An experimental investigation of the effect of using a biomaterial on the efficiency aqueous-base drilling mud at low temperatures

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ABSTRACT

Weighted and unweighted aqueous mud formulations from a biomaterial, at cold temperature of 5^{o}C, were tested for their rheological characteristics. Based on API guidelines and recommended equipment for drilling fluid tests, the rheological properties of the formulations were determined. The muds exhibited pseudoplastic behavior. The fluid loss volumes of the weighted and unweighted muds are 14ml and 21ml, respectively, while the filter cake thicknesses are 2.5mm and 3mm respectively. The yield stresses of the weighted and unweighted muds are 209 lb/100ft^2 and 159 lb/100ft^2 respectively. Plastic viscosity of 42cP for the weighted mud against 23cP for the unweighted mud showed that the weighted mud has a better cutting lifting capacity if PV is used as an indicator. Mucuna solannie additive can also perform in cold temperature, and has the potential to be used in cold temperature drilling.

Keywords: *biomaterial, cold temperature, fluid loss, rheological properties*

1. INTRODUCTION

Drilling fluids for Oil and Gas industry are complex mixtures of natural and synthetic chemical compounds used to achieve several goals. In addition to several functions, drilling fluids are fluid compositions used in drilling operations to provide primary control of the subsurface pressure of the formations. These fluids are Non-Newtonian and generally pseudoplastic in nature. Drilling fluid is related either directly or indirectly to most drilling problems giving the Drilling Engineer, the task of selection and maintenance of the best drilling for the job [2]. They do not conform to Newtonian law due to larger particles than molecules they contain in significant quantities and thus are classified as non-Newtonian fluids [1] as shown in Fig 1 and Fig. 2. It ranges from ordinary water-base or oil-base to more complex systems like the compressed air and synthetic polymers [1].

To enhance the performance of drilling fluids, additives are added to achieve a desired composition for a given purpose. These additives comprise viscosifiers, dispersants, weighting materials, surfactants, shale inhibitors, lost circulation materials, filtration control additives and salinity control chemicals.

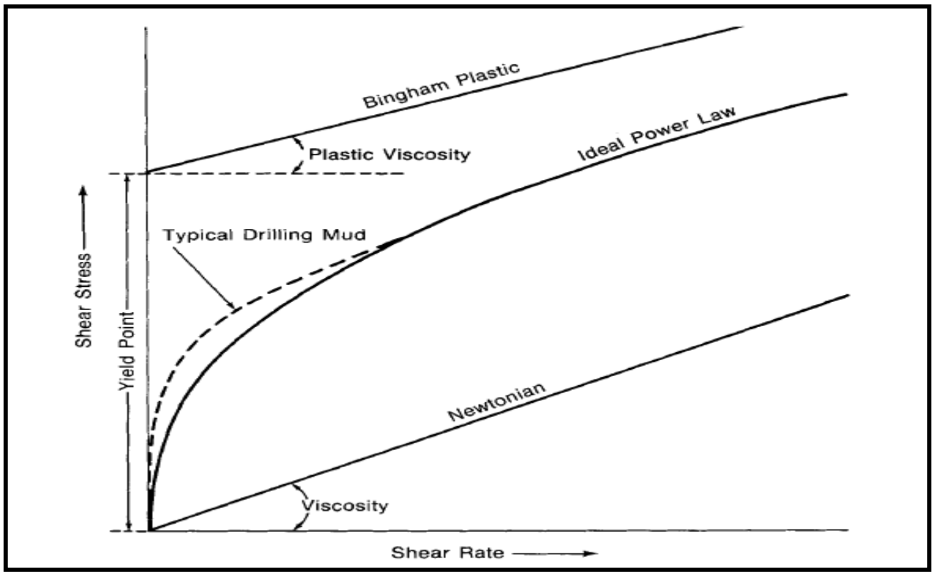

Figure 1: Ideal Consistency Curves for common flow models [1]

