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Comparative Analysis of Refined – Sawdust and Other Conventional Loss Circulation Materials Used In Drilling Fluids Application

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ABSTRACT

The study aims at providing a comparative evaluation of the sealing and blocking efficiency of a novel LCM (Refined – Sawdust) and a conventional LCM (Calcium Carbonate), used by the oil and gas industry to combat loss of circulation problems in drilling operations. Refined – Sawdust was used as an LCM in water -based mud, in comparison with the loss control capability of other LCM ($CaCO_3$).

Results showed that there is no much difference between the plastic viscosity, funnel viscosity, yield point, gel strength and filter cake thickness exhibited by the conventional LCM and that exhibited by the refined – sawdust LCM. Also, the ability of the LCMs to seal off fractures in time and reduce fluid losses was influenced by the particle size of the LCMs. The results showed that the mud samples formulated with the composite LCM yielded the better results when compared with other mud samples prepared with a specific particle size of the same LCM.

This research showed that the use of refined – sawdust as LCM had a good effect on the rheological properties of the mud. It also shows that refined – sawdust of different particle sizes has the ability to form adequate mud/ filter cake thickness and is suitable to be used as LCM. Again, refined – sawdust showed a good ability to be suspended within the mud, without forming settlement within the mud during drilling operations. Finally, the research showed that the use of refined – sawdust especially the composite refined – sawdust LCM (fine, medium and coarse) has a competitive advantage over other conventional LCMs, in terms of fluid loss control capability, loss circulation control, rheology, cost, availability and eco - friendliness.

Keywords: Drilling fluids, Mud, Drilling operations, Loss Circulation Materials LCM, Rheology, Permeable formation, Refined – Sawdust, Calcium Carbonate, Water – Based Mud, Filter Cake, Filtrate, fluid loss.

I. INTRODUCTION

In the Oil and Gas industry, drilling operation involves the use of drilling fluids, usually referred to as "drilling" mud or simply called "mud". This drilling mud is used in drilling because of its numerous functions in the drilling process which include: to cool the drill bits, lubricating and supporting the drill bit and drilling assembly, removing cuttings from the well, suspending and releasing cuttings, controlling formation pressures, seal permeable formations, maintain wellbore stability, minimize formation damage, transmit hydraulic energy to tools and bit, control corrosion, facilitate cementing and completion, among other functions [1, 9]. During drilling, mud is being circulated within the wellbore by means of pumps to enable it carry out its functions as expected. However, real life operations have shown that there is always a loss of mud sent into the wellbore, observed when the amount of mud that returns is significantly less than the amount sent into the wellbore [2]. This usually occur due to drilling through highly permeable formations, cave-like beds and formations with inherent or induced fractures, which seems to absorb some of the mud that passes through it in the course of drilling [1, 2]. In many cases, partial loss of mud (Fluid Loss or Loss Circulation) is observed, while in some cases a total loss is observed [3, 17]. This problem of loss circulation became very challenging in the industry as more drilling fluids or mud has to be consumed in the drilling process, leading to a higher drilling cost. Also, the seepage of mud into the formation leads to deep aquifer pollution problems [4]. Again, the drillers need to be completely on the watch monitoring the mud levels as they drill, to enable them know when to increase the volume and the various properties, especially rheological properties of the mud being used in drilling. This is because any mistakes can lead to numerous drilling problems like, wellbore collapse, formation damage, stuck - pipe, blowout, etc.

The problem of Loss Circulation has therefore become very prominent and challenging in drilling operations. The loss circulation of drilling fluids can be categorized into three groups: complete, partial and seepage loss [9]. Complete Loss Circulation occurs when the rate of loss circulation is greater than 500 barrel per hour (bph). Long horizontal and vertical fractures, vertical fractures with large openings, big voids and other highly permeable zones usually cause this type of loss circulation [2, 9]. Partial Loss Circulation occurs when the Loss circulation rates is between 10 to 500 bph [2, 5]. This basically occurs in small natural fractures, gravels and vertical fractures with small openings. Finally, the seepage loss category describes the light losses with the loss rate of between 1 and 10 bph [2, 9]. This type of loss circulation can be easily controlled by the reducing or stopping the pumping of mud and allowing the fractures to be filled by the solid phase of mud. Loss circulation causes several problems, such as the loss of several barrels of drilling fluids, increase in the non-productive rig time, loss in the wellbore, and in some cases, blowouts [6, 8]. Loss Circulation is also responsible for the excessive caving of formations, which in turn results in cement job problems and reduces the effective permeability of the near wellbore region [9, 10]. These types of problems introduce excessive costs in drilling operations, which runs in several millions of dollars annually [11].

The problems of Loss Circulation can be controlled, managed or prevented using various techniques, such as adding loss circulation materials (LCM) to the drilling fluid formulation. However, the most commonly used method in combating loss circulation is the use of LCMs [13, 14]. There are basically 3 types of LCMs being used in drilling fluids applications namely; granular, flakes and fibers [9, 12]. These LCMs are usually introduced into the mud to plug or seal off the cracks or pores in the permeable formation zones during drilling operations [15, 16]. The most conventionally used LCM in drilling mud formulation is calcium carbonate based. The particular type of LCM chosen for a given mud system depends on the properties of the formation to be drilled, revealed by the critical study of the formation. This is because the effectiveness of an LCM depends on the type of formation it is being applied. Also, the particle size of a given LCM being used depends on the type of formation. Again, the mud engineer may decide to use a combination of particle sizes based on what the expectations are, as revealed by the study of the formation properties [20, 21]. The particle size distribution is an important factor affecting the ability of LCMs to seal fractures, loose sands and gravels. Optimizing the particle size distribution of LCMs is an important aspect of combating loss circulation. Apart from the conventional LCMs, the use of alternative or novel products, usually plant based and more ecofriendly LCMs has evolved [18, 19]. These alternative LCMs tend to be more readily available, cheaper and more eco - friendly.

