Rheological and Filtration Properties of Kaolinite Based Drilling Mud.

Aminu Abdulkadir, Lilian Amen Osawemwenze , Gideon Majiyebo Adogbo

Abstract - The demand for drilling mud is on a high increase due to drilling operations ranging from oil wells to ground water bore holes that are being carried out. This necessitates the testing of clays that are abundant and less expensive to make drilling mud. Beneficiated Kaolin clay, barite, bentonite, starch and pipe-borne water were used in the preparation of drilling mud mixtures at various percentage compositions for 12 samples to ascertain the right formulation for the drilling mud; the rheological behavior and filtration property of each of the drilling fluid were measured. Kaolinite clay had a poor permeability as compared to bentonite, the sample with the highest bentonite ratio had the best filtration property; the analysis also showed that high water and barite content has a negative effect on the filtration property of drilling mud. Viscosity measurement were taken within $8.574s^{-1}$ and $170.3s^{-1}$ shear rates, the sample which contained 8w% of bentonite recorded the highest value of viscosity due to its high bentonite content which led to a significant increase in shear stress at a constant increase in shear rate. When the quantity of bentonite and starch were varied with kaolin there was a decrease in the permeability of the drilling mud, the lower the permeability the better the drilling mud. The addition of local bentonite improved the rheological and filtration property of the fluid which was pseudo plastic, the kaolinite clay only served as a weighting agent.

Keywords: Drilling mud, kaolin clay, Bentonite clay, Starch, Barite, Filtration Property and Viscosity.

1 INTRODUCTION

Drilling fluids carry out a lot of functions in drilling operations, additives are added to the base fluid, water or oil to make the water, oil or gas based mud to perform this task and to increase the filtration characteristics of drilling fluids [1], [2], [3]; drilling fluids properties such as apparent viscosity, permeability, density, plastic viscosity and yield point play important role in designing efficient and optimized drilling operation, it is important to ensure that drilling fluids have the right rheological properties. The control of the flow properties and the filtration rate of drilling operations are important aspects of drilling technology as rheological changes in drilling fluids have many effects on the degree of efficiency with which a fluid performs its primary functions [4]. Kaolinite clay is an important industrial clay for economic benefit and is present in almost every state in Nigeria and has a high proportion of aluminium-silicate like the bentonite clay but as reported by adogbo et al., [5], it does not have a good swelling ability but can be used as a weighting agent. The introduction of imported commercial bentonite in the year 1960 has drastically reduced the use of local clay in Nigeria for drilling in the petroleum industry which started in early 1950 [6].

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Bentonite is highly colloidal clay, which hydrates in water and greatly increases viscosity. Among others, it is added to fresh water mud to increase hole cleaning capability, reduce filtration into permeable formation, form a thin filter cake of low permeability and promote hole stability [7], [8], [9], it gives the proper rheological and filtration control properties. Attempts to use the bentonite in Nigeria has yielded little or no result because of its low yield and inability to meet up with API specification, Joel et al.,[10] carried out chemical analysis of both imported and local bentonite which indicated that the Nigerian bentonite is predominantly calcium based exchange cation while the imported sample is sodium based. This accounts for the high yield and faster hydration capabilities obtained with the imported sample than the local sample. Fossil sodium based bentonite deposited under reducing and alkaline environment can occur in tropical countries; in 1992, Terraminer reported the occurrence of more than 2 billion metric tons of bentonite reserve in Nigeria, presently proven reserve has risen to more than 4 billion metric tons, the bentonite occurs as a continuously highly fossiliferous sedimentary bed of early Mid-Eocene age[11]. Organic polymers are commonly used to control the rheology and filtrate loss required for water-based drilling fluids; starch is often used and carboxymethyl cellulose [12], [13]. Additives such as barium sulfate is often used to vary the density of the drilling fluids in order to overcome the problems related to formation pressure [2]. In this work, we extend our previous study where only Kaolinite clay, Barite, starch and water were used in producing drilling mud which did not have pseudo plastic rheological behavior [5]. Here local bentonite is being added aimed at developing a water based drilling mud, the rheological and filtration properties of the drilling mud are analysed.