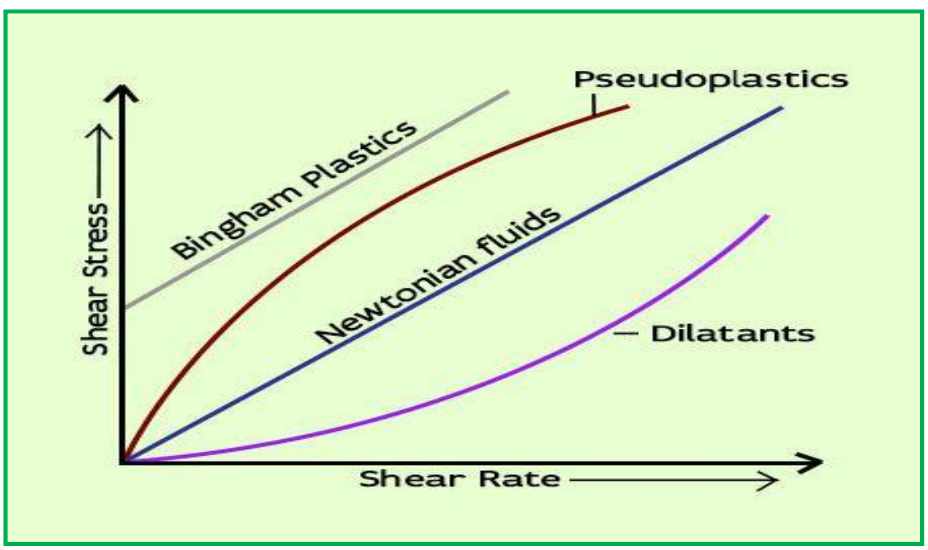

Figure 2: Comparison of shear stress, shear rate properties and yield point [2]

The number of additives present in a particular composition depends on the type of formation being drilled, subsurface conditions (pressure and temperature), local experience, costs, logistics and the recommended drilling program [1].

The principal functions of a drilling fluid amongst others are Removal of cuttings from below the bit to the surface and control subsurface pressure, Lubrication and cooling of the bit and drill string Formation of filter cake to prevent fluid loss and maintain wellbore stability. Usually the circulation cycle of the drilling fluid in the fluid columns starts from the uppermost component of the drill string and through drilling bit. It collects cuttings at the well bottom, makes a U-turn, and flows to the surface through the annulus.

The functions demonstrate the importance of drillings fluid in any drilling program and the need to carefully study its formulation and properties, since one property can provide more than one function.

The continual use of synthetic polymers from the foreign market has become expensive and in most cases, not suitable for some formations. Therefore, the need to source for local materials with peculiar characteristics to introduce specific behaviors to the drilling mud formulation cannot be overemphasized. This is completely in line with the local content policy currently advocated in Nigeria.

2. LITERATURE REVIEW

Many researchers have studied the effects of local materials additives on drilling fluid characteristics. Mostly, the concentration has been on the rheological behavior (viscosity and fluid loss properties) of these additives on aqueous mud.

The advantages of aqueous formulations include high true yield strength, higher shear thinning, and reduced circulating pressure losses and good bit hydraulics [6].Furthermore, it is less expensive. Use of rice husk in aqueous mud as a fluid loss control additives has been studied. A sample of rice husk from a local mill was dried by placing it in the vacuum for 3-4hours at about 45°C and the moisture content was removed. The dried sample was ground into smaller sizes with a blender and then sieved to 125 microns to obtain fine particles [3]. It was found that rice husk compares favorably with standard polymers like poly-anionic cellulose (PAC) and carboxymethyl cellulose (CMC) except that it requires twice the quantities of the standard polymers [3]. This is due to the presence of lignin (pheny propanoid polymer) which is naturally present in the rice husk. It was also found that the rice husk has less filter cake thickness than the standard polymers. This shows that the bound mud particles in rice husk are more compressible than those of the standard polymers [3].