However, the success rate of conventional LCM products, slurries and pills, when applied in moderate and severe loss zone is not encouraging, especially for severe and total loss control [2, 9, 17]. This is due to the technical limitations of conventional products, pills and slurries. Hence, the need for identification and development of novel products with improved composition of loss control slurries, superior LCMs, high performance LCM blends, effective and representative test methods, etc., for effective sealing and blocking of loss zones for trouble free, efficient, timely and economic drilling operations [1, 3, 7, 10]. Also, there is need to develop more eco - friendly LCMs to be applied in drilling operations. Again, most of these conventional LCMs are usually imported, resulting in delays experienced in the process of clearance from custom and the associated costs [1, 13].

Over the past few years, several eco-friendly LCMs have been developed to reduce the environmental impacts caused by various conventional LCMs [9, 10, 11]. Some scientists used different rice fractions, such as rice husks, rice tips, rice straw and rice bran to mitigate the loss circulation, while some used cotton seed hulls as an environmentally friendly LCM [1, 4, 18, 19]. This additive also improves the bit lubrication. Some Scientists used coconut coir to prevent the loss of drilling fluid, while others introduced a wood-based additive to control the lost circulation [1, 2, 9, 13, 19]. This eco-friendly additive can be screened to different sizes and used in various drilling operations. Several studies have also worked on the use of saw dust as an LCM and has shown its potentials as a good LCM. Also, most of these novel LCM products are sourced locally, resulting in more affordable prices of the products and they are readily available [18].

However, most studies have not shown a comparison between the conventional LCMs and these developed novel LCM products. It is against this backdrop that this study aims at presenting a comparison between the use of Refined – Sawdust as an LCM and the use of other conventional LCMs, particularly Calcium Carbonate. This study therefore focuses on the comparative analysis of refined – sawdust and conventional LCM (Calcium Carbonate $CaCO_3$) in drilling mud formulations and in drilling operations, especially in relation to their rheological properties, stability of the products, loss circulation control capacity (filtrate control and filter cake formation), availability and cost.

II. MATERIALS AND METHODS

2.1 EXPERIMENTAL DESIGN

In the course of the study, experiments were carried out using various drilling mud samples formulated with the LCM products under review. The LCM products used include Refined – Sawdust as novel LCM and Calcium Carbonate $CaCO_3$ as conventional LCM. Another mud sample was also prepared without using any LCM at all. This is to serve as a control mud sample which would show the amount of loss in circulation and other rheological properties of mud if no LCM is used in the mud formulation.

A total of 9 mud samples were prepared and used for experiment/ analysis. The first mud sample being the control mud sample was prepared without using any LCM. The second to fourth mud samples were prepared using calcium carbonate $CaCO_3$ of different particle size as LCM. The second mud sample was prepared using only $CaCO_3$ fine, while the third and fourth mud samples were prepared using only $CaCO_3$ medium and coarse respectively, as LCM. The fifth mud sample was prepared using a composite of $CaCO_3$ fine, medium and coarse as LCM. The sixth mud sample specifically was prepared using only refined – sawdust fine, while the seventh and eighth mud samples were prepared using only refined – sawdust medium and coarse, respectively as LCM. The ninth mud sample was prepared using a composite of the three particle sizes of refined – sawdust as LCM. It was necessary to use the same particle size for calcium carbonate and refined – sawdust in formulating the mud samples used in the experiment. This is because the comparison study or evaluation will not be complete or strongly reliable, if the mud samples used for experiment were not prepared using similar conditions and particle sizes.

The total amount of LCM used in preparing each mud sample is 50g. However, for the composite sample LCMs, 20g of the fine particle size was used, with 20g of medium particle size and 10g of the coarse particle size. These were all blended together to achieve a uniform mixture before being added into the mud formulation. The composite samples were prepared for both the Calcium Carbonate LCM and the refined – sawdust LCM.

The refined – sawdust samples were obtained from LA PRINSO Global Services, Port Harcourt, Rivers State. The samples were further manually cleaned during inspection to remove traces of foreign materials. Then the samples were placed in an oven at 105ºC for 3-4 hours. This was done to remove their moisture content and thus obtain dry samples.

The experiments were conducted in accordance with the standard stipulated in API RP13B-1; recommended Practice Standard Procedure for Field Testing of Water-Based Drilling Fluids/mud [9]. Being a Water based drilling mud, water was used as the base fluid throughout the study.

The experimental analysis of this study, which includes; Sieve Analysis, Rheology and filtration test was conducted at PROPATJI CONCEPT INDUSTRIAL LIMITED, Port Harcourt, Nigeria.

All experiment was done in triplicates and the average value reported.

2.2 SIEVE ANALYSIS

The LCMs used for the experiments, especially for calcium carbonate and refined – sawdust were made to pass through sieves. They were sieved using various sizes of sieves to obtain the fine, medium and coarse grades of particles.

PROCEDURES:

1. Sieves with sieve apertures of 85 (fine), 100 (medium), and 150 (coarse) 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.

2.3 PREPARATION OF MUD SAMPLES

The test was carried out on drilling fluids of appropriately measured samples. It was based on the fact that 1gm/350cm³ of the sample is equivalent to 1lb/bbl (42gal) of the actual mud system [9]. Also 8.33cm³/350 is equivalent to 1gal/bbl (42gal) of the actual mud system.

1lab barrel = 350cm³ (final volume 1gm=1b, 1gallon = 8.33cm³).