2 METHOD AND MATERIALS

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The kaolinite clay was sourced from Kankara town in Katsina State, Nigeria. The starch used was prepared from cassava tubers, the barite and bentonite clay used was also from Nigeria. The preparation of the samples and the determination of their density is the same process as reported in Adogbo et al.,[5]. The viscometer reading was taken at speed of 5, 10, 20, 50 and 100 rpm, the dial readings were taken after 6 rotations of the spindle.

The permeability of the drilling mud was determined using a laboratory constant head permeameter. The water discharged into the collecting burette was measured.

The permeability of the mud samples were calculated using the relation:

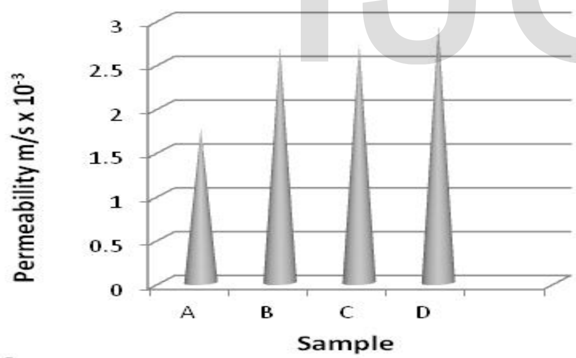
$$k=\frac{Q \times L}{19.64 \times h} \quad (1)$$

Where: K = permeability, Q = discharge of the water

L = Length of the sample cup, H = Head difference outside and inside the collecting cylinder.

3 RESULTS AND DISCUSSION

The following results were gotten after the work was carried out:



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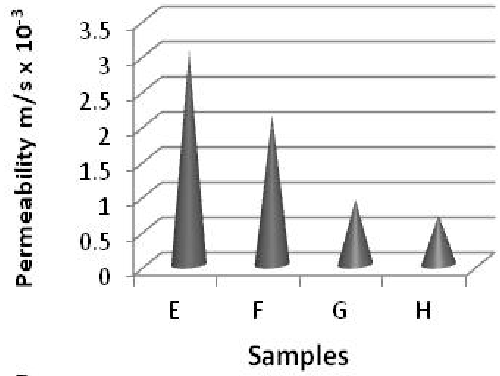

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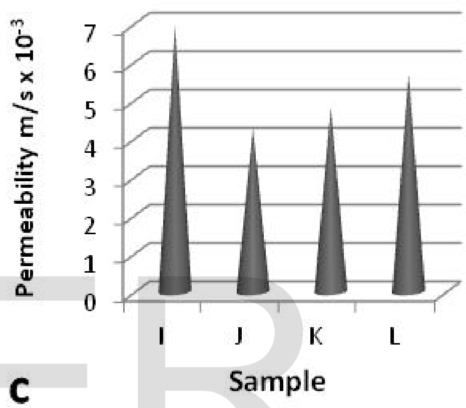

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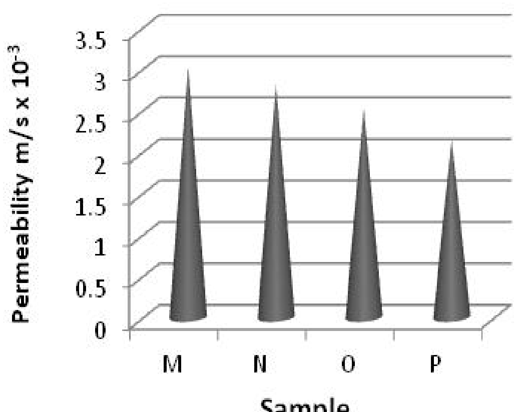

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Fig 1. Filtration property of drilling mud samples.