Another research investigated the use of cassava starch flour in bentonite as an additive to control fluid loss and viscosity in aqueous mud [4]. Different samples of mud were formulated from different masses of cassava starch flour (2 g, 4 g, 6 g and 8 g) and an additional one being the control bentonite (without cassava starch flour). Fluid loss and rheological tests were conducted to determine the yield point, gel strength, plastic viscosity and other rheological parameters of the various samples [4]. Results show that the introduction of cassava starch flour into the mud samples from concentrations of 2 g to 8 g reduced its fluid loss by an average of 8 % [4]. The swelling ability of the cassava starch flour caused an increase in the quantity of the cassava starch flour in the aqueous mud and increased mud viscosity. Also, greater suspension ability of the cuttings (gel strength) and reduced filter cake thickness was observed with lesser amount of cassava starch flour [4].

Another research work investigated the effect of locally biodegradable and environmentally friendly additives such as corn cobs from *Zea Mays* and coconut shells from Cocosnucifera on rheological properties [5]. With different concentrations, their effects were evaluated on fluid loss properties using low pressure low temperature (LPLT) filter press at 90 °C and 100 psi. The results of the formulated mud with the two additives (corn cobs and coconut shell) were compared to the individual mixtures of corn cobs and coconut shells, and without any additive [5]. Results from the experiments show that a decrease in pH values was observed with increasing concentration of the 3 samples. As the concentration of the additives increased, the density of the mud increased also. But the reverse is the case for the third sample which is the combination of the two additives. Another result showed that corn cobs are better fluid loss control additives than the coconut shell but the combination of both yields a better result [5].

Similarly, a comparative analysis of the effects of cashew and mango extracts on the rheological behavior of aqueous mud has been carried out [7]. Fresh leaves of mango and cashew were washed and rinsed with tap and distilled water respectively [7]. The raw materials were added in different concentrations to the mud formulation and three different samples were prepared [7]. The mud had a pH of 9.1 which is alkaline. Increase in concentration of the two extracts showed an increase in gel strength but the mango extract sample gave the highest gel strength. From all the parameters studied, it is concluded that mango extracts improve rheological properties more than cashew extract [7].

3. MATERIALS and METHOD

3.1 Equipment and Raw Materials

The equipment used include the mud balance, rotary viscometer, spatula, weighing balance, wash bottle, measuring cylinder, beaker, stop watch, mixer and low pressure low temperature (LPLT) filter press. The raw materials used for the unweighted mud are fresh water, caustic soda, Mucuna solannie, Brachystegia eurycoma, Pleurotus and XCD polymer. The additional raw materials for the weighted mud are barite and Potassium chloride.

In this compound Water the base fluid and acts as a carrier for mud additives and Potassium Chloride (KCl) is used to an inhibits clay hydration.XCD Polymer is used to achieve viscosity and fluid-loss control in mud formulations. Finally utilizing Sodium hydroxide (Caustic soda) to controls the pH of the formulation. Pleurotus contains high concentration of fiber and can function as the main source of the fluid loss control in mud [8].

Brachystegia eurycoma locally known as ‘Achi’ in Igbo Language serves as a thickener to improve the gel strength of the mud. Barite is the weighting agent and increases the ability of drilling mud to balance the formation pressure and suspend cuttings. Mucuna is of the family of Fabaceae. It is a genus of over 100 accepted species of climbing vines and shrubs [8]. The plants bear pods and their seeds are buoyant in aqueous medium. Common among the species are M.pruriens, M. hoitoni, M.flagellipes, M.solannie etc.

The M.Solannie commonly known as 'Ukpo' in Igbo Language is traditionally used as efficient food thickeners. This specie can equally be used in beverage and other food producing industries.

The M.Solannie is added to the drilling mud formulation to act as a viscosifier and a gelling agent.The effects of Mucuna solannie on weighted and unweighted muds under low pressure and low temperature was investigated in the experiments. The compositions of these additives are presented in Table 1.