The water-based mud was formulated by adding appropriate concentrations of the materials into the base fluid (water) to obtain 1bbl (350ml) with measured mass. A Hamilton beach mixer was used to obtain a homogenous mixture. The LCMs under review formed part of the materials used in formulating the mud samples used for experiment. Below is the formula for mud samples developed for the study.

Table 1 Mud Formulation

S/N	MATERIAL	MASS(g)	MIXING TIME (mins)
1	Water	350	1
2	Caustic Soda	0.5	2
3	Soda Ash	0.5	2
4	Bentonite	25	15
6	PAC R	5	10
7	LCMs	50	15

PROCEDURE:
The mud samples were prepared using the formula stated in table 1 above. The mixing order was according to the numbering and the mixing time stated above. The Hamilton Beach mixer was used for efficient mixing.

2.4 DETERMINATION OF MUD DENSITY

Mud density is used to control subsurface pressures and stabilize wellbore and it is commonly measured with a mud balance capable of +0.1lb/gal accuracy. A mud balance calibrated with fresh water at 700 + 50 should give reading of 8.3 lb/gal [9]. When we drill the wellbore, we replace a cylinder of rock with a cylinder of mud. The first critical step towards designing a drilling fluid is to establish the mud weight required to provide the correct level of borehole pressure support. Mud balance is the instrument used for drilling fluid density determination. 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.

PROCEDURES:
1. The cup of the mud balance was filled to the brim.
2. The filled mud cup was covered with the cap to allow excess mud and air out of the cup.
3. The mud balance was cleaned of any excess mud while holding the cap tightly to the cup.
4. The mud balance was made to balance on the provided knife edge using the rider.
5. When balanced, the reading on the scale as indicated by the arrow was recorded.

2.5 DETERMINATION OF WATER BASED MUD (WBM) RHEOLOGY

The Mash Funnel and the Graduated mud Cup was used to determine the Funnel Viscosity. The FANN 33 viscometer was used to measure the plastic viscosity (PV), yield point (YP), and gel strength. Rheological properties measured with a rotational viscometer are commonly used to indicate solid buildup flocculation or de-flocculation of solids, lifting and suspension capabilities, and to calculate hydraulics of drilling fluid. A rotational viscometer is used to measure shear rate or shear stress of drilling fluid from which the Birmingham Plastic parameters; plastic viscosity (PV) and yield point (YP) are calculated directly. The instrument was also used to measure gel strengths. The plastic viscosity is due to the physical size and presence of any solids or emulsified droplets in the fluid. The PV should be as low as possible and to reduce the PV we need to reduce the solids as well. The yield point is the viscosity due to the chemical attraction between the particles and to increase the YP, we need to add products with attractive forces. The Gel strengths refer to the increase in viscosity at zero shear rates. It is a measure of the attractive forces under static conditions. The equations to calculate the rheological properties, plastic viscosity and yield point are stated in equations below. The gel strength was read directly from the viscometer.

Plastic viscosity (PV) = $\Theta 600 - \Theta 300$ (1)

Yield point (YP) = $\Theta 300 - PV$ (2)

PROCEDURES:
Place the VG Meter cup containing the sample on the VG Meter platform and raise the platform until the mud level reaches the scribed line around the VG Meter sleeve.
1. Tighten the screw to hold the platform in place while using the VG Meter.
2. Pull the red knob up or push it down only with the meter running.
3. Toggle the switch in the high-speed position, the sleeve will be turning at 600rpm. The first reading will be

taken at 600rpm. Record the reading.
4. Toggle the switch to the low-speed position with the red knob still all the way down. This will shift the sleeve to 300 rpm where the second reading is taken. Record the reading.
5. Push the toggle switch off for 10 seconds. After 10seconds push the switch back on to the low-speed position while watching the dial. The dial turned to a high number and then fell back to a lower value. The highest dial value is taken before it dropped back as the 10sec Gel strength.
6. The VG meter cup is turned off again without changing the position of the red knob for 10mins. After 10mins the toggle switch is pushed low while watching the dial. The highest value reached before the dial falls back is the taken as the 10mins Gel strength
7. The procedure is repeated for with all the LCM mud samples.

2.6 DETERMINATION OF FILTRATE VOLUME AND MUD CAKE THICKNESS

This test determines the rate at which fluid is forced through the filter paper under specified conditions of time, temperature and pressure. The test is conducted at 100psi and the filtrate volume is read and recorded after 5mins, 10mins, 15mins, 20mins 25mins and 30mins. The thickness of the solid filter cake deposited 32nd of an inch is measured after the test.

PROCEDURE:
1. Mount the API filter press apparatus on the work table.
2. Remove the cell from the rack if not already removed disassemble the cell.
3. Fill the cell with mud sample to 3-4cm to the brim of the cell.
4. Cover the cell body with the regulator cap and place the assembly into the filter press stand.
5. Back off the T screw on the regulator fully but without removing the t-screw. Place the CO2 cartridge in the cartridge barrel and fasten to puncture the cartridge (ensure no leakage of CO2).
6. Place a 25ml graduated measuring cylinder under the cell to collect the filtrate.
7. Pressurize the cell to 100psi by turning the T-screw clockwise and pushing the red knob in.
8. Start the timer and run the test for 30mins. Values of mud filtrate were taken at 0-5th mins, 5th – 10th mins, 10th- 15th mins, 15th – 20th mins, 20th – 25th mins and 25th – 30th mins.
9. The filtrate volumes were recorded and the filter cake thickness observed.

III. RESULTS AND DISCUSSIONS

The results of the experiments for the measurement of the already stated properties of the nine formulated mud samples are presented here. All the experiments were done in triplicates and the average values reported. These results are hereby presented and discussed.