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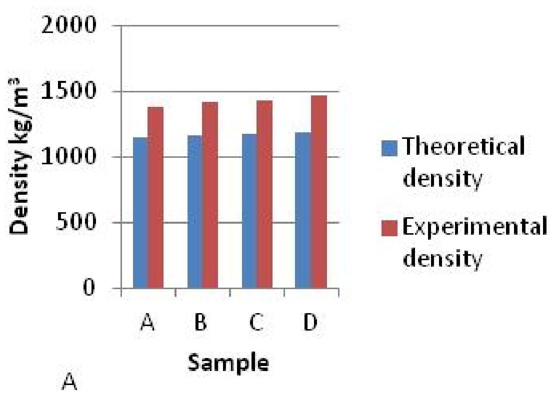
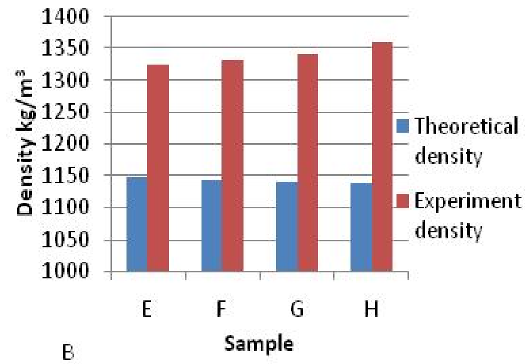
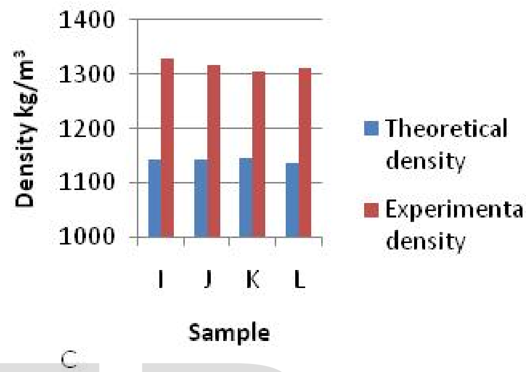
The filtration property of drilling mud is the measure of the ability of the solid components of the mud to form a thin, low-permeable filter cake. Low permeability decreases drilling difficulties because a thick filter cake restricts the passage of tools and allows an excessive amount of filtrate to pass into the formation thus causing a cave. From the Fig. 1A above, sample A has the lowest permeability which is due to the high content of kaolin, as the kaolin content decreases and barite content increases in samples A,B,C,D respectively, the permeability of the drilling mud increases since the bentonite, starch and water content are kept constant in all the samples. In Fig 1B, sample G and H have the lowest permeability compared to E and F which is due to increase in the bentonite content in sample E-H as the kaolin decreases across the samples and barite, starch and water content are kept constant in all the samples. In Fig 1C, sample I has the highest permeability which is not the expected result since it has the highest amount of kaolin content and comparing it with Fig 1A where sample A with the highest kaolin content had the lowest permeability, this could be as a result of inherent defect in the permeameter. The kaolin content was decreased while the water content was increased from sample J – k, barite, bentonite and starch content were kept constant. In Fig 1D, sample P has the lowest permeability, permeability decreases as the starch content increases with decrease in the kaolin content while barite, bentonite and water were kept constant. In all the samples, sample H has the lowest permeability due to its high bentonite content.







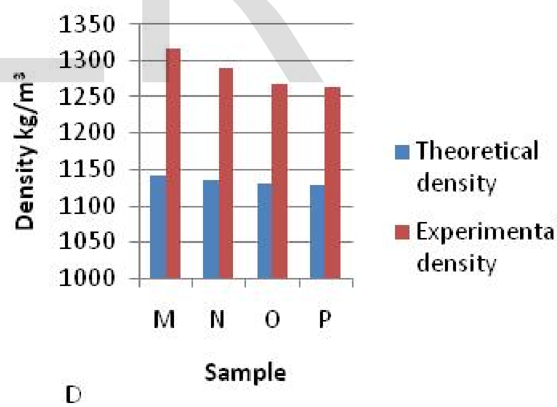


Fig 2. Density variation of drilling mud.

