of water for Water based Mud (WBM) formulation was used in the preparation of the mud. The mud is a repetition of a standard mud prepared for an Oil & Gas Company.

The prepared mud samples properties were determined. Two (2) mud samples were formulated (one standard WBM mud and one (1) other mud with nonparticle (SiO_2). See Table 1 and procedure below for formulation.

Table 1: Mud Formulation Table

Composition	Mud A	Mud B	Function	Mix time
Water	329.79ml	329.79ml	Base fluid	-
Soda Ash	0.1ppb	0.1ppb	Calcium removal	2
Caustic soda	0.1ppb	0.1ppb	Alkalinity control	2
Bentonite	8.0ppb	8.0ppb	Viscosifier	15
Xanthan gum	1.2ppb	1.2ppb	Viscosifier	5
Poly PAC UL	1.0ppb	1.0ppb	Fluid loss control	3
Calcium carbonate	15.46ppb	15.46ppb	Weighting material	2
Borax	2ppb	2ppb	Preservative	1

The mixing time for the additives used in the drilling mud was in minutes.

2.3 Mud Density

The drilling mud density was determined using a Baroid mud balance. The instrument consists of a constant volume cup with a lever arm rider calibrated to read directly the density of the fluid in pounds per gallon (ppg). The lid was removed from the cup and completely filled with the mud to be tested. The lid was replaced and the mud

that was expelled through the hole in the cup was wiped off. The balance arm was placed on the base with the knife edge resting on the fulcrum. The mud density was read directly in pounds per gallon.

2.4 Sand Content

The glass measuring tube was filled to the indicated mark with the formulated fluid, water was added to the relating mark and the tube was closed and shook vigorously. The mixture was poured into the screen and discarded the fluid. This action was repeated until the washed water passed through clear and washed the sand retained on the screen. The funnel was then fitted on the screen, turned upside down the funnel and the screen

onto the tube, washed the sand into the tube by collecting water and solids in the tube and then allowed the sand to settle. Finally, the percent by volume of the sand was read from the graduation.

2.5.1 Apparent Viscosity

The fluid sample point was recorded and the sample placed in a suitable container, then the rotor was placed exactly at the scribed line and the temperature of the sample recorded. While the rotor was rotating at a speed of 600 RPM, the reading was allowed to reach a steady value, then changed to 300 RPM, and again allowed the reading to reach a steady value. The fluid was then stirred at high speed for 10secs and allowed to stand undisturbed for 10secs before shifting to 3 RPM and the maximum reading was recorded. Finally, the fluid was re-stirred at high speed for 10secs and allowed to stand undisturbed for 10secs. Same was done at 3 RPM again and the maximum reading recorded.

2.5.2 Plastic Viscosity and Yield Point Value

The Faan V-G Meter cup was filled to 350cc mark (this is also the barrel equivalent volume) with freshly agitated sample and the cup placed on the moveable work table. The table was adjusted until mud surface was at the scribed line on the rotor sleeve, then the motor was started by placing the switch in the high speed position with the gear shifted all the way down. This is the 600 rpm setting.

Note: The gears are changed only when the motor was running.First off, at a steady indicator dial value, the 600 rpm reading was recorded. Finally, the motor switch was turned low, waited for steady reading and then recorded the 300 rpm reading and obtain the following value:

2.6 Gel Strength

The sample was stirred thoroughly at 600 rpm (15 seconds was ok), by me, then the gear shift was slowly lifted to first position (center position) then the motor was shut off. After 10seconds, the motor switch was then turned to low (3 rpm), finally, the dial was read at maximum deflection units, in lb/100sq.ft, as the initial gel.Steps 1 and 2 was repeated and waited for 10mins and then turned motor to low. Finally, the maximum deflection units were read (i.e. at gel break) to get the 10min gel.

2.7 Fluid loss Test

The atmosphere filter press is a laboratory equipment used in determining the level of filtration for different kinds of flowing fluids using a CO_2 cartridge. CO_2 cartridge serves as a pressure vessel for the operation instead of electrical automation. The diagram of the filter press apparatus is shown in Figure 3.3.

Procedure:

First off, I coupled the press cup up to the hob, after coupling the press cup up to the hob, I then poured the sample to be experimented up to the 3 size of the press hob, then placed the hob on the wooden base close to the cover and tighten the screw on the cover to faster the press hob in question, then placed the cylinder directly under the outlet hole of the press hob for collection of filtrate. The CO_2 discharge valve was locked, and I inserted the CO_2 cartridge into its cylinder and faster to the cover, then I immediately adjust the CO_2 pressure value up to 100ps, took the reading for the first 30 minutes with a stopwatch then monitored the pressure meter with time as it deviates from 100psi. Ensure to adjust it back. After 30 minutes, I reduced the pressure back to the original value from the control valve, then discharged the pressure on the line by adjusting the red knob or pushing it backward, took the cylinder, collect and measure the filtrate value. Finally, weighed the filter paper, then dry and reweighed the filter paper and filter cake.