3.1 ANALYSIS OF WATER BASED MUD

Drilling mud samples were formulated according to standard API procedure. This includes the blank or control mud sample which was formulated without the use of any LCM. In the 2nd, 3rd and 4th mud samples, fine, medium and coarse $CaCO_3$ respectively were used as LCM. While for the 5th, 6th and 7th mud samples, fine, medium and coarse sawdust respectively were used as LCM. The results of the analyses carried out on the prepared mud samples are presented and discussed below. They include mud density/ weight, funnel viscosity, plastic viscosity, yield point, gel strength, fluid loss or filtrate test and mud/ filter cake test.

3.2 MUD DENSITY

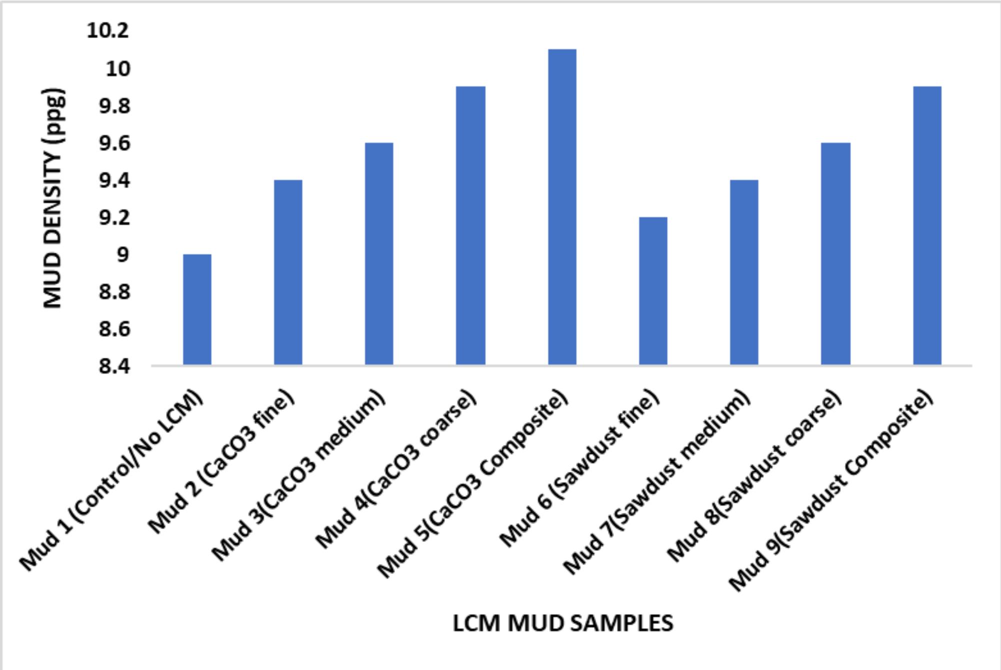

Figure 1 MUD DENSITY

Mud density is a very important property of the drilling mud because it is important in controlling the formation pressure while drilling and very important in maintaining the wellbore stability.

From the result in figure 1 above, it can be seen that the mud sample 5 ($CaCO_3$ composite) had the highest mud weight of 10.1 ppg, followed by mud 4 ($CaCO_3$ medium) and mud 9 (Sawdust composite) with 9.9 ppg each. Also, the mud sample 1(control/ no LCM) had the least mud weight of 9.0ppg, followed by Mud 6 (Sawdust fine) with 9.2ppg and Mud 2 ($CaCO_3$ fine) and Mud 7 (sawdust medium) with 9.4 ppg each.

Generally, all the mud samples had a good mud weight of 9.0ppg and above, which is good enough for surface – hole drilling purpose, meeting up with the standard mud weight range of 9 – 12ppg.

However, comparing from the results, Mud 7(Sawdust medium) had the same value of 9.4ppg with Mud 2 ($CaCO_3$ fine). Mud 8(Sawdust coarse) of 9.6ppg had the same mud weight as Mud 3($CaCO_3$ medium) of 9.6ppg.

The results of the mud density or mud weight obtained from this study shows that saw dust of various particle sizes and their composite samples, when used as LCM in mud formulations can give similar results of mud weight as conventional LCMs like $CaCO_3$.

3.3 RHEOLOGICAL PROPERTIES

The FANN 35 viscometer was used for the experiment and the result of the VG meter readings were used for calculations to generate the values for the Plastic Viscosity, Yield Point and gel strength, while the funnel viscosity was determined using the Marsh funnel and graduated mud cup. The results are presented in figure 2 to 5 below.