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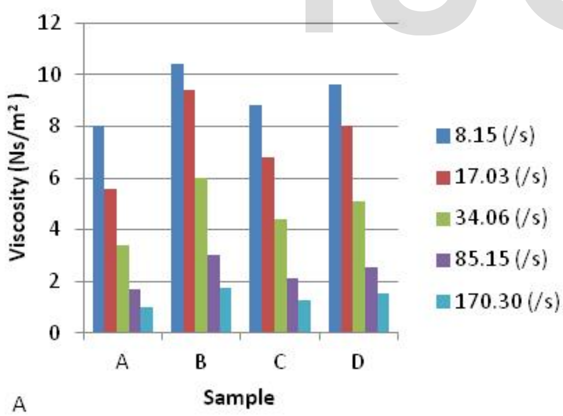
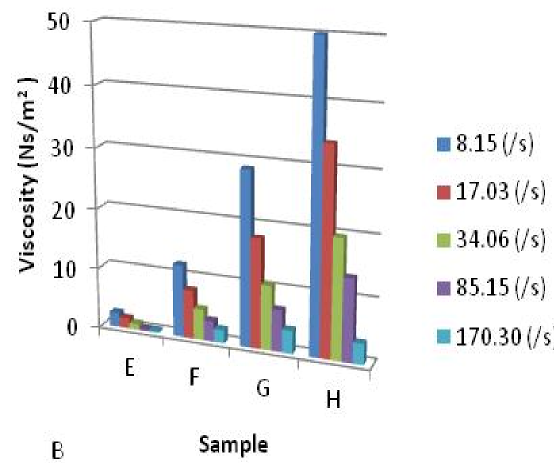
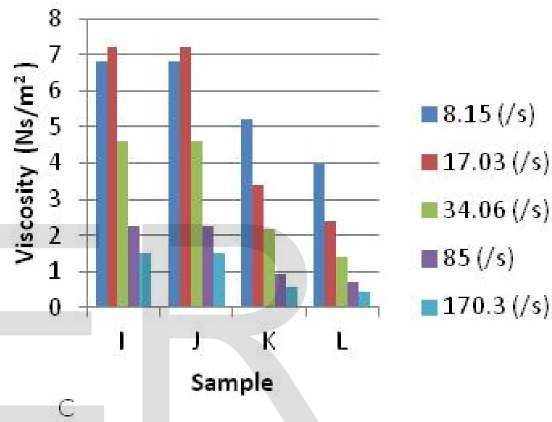
There was a general increase in the mud sample experimental density which was higher than the theoretical sample; this phenomenon was also observed in the work that was previously done and it was discussed extensively [5]. In Fig. 2A there was a general increase in the density from sample A to D, the local bentonite, starch and water content were kept constant while the barite and kaolin content were varied with increase in barite and decrease in kaolin. The increment in density shows barite as a density builder which is in line with the work that was previously done although in the previous work, bentonite was excluded from the samples; the kaolin had negligible effect on the density. In Fig. 2B, barite, starch and water were kept constant while bentonite and kaolin were varied with increase in bentonite and decrease in kaolin from sample E - H. There was increase in density but the increase was small compared to the values in Fig 2A, this shows that the local bentonite is not a density builder compared to barite. The densities in Fig 2C and 2D were also lower compared to the density in Fig 2A, kaolin was varied in all the drilling mud content but had little impact on density compared to barite, in Fig. 2C and 2D where kaolin clay was varied, decrease in kaolin content also led to a corresponding decrease in the densities of the drilling mud although the difference was little thus kaolin can also be used with barite as a weighting agent. Starch and water do not have impact on density.