Table 1: Concentrations of additives for weighted and unweighted mud

Material	Unweighted mud	Weighted mud
Fresh water	350 ml	350 ml
Caustic soda	0.25 g	0.25 g
Mucuna solannie	3 g	6 g
Brachystegia eur.	3 g	6 g
Pleurotus	3 g	8 g
XCD polymer	0.75 g	1 g
Potassium chloride	-	20 g
Barite	-	75.4 g

3.2 Experimental Procedure

The unweighted mud (Sample A) was prepared by pouring 350cm3 of water into a mixing cup and other additives were added in the concentrations given in

Table 1. This mixture was allowed for 10hrs for aging. Then mixing was carried out with the Hamilton Beach mixer for 1h: 30mins to achieve homogeneity.

After this time interval, agitation was stopped and temperature checked to make sure it's within the 5^{o}C temperature target. The mud weight was taken with a mud balance.

The next step was the determination of the viscometer readings and the sample was placed in an OFITE six-speed model viscometer where readings at 600rpm, 300rpm, 200rpm, 100rpm, 6rpm and 3rpm were taken in accordance with the API guidelines.

The sample was then placed in the low pressure filter press equipment for 48hrs and the filtrate was collected in a measuring cylinder. Readings for the filter cake thickness and fluid loss volume were taken.

The same procedure was followed for the weighted mud (Sample B) except that the formulation composed of a 75.4g barite ($BaSO_4$) and a 20g Potassium chloride (KCl). These additives were introduced for weighting and clay hydration inhibition purposes. Readings for the different parameters were recorded and tabulated as shown in Tables 2 – 5.

4. RESULTS and DISCUSSION

The viscometer readings at 600rpm, 300rpm, 200rpm, 100rpm, 6rpm and 3rpm for the weighted and unweighted mud formulations are given in Table 2 and Table 4 respectively.

The expanded equations for plastic viscosity (Pv), apparent viscosity (Av) and yield point (Yp) from viscometer readings are given in equations 1 – 3 [9]:

1. $Y_p = \theta_{300} - Pv$
2. $Pv = \theta_{600} - \theta_{300}$
3. $Av = \frac{\theta_{600}}{2}$

The above equations are used to calculate the values for the plastic viscosity, apparent viscosity and yield point as presented in Tables 2 and Table 4.

Table 2: Rheological test results for weighted mud

Shear Rate and Rheological Properties	Value
600rpm	293
300rpm	251
200rpm	213
100rpm	169
6rpm	97
3rpm	72
Pv	42
Av	147
Yp (lb/1002)	209
Fluid loss volume (ml)	14
Filter cake thickness (mm)	2.5

Similarly, Equations 4 – 5 are used to compute the values of the shear rate, shear stress and viscosity [9].

4. Shear rate = 1.703 × RPM

5. Shear stress =5.11× Dial reading

That's 1.06 = Geometry factor of the viscometer and where 0.4788 is the Conversion factor from $lb/100ft^2$ to Pascal To calculate Viscosity applied shear stress divided by shear rate.
Therefore, the shear rate, shear stress and viscosity values for the various readings are tabulated in Table 3.

Table 3: Calculated results from weighted mud test

Rotor speed (rpm)	Dial Reading	Shear Rate (1/s)	Shear Stress (Pa)	Viscosity (cp)
600	293	1022	1497	1.46
300	251	511	1283	2.5
200	213	341	1088	3.19
100	169	170	864	5.08
6	97	10	496	49.6
3	72	5	368	73.6

The same procedure is followed to determine the different parameters for the unweighted mud sample.