3.3.1 RHEOLOGY PARAMETERS

3.3.1.1 FUNNEL VISCOSITY

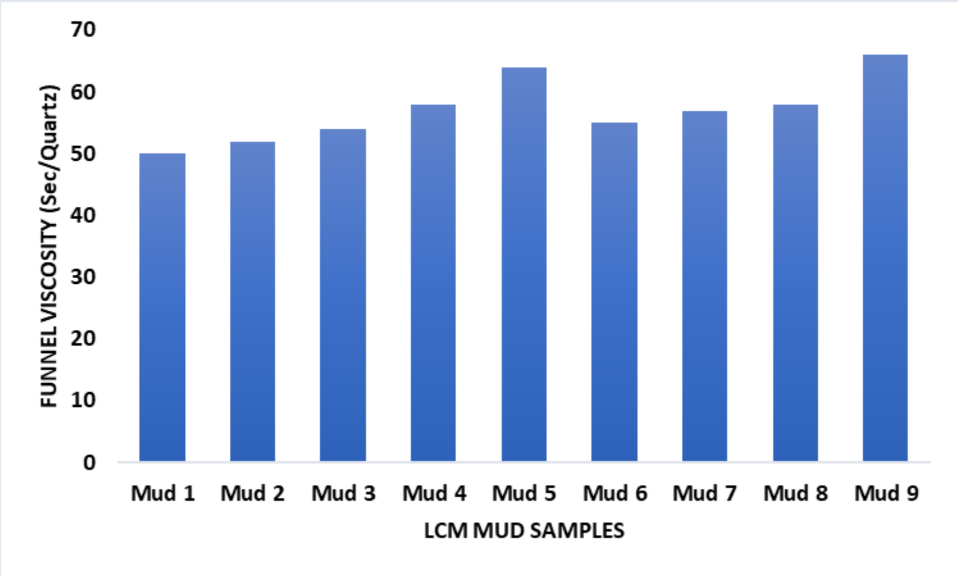

Figure 2 FUNNEL VISCOSITY

Funnel viscosity is defined as seconds for one quart of mud to flow through a Marsh funnel. It is a measure of the resistance of flow observed in a suspension, without considering the underlying interactions. Funnel viscosity quantifies the flowability of the drilling fluids. It is not a true viscosity but serves as a qualitative measure of how thick the mud is. The unit is sec/qt.

The study reveals that mud 9 being the mud sample which used sawdust composite as LCM had the highest Funnel Viscosity (66 sec/qt), followed by mud 5 ($CaCO_3$ composite) with 64 sec/qt, while mud 1, being the control mud sample without any LCM had the lowest (50 sec/qt). However, the mud samples formulated with $CaCO_3$ of various particle sizes had similar values with the mud samples prepared with sawdust of various particle sizes. This can be seen with mud 4 and mud 8, which has the same Funnel Viscosity of 58 sec/qt which are the coarse particle grades of $CaCO_3$ and sawdust respectively. The same similarity also exists between mud 3 ($CaCO_3$ medium) with funnel viscosity 54 sec/qt and mud 6 (sawdust fine) of 55 sec/qt, as can be seen in figure 2.

Generally, the results showed that the mud samples with the composite LCMs of sawdust and $CaCO_3$ produced better results than the individual mud samples prepared with the various particle sizes alone. Comparing the effects of sawdust in the funnel viscosity of drilling mud with that of $CaCO_3$, the results showed that sawdust produced similar result with $CaCO_3$, for the various particle sizes alone and even a better result with the composite sawdust LCM mud sample.

This shows that sawdust can be used as a good substitute or replacement for $CaCO_3$ as LCM in water-based mud. Again, the result shows that the funnel viscosity of the mud sample with sawdust composite is higher than that of $CaCO_3$ composite. It can therefore be deduced that Sawdust would be a good substitute for $CaCO_3$ as LCM in Water Based Mud.

3.3.1.2 PLASTIC VISCOSITY

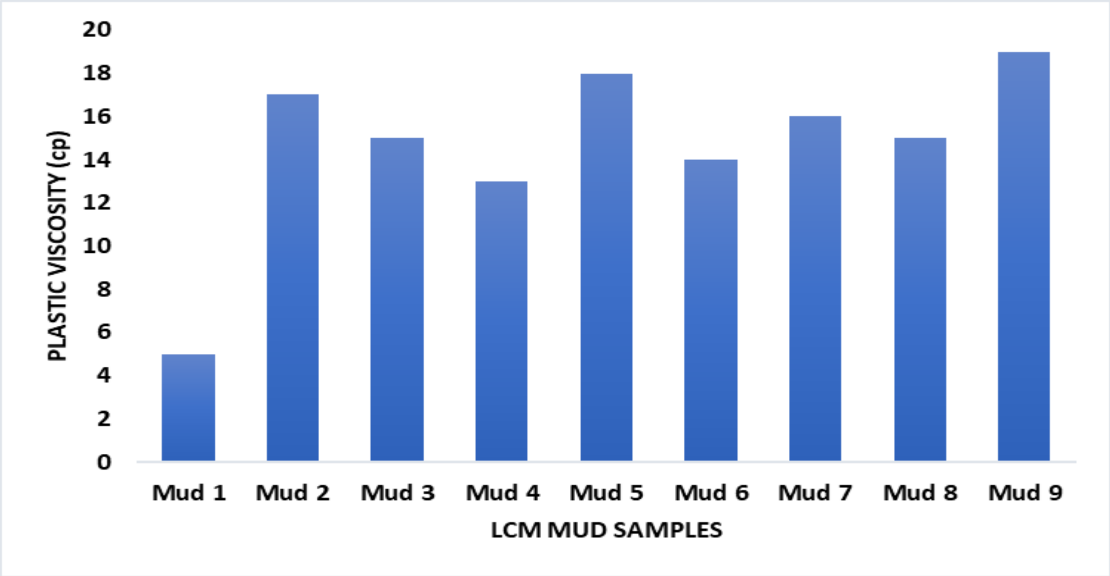

Figure 3 PLASTIC VISCOSITY

Plastic viscosity PV is a combination of resistance to flow caused by the friction between the suspended solids and the based fluid in the drilling fluid. A high PV may be caused by viscous base fluid and excess solids. A high plastic viscosity is associated with wellbore problems, while the low plastic viscosities at high temperature indicate that the mud formulations are lubricious and are capable of a fast rate of penetration (ROP). Mud formulations that retain their rheological properties and have low PV at high temperatures are suitable for use as drilling fluids.

The result of the study showed that mud 9 (sawdust composite) with 19cp had the highest PV, followed by mud 5 ($CaCO_3$ composite) with 18cp, while mud 1 (control) with 5cp had the lowest PV. The mud samples prepared with each particle size of the sawdust and $CaCO_3$ had similar values, without any significant differences, ranging from 13cp to 17cp, across the various particle sizes. Mud samples prepared with the composite particle sizes of the LCMs (mud 5 and mud 9) had higher PV values than the ones with individual particle sizes.