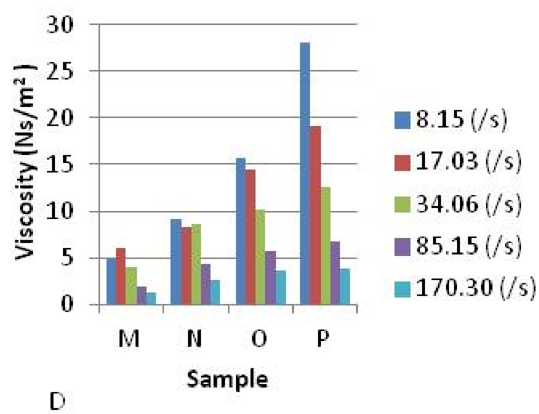


Fig. 3. Variation of viscosity at constant shear rate for drilling mud sample at different shear rates.

From Fig. 3A above, it can be seen that at a shear rate of $8.515s^{-1}$ the apparent viscosity for each of the samples are at their peak and the lowest apparent viscosity for the samples was obtained at a shear rate of $170.3s^{-1}$, this implies that as the apparent viscosity increases, the shear rate

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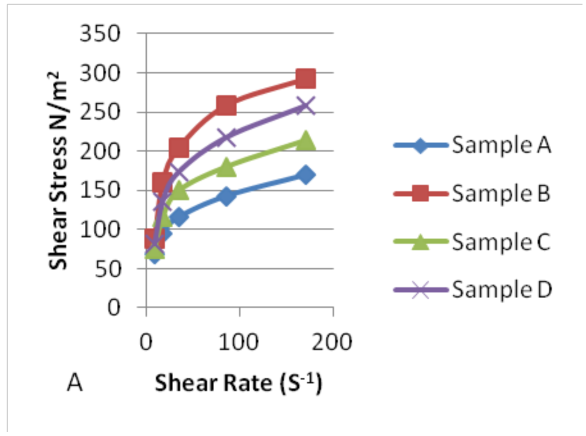
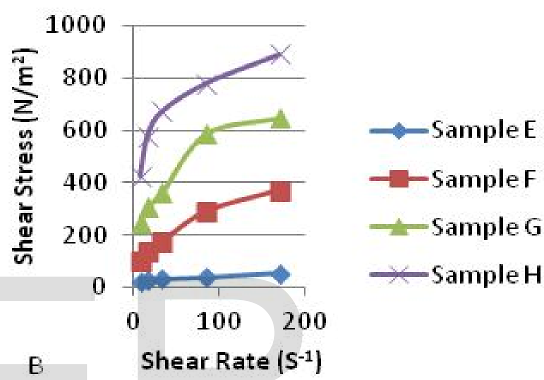
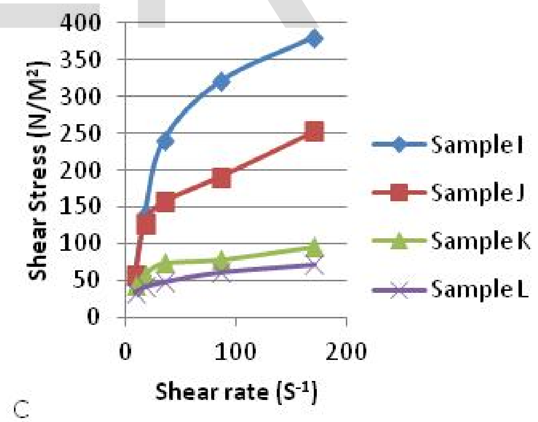
decreases showing a pseudo plastic fluid this agrees with literature [3],[6], the result gotten in the previous work is contrary to that obtained here as there was no corresponding decrease in viscosity with increase in shear rate thus the fluid flow was not pseudo plastic [5]. The increase in barite quantity in samples A-D does not give a corresponding increase in their viscosity which accentuates the fact that barite is not a viscosifying agent; in the previous work, bentonite was absent as a result the viscosity values were lower compared to this present values, kaolinite clay did not serve as a viscosifier because it is non- expandable, the cohesive energy in kaolin clay is primarily electrostatic, augumented by vandeer waal attraction and a certain degree of hydrogen bonding between the hydroxyl group of one layer and oxygen atoms of the adjoining layer as a result, only surface hydration energy would be available to open up the crystallites and this energy is apparently insufficient to overcome the rather large cohesive energy . Fig 3B shows that at constant shear rate, there is a significant increase in the viscosity from sample E to sample H this is due to the increase in the bentonite content of each sample by 2w% with a corresponding decrease in the kaolin content by 2w%. Kaolin is non-expanding clay but bentonite clay expands when hydrated because its clay particles are thinner and come apart more easily than those of other clays, bentonite increases 10 times its original volume which accounts for its viscosifying property. Sample H is the most viscous due to its high bentonite content. Fig 3C shows a decrease in viscosity at constant shear rates as the quantity of water increases by 2w% for each sample, the kaolin content was also varied but decreases from sample I – L, while other contents were made constant, the increase in water content increased the movement of the molecules in the mud mixture making it less viscous. Fig. 3D shows an increase in viscosity as the quantity of starch increases with 2w% for each sample, this is due to the gelling characteristics of starch which increases the viscosity of the mud as was discussed in the previous work. The viscosity values gotten here are higher than those gotten in the previous work where bentonite was not added in the sample mixture [5].