Table 4: Rheological test results for unweighted mud

Shear Rate and Rheological Properties	Value
600 (rpm)	205
300 (rpm)	182
200 (rpm)	145
100 (rpm)	112
6 (rpm)	59
3 (rpm)	43
Pv	23
Av	103
Y_p	159
Fluid loss volume	21 ml
Filter cake thickness	3 mm

Similarly, calculated parameters for shear rate, shear stress and viscosity from results are presented in Table 5 below:

Table 5: Calculated results from unweighted mud test

Rotor speed (rpm)	Dial Reading	Shear rate (1/s)	Shear Stress (Pa)	Viscosity (cp)
600	205	1022	1048	1.03
300	182	511	930	1.82
200	145	341	741	2.17
100	112	170	572	3.36
6	59	10	301	30.1
3	43	5	210	42

4. Discussion

From Tables 3 and 5, there is a variation of viscosities at different spindle speeds. Viscosity increases as the rotor speed reduces. This is in agreement with the behavior of a drilling mud [8].

Fig. 3 shows the behavior of non-Newtonian fluids on a plot of shear stress against shear rate for the weighted and unweighted mud samples and conforms to Figs.1 & 2. Fig.3 shows that the formulated sample in this research is a pseudoplastic liquid and can be used a drilling mud.

The shear stress of the weighted mud sample is higher than that of the unweighted formulation. The rheological properties of the aqueous muds in Fig. 2 show that as the shear stress increases with increasing shear rate, viscosity decrease due to the high shear rate as the additives increases in concentration.

One characteristic of a good viscosifier is its ability to maintain stable viscosity under the attack of sodium and calcium ion [1]. From the results presented, *Mucuna solannie* has proven to be a good thickener for both samples as it ensured the samples remained viscous.

An increase in the solid content present in a drilling mud will result in high plastic viscosity. Solids can be weighting materials like barite, lost circulation materials, drill solids etc. Hence, the weighted sample has more plastic viscosity. To lower the PV, solid control equipment will be used.

Yield point Y_p is the resistance to initial flow or the stress needed to start the movement of fluid. The yield point evaluates the ability of mud to lift cuttings out of the annulus. A higher Y_p means the drilling fluid can lift cuttings better than a fluid of similar density [9].

The yield points for both samples (209 lb/100ft2 and 159 lb/100ft2) are within the API recommendations for a good drilling mud.

Fluid loss is the amount of filtrate that passes through the filter cake [9]. It is often controlled by mixing additives with the mud.

Some factors affect the property such as cake compressibility, temperature and time. Also the amount, size and nature of solids in the fluid affect it.

From the results, more fluid was lost in the unweighted mud sample (21 ml) than in the weighted mud sample (14 ml). This can be attributed to the presence of barite and a double quantity of Mucuna solannie.

An appropriate drilling mud should form a filter cake on the walls of the hole to prevent the formation from caving into the wellbore. This filter cake can prevent the invasion of the formation by mud filtrates. The quantity of the filter cake should be reasonable to minimize excess buildup of cakes in the wall which can cause formation damage and probably, differential sticking [2]. When the drilling fluid contains different sized particles, the larger particles form the skeleton of the filter cake, whereas smaller particles bridge the pore spaces [9]. This whole process is called 'wellbore stabilization'.

The weighted mud sample formed a filter cake of 2.5mm thick while the unweighted mud formed a filter cake of 3mm thick.

Filter cakes formed by both samples is reasonably accepted for their individual concentrations.