From the result presented in figure 3, it can be seen that there is no much difference between the PV of mud samples prepared with saw dust as LCM and that of $CaCO_3$. Also, the mud sample with composite sawdust (mud 9) as LCM produced the highest PV. Hence, saw dust can serve as a good substitute for these conventional LCMs in drilling mud formulations.

3.3.1.3 YIELD POINT

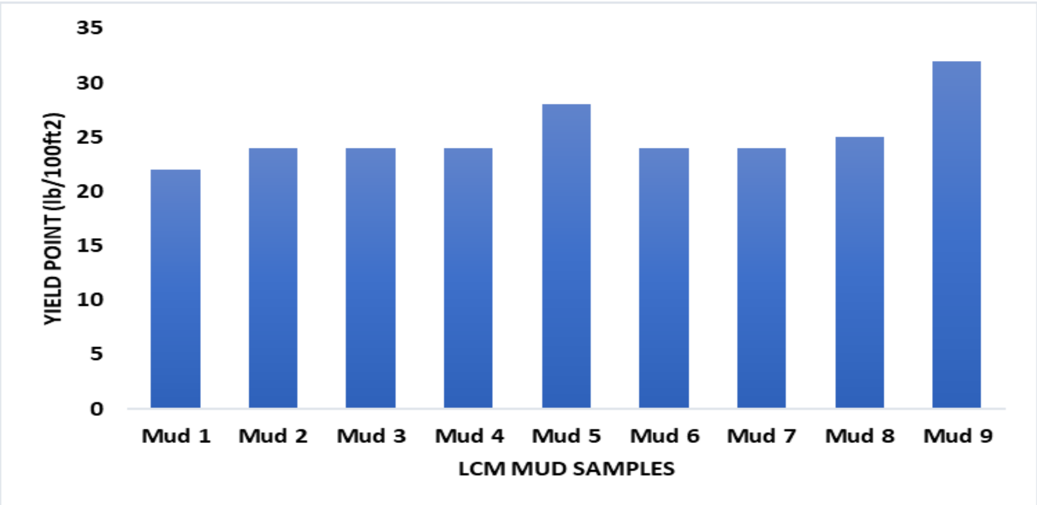

Figure 4 YIELD POINT

Yield Point YP shows an indication of the drilling mud to suspend weight materials and remove cuttings from the wellbore. It reflects the resistance to initial flow or the stress required to initiate fluid movement. A mud with higher yield point will carry cuttings better than the one with lower yield point, even if both have the same mud density.

The result of the study shows that mud 1 (no LCM) being the control mud sample had the least YP of 22 lb/100ft^2, while mud 9(sawdust composite) had the highest YP of 32 lb/100ft^2, followed by mud 5 ($CaCO_3$ composite) with 28 lb/100ft^2. The mud samples prepared with each particle size of the sawdust and $CaCO_3$ had similar values, without any significant difference, ranging from 24 lb/100ft^2 to 25 lb/100ft^2, across the various particle sizes.

This result as can be seen in figure 4, shows that the mud samples prepared with sawdust composite (mud 9) and $CaCO_3$ composite (mud 5) as LCM has the highest capacity to suspend and release cuttings from the wellbore.

Hence sawdust, especially the composite of the particle sizes can serve as a good replacement for the conventional LCMs in drilling mud formulations.

3.3.1.4 GEL STRENGTH

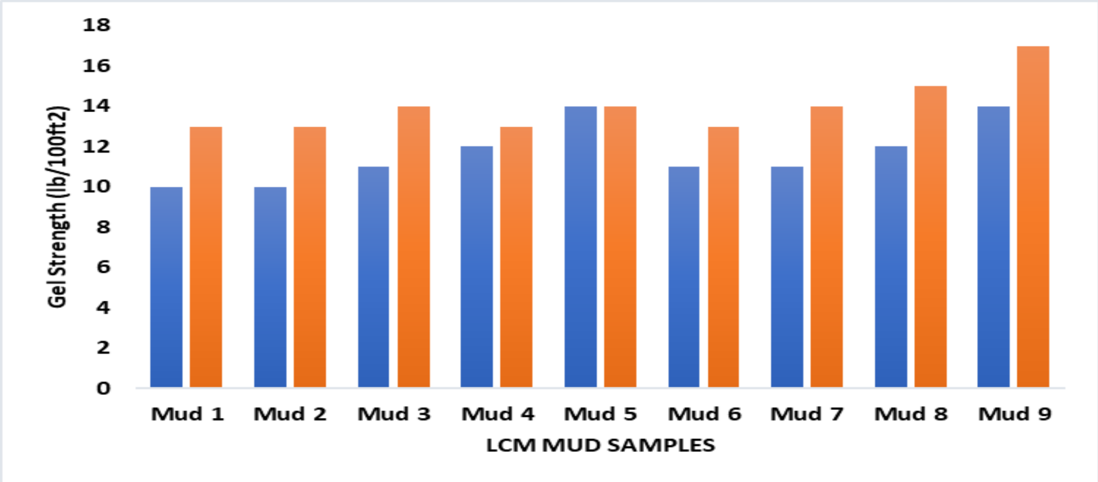

Figure 5 GEL STRENGTH

Gel Strength is a property of mud that enables it suspend cuttings when pumping or circulation has been stopped. It measures the attractive forces of mud particles under static conditions for 10 seconds and 10 minutes. It also helps to determine if cuttings would settle in the wellbore under static conditions. The ability to maintain the proper value of gel strength depends on effective solids control. A reasonable gel strength is vital to prevent immediate settling of solids when circulation has stopped.