3 RESULTS AND DISCUSSION

3.1 Mud Density

Table 2: Mud Density of Samples

Mud Sample	grams	g/cm3	Ppg	lb/ft3	Psi/1000ft	SG
Sample A	54.05	1.081	7.80	59.30	409.4	0.25
Sample B	54.15	1.083	7.95	59.50	410.2	0.98

Table 4.1 above, in this study. it is observed that the mud formulated with nanoparticle (sample B) is denser than the standard mud(sample A). Sample B containing the SiO2 contributed to an increased mud weight of 7.95lb/gal, 59.5 lb/ft3 and 410.2 psi/1000ft2, being the fluid with the highest mud density, and would be useful for controlling formation pressure and maintaining wellbore stability.

3.2 Sand Content

Table 3 below shows the results obtained from the sand content experiment of the mud samples formulated and characterized in this study.

Table 3: Values of Sand Content for all Mud Samples Percentage

Mud Samples	**Sand Percentage, %**
Sample A	0.25
Sample B	0.04

Rheological Analysis

The figure below shows the results obtained from the Rheological analysis conducted on the formulated mud samples (sample A and B). Figure 1 below illustrates the comparison of the rheological (flow) analysis of mud samples A (standard / control mud) to mud sample B (mud with nona particle, SiO2), used for this study. As shown in Figure 1, a comparison of sample A to sample B yields better and higher rheological (viscosity) values. This shows that for this particle type of mud, nanoparticle, SiO2, can be used as a rheological (flow characteristic) control additive.

3.3.1 Plastic Viscosity

Figure 1 Rheological Property (Rheometer speed against Dial reading) Variation with Nano Silica

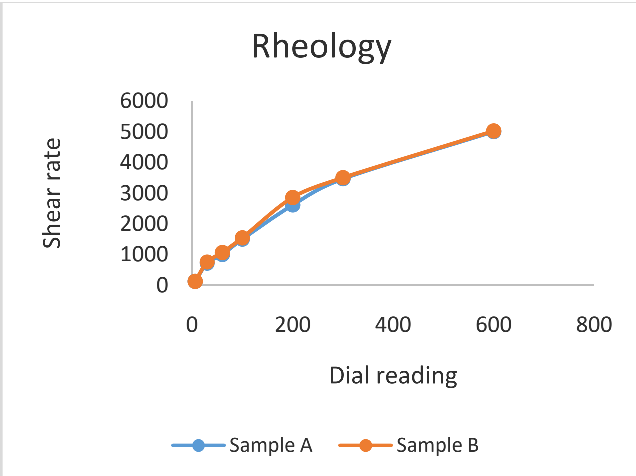
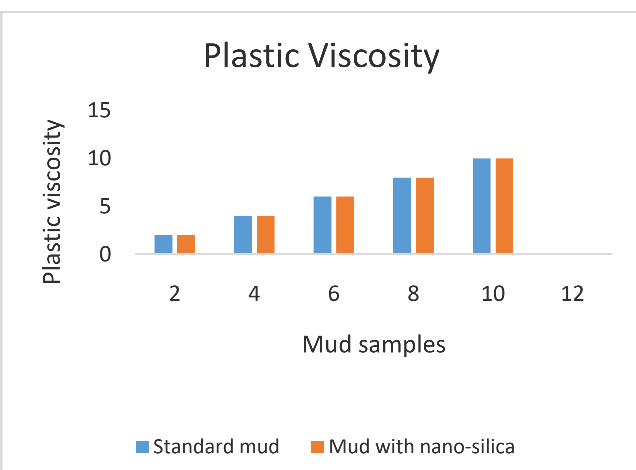


Table 4 shows the results obtain from the Rheological analysis – Plastic Viscosity, for the formulated mud samples (A and B).

Samples	Viscosity	10″	10’
Sample A	18	3	10
Sample B	18.5	4	10

Figure 2 illustrates the comparison of the Plastic Viscosity behaviour of mud samples A (standard / control mud) to mud sample B (mud with nano particle, SiO_2), used for this study.



From Figure 2, there was a remarkable increase in plastic viscosity with the use of nano silica. The plastic viscosity increased by 87.5% with nano silica. Increasing the plastic viscosity of the mud results in a remarkable increase in the amount of recovered cuttings. Though, optimization is also needed here as a very high plastic viscosity generates higher resistance in mud which in turns will affect cutting lifting performance. Also, a low PV indicates that the mud is capable of drilling rapidly because of the low viscosity of mud exiting at the bit.

3.3.2 Apparent Viscosity

Table 5 below shows the results obtain from the Rheological analysis – Apparent Viscosity, for the formulated mud samples (A and B).