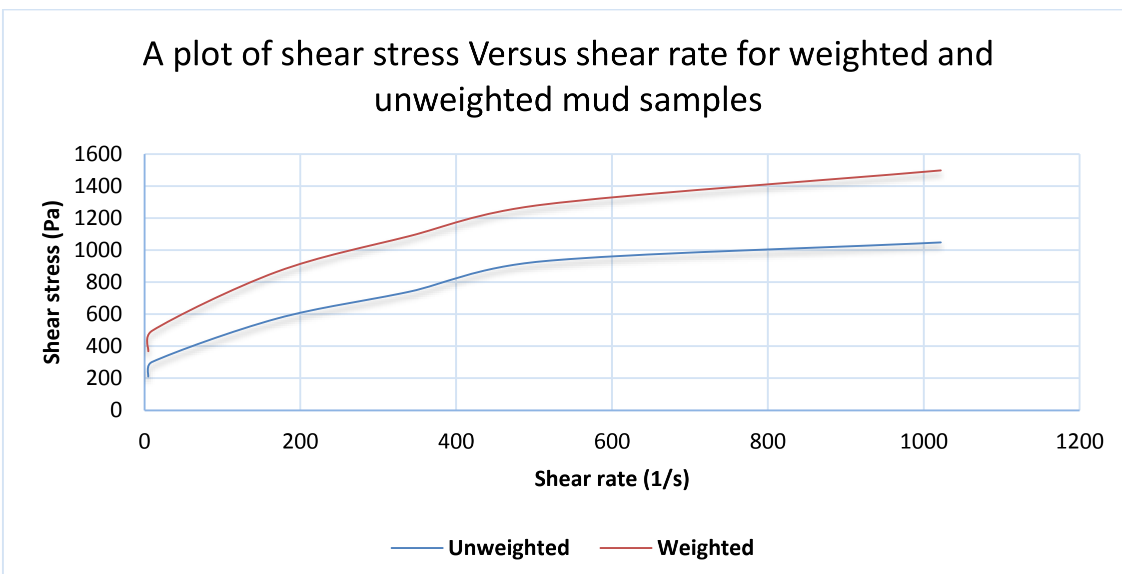

Figure 1: Rheogram for weighted and unweighted mud samples

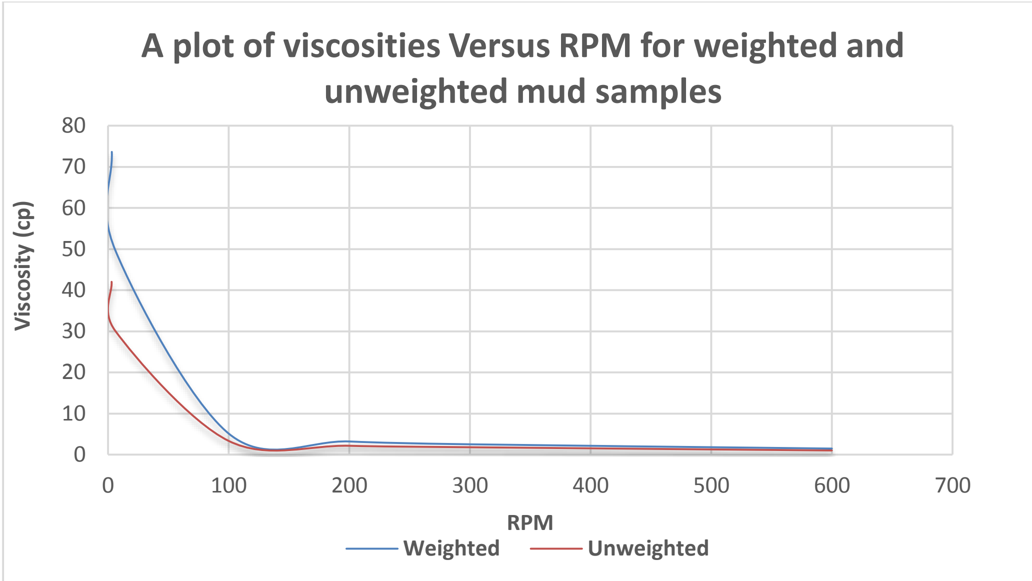

Figure 2: Viscosities Versus RPM for weighted and unweighted mud samples

5. CONCLUSION

An increase in the shear stress results in a decrease in the viscosity and *Mucuna.solannie* proved to be a good viscosifier as it maintained relatively stable velocity. Also, the formulations exhibited good fluid loss properties; the weighted mud sample had a lower fluid loss volume and filter cake thickness. More so, the weighted formulation showed better lifting capacity due to higher plastic viscosity. Generally, it can be concluded that *Mucuna solannie* has a potential as an additive in a cold temperature drilling environment due to the understandable properties the drilling muds exhibited.

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