From the result of the study, mud 1 and mud 2 had the least Gel Strength (10 lb/100ft^2 and 13 lb/100ft^2 for 10sec and 10min gel respectively), while mud 9 had the highest Gel Strength (14 lb/100ft^2 and 17 lb/100ft^2 for 10sec and 10min gel respectively) as shown in figure 5.

From the results, mud samples that used saw dust as LCM displayed a good Gel Strength when compared to the conventional LCM $CaCO_3$. This shows that sawdust has the tendency to be used as replacement for other conventional LCM.

Also, mud 9 which was prepared using sawdust composite, showed the highest gel strength, which makes it to show the best capability to suspend cuttings when pumping or circulation has been stopped. It is therefore advised that the composite sample of the various sawdust particle sizes be used as LCM in the preparation of water – based drilling fluids.

Generally, it can be seen that most of the mud samples that showed a high yield point also had a high gel strength. Hence, we notice that for the mud samples used in the study, Gel Strength increased with increase in Yield Point.

3.4 FILTRATION TEST

3.4.1 FLUID LOSS WITH RESPECT TO TIME

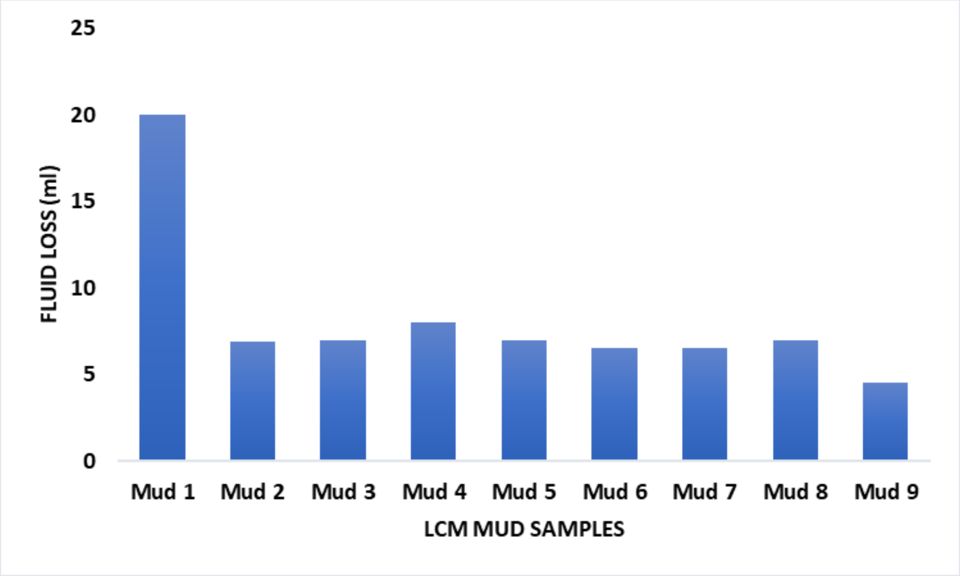

Figure 6 FLUID LOSS

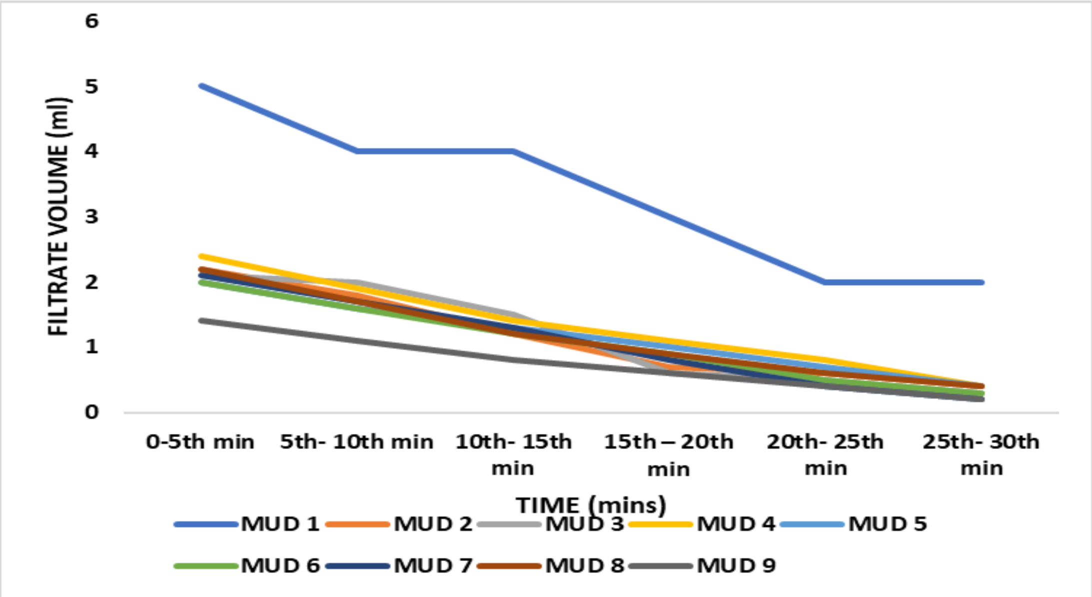

Figure 7 FLUID LOSS WITH RESPECT TO TIME

The term Fluid Loss or mud filtrate is used to refer to the fluid of drilling mud that filters into the formation in the process of drilling. It is the liquid part of mud which passes through a medium and become separated from the mud cake or filter cake. Reducing the volume of filtrate in drilling operations can reduce several problems associated with drilling.