Table 6: Apparent Viscosity of Mud Samples

Sample□	Vi□co□ity	10″	10′	Vi□co□ity	Value
Sample A	18	3	9	10	16
Sample B	18.5	4	16	10	17

3.3.3 Gel Strength

Fig 3: Gel Strength of Samples

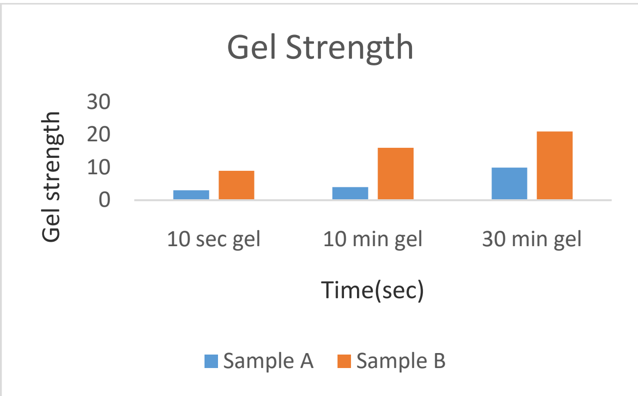


Figure 3 shows the comparison of the Gel Strength property of mud samples A (standard / control mud) to mud sample B (mud with nano particle, SiO_2).

Gel strength measurement was made on viscometer using the 3-rpm reading, which were recorded after stirring the drilling fluid at 600 rpm to break gel. The first reading was noted after the mud is in a static condition for 10 seconds. The second reading and the third reading were after 10 minutes and 30 minutes, respectively. Low gel strength indicates inability to suspend cuttings. It can lead to pipe stuck and hole pack off due to insufficient cutting suspension. From figure 4.8, it can be seen that at 10secs, the nano silica improved the mud gel strength by 53.85%, same as in 10 mins and after 30 mins, the gel strength of the mud was improved by 50%. This implies that with nano silica, the ability of the drilling mud to suspend drill solid and weighting material when circulation is ceased is improved significantly. It is also good to note that excessive gel strength will lead to high pump initiation pressure to break circulation after mud is in a static condition for a period of time. High pump pressure may result in formation fracture and lost circulation, hence optimization is needed here.

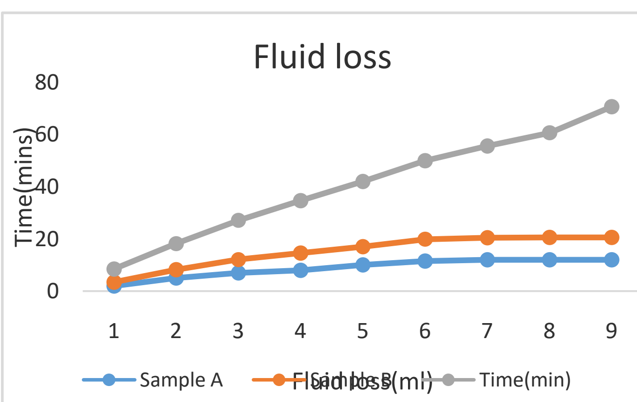
Fluid loss

Table 7 below shows the results obtain from the filtration characterization – Atmospheric HPHT filtration of the formulated mud samples (A and B).

Table 7: Filtrate loss for mud samples

Time(mins)	Sample A	Sample B
5	2	1.45
10	5	3.2
15	7	5.1
20	8	6.6
25	10	7
30	11.5	8.4
35	12	8.5
40	12	8.6
50	12	8.6

As nano silica improves mud viscosity and density, it also reduces fluid loss. At 5 mins, the fluid loss is reduced by 27.5%, at 10 mins there was fluid loss reduction of 36%, at 15 mins, there was 27.14% reduction in fluid loss, at 20 mins, there was 17.5% reduction in fluid loss, at 25 mins, there was 42.9% reduction in fluid loss, at 30 mins, there was 27% reduction in fluid loss, at 35 mins, there was a 29.2% reduction in fluid loss. At 40 and 50 mins, there were 28.3% reduction in fluid loss. Fluid loss prevention is a key performance attribute of drilling fluids. For water-based drilling fluids, significant loss of water or fluid from the drilling fluid into the formation can cause irreversible change in the drilling fluid properties, such as density and rheology occasioning instability of the borehole.



. CONCLUSION:

Deeper holes are being drilled more frequently and high temperature holes are becoming a big problem because of the tendency of drilling mud to degrade, thus affecting cuttings transport performance. There are numerous findings on the benefit of using nanomaterials in drilling mud for high temperature environments, this study complements the existing literature by investigating the effect of nanosilica in water-based mud in a laboratory study. The laboratory study was divided into four parts: rheological determination, fluid loss test, sand content determination, and density determination. All these studies were conducted using water-based mud with and without silica nanoparticles. In the course of the study, the rheological, fluid loss properties, the rheological behaviour of the mud, and the cuttings transportation efficiency were directly and indirectly ascertained.

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