The result in figure 6 shows that mud 1 being the control mud sample had the highest filtrate volume of 20ml, while mud 9 had the least filtrate volume of 4.5ml, followed by mud 6 and mud 7, which had 6.5ml each, over a period of 30 minutes, when the API Filter press was used to determine the filtrate volume of the mud samples at 100psi.

Figure 6 shows that the mud samples prepared with sawdust LCM also had good filtrate control ability as they recorded moderate filtrate volumes. This is because they showed similar and lower values of fluid loss with the mud samples prepared with $CaCO_3$, with filtrate volume range of 6.6ml to 7ml.

Mud 9 being the mud sample prepared with the sawdust particle size composite showed the best filtrate or fluid loss control ability, as it had the least filtrate volume. Also, all mud samples showed fluid loss that falls within the acceptable range of 3 – 7ml.

Figure 7 shows a relationship between fluid loss or filtrate volume of the various mud samples under review and time. This shows that the amount of fluid being lost from the mud reduces with respect to time in the course of drilling operation. This could be understood, as more filter cake is formed with time, plugging of the porous formation and thereby reducing the amount of filtrate seeping into the formation.

However, the rate at which the volume of fluid lost from the mud with time varied for different mud samples, as shown in figure 7.

3.4.2 MUD/ FILTER CAKE THICKNESS

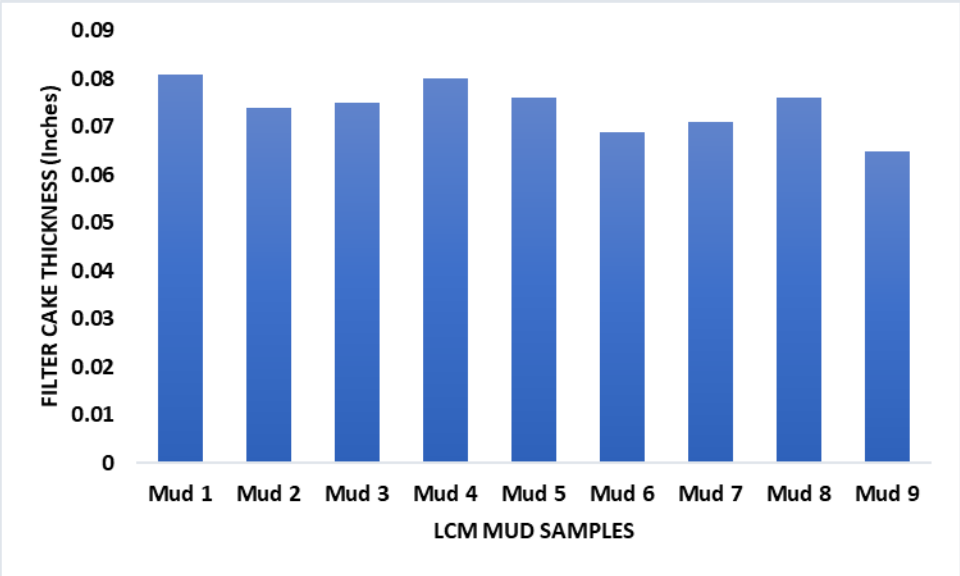

Figure 8 MUD/ FILTER CAKE THICKNESS

Filter or mud cake is a very thin layer of solid particles deposited from the drilling fluid onto the surface of the drilled formation. This is very important during drilling process because it helps to reduce fluid filtrate invasion, thereby contributing to the wellbore stability. In drilling operations, it is better to have a filter cake that is impermeable and thin. Thin mud cake is always desired because thick mud cake would lead to increase in torque, drag while tripping out of the hole or logging, and can cause differential sticking.

From the results shown in figure 8 above, mud 1 had the highest filter cake thickness of 0.081”, followed by mud 4 with 0.08” .

Mud 9 (sawdust composite) had the least filter cake thickness of 0.065” . The rest of the mud samples had similar or related filter cake thickness ranging from 0.069” to 0.076” .

From the results, there is an indication that mud 1 with no added LCM would show a higher filtrate volume, as seen in the result of the fluid loss test in figure 6 above. Again, there is no much difference between the filter cake thickness of the mud samples prepared with sawdust as LCM and the ones prepared using other conventional LCMs ($CaCO_3$). The lower filter cake thickness of mud 9 makes it more suitable to reduce the amount of filtrate passing through it in the course of drilling operations. These results show that sawdust especially when used as LCM (especially composite sample of the particle sizes) has the tendency and capability to serve as a replacement for the conventional LCM in drilling fluid formulations.

IV. CONCLUSION

After a careful consideration and study of the results obtained in the course of this study, the study hereby concludes thus;

Sawdust has a better filtrate control ability than the conventional LCM under review ($CaCO_3$), hence can serve as a good replacement for $CaCO_3$ as LCM in the formulation of water- based drilling fluids.

Sawdust facilitated a good (thin) filter cake formation in the mud samples in which it was used as LCM, thus can serve the same purpose as the conventional LCM.

The rheological properties exhibited by the mud samples prepared with sawdust showed much similarity with the ones prepared with conventional LCMs. Hence sawdust can serve as a good LCM in place of the conventional LCM under review.

V. RECOMMENDATION

It is recommended that further studies be carried out to ascertain the rheological and filtrate control capacity of mud samples formulated using sawdust of different particle sizes combination in one mud formulation and varying the concentrations of the different particle sizes. Hence, performing experiments with a combination of sawdust fine and medium as an LCM, sawdust fine and coarse, and sawdust medium and coarse, or even a composite of the three particle sizes. Studies should also be carried out using a combination of sawdust and $CaCO_3$, to ascertain the best combination of LCM that can be applied in drilling fluids formulations. This would help to ascertain if the particle size combination would improve more on the rheological properties and filtrate control capacity of sawdust as LCM in drilling muds.

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