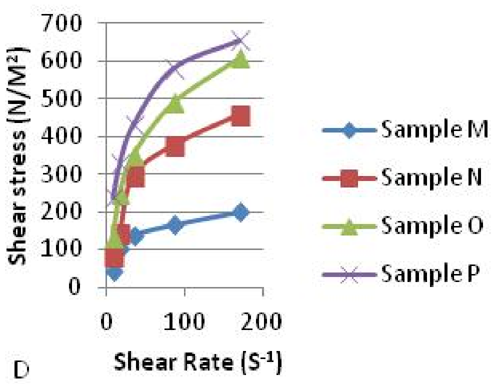


Fig. 4. Variation of Shear Stress with Shear Rate for Drilling Mud

In Fig. 4A, the bentonite, water and starch content were kept constant while the barite content was increased and the kaolin content was decreased for samples A-D, the graph shows a proportional increase in shear stress as the quantity of barite increases with a constant amount of 3W% bentonite in all the samples except for sample B which has the highest pseudo plastic curve which cannot be explained but may be due to inherent defect in the viscometer or an error. In Fig. 4B, there is a wide variation of shear stress between the pseudo plastic curves of the samples when there was an increase in the quantity of bentonite by 2w%. This is due to the expanding and high viscosity properties of bentonite, sample H which has the highest quantity of bentonite shows the best pseudo plastic behavior. Fig. 4C shows poor pseudo plastic curves since bentonite and starch were kept constant while kaolin and water content were varied; Fig. 4D also shows a large variation in shear stress as the quantity of starch increases which is due to the gelling property of starch thereby increasing the viscosity of the drilling mud as was discussed extensively in the previous work [5]. Fig. 4B gave higher values of shear stress as the shear rates increased compared to the other samples due to the increasing bentonite content.

4 CONCLUSION

All the samples of drilling mud showed pseudo plastic flow behavior. Barite was the main determinant in building density although kaolinite clay was also significant in building density as was seen in the analysis but had lesser impact compared to barite. The variation in the quantity of bentonite in the samples E-H of drilling mud gave an increase in viscosity from 2.4Ns/m^2 to 50Ns/m^2 and there was a significant decrease in the value of permeability from 3.055 x 10^{-3}m/s to 6.943 x 10^{-4}m/s when the quantity of bentonite was varied which shows that the Nigerian bentonite can be used as a viscosifier and to adjust the filtration rate of drilling mud sample.

The rheological behavior of the drilling mud using the clays was positive thus, the addition of bentonite clay improved the properties of the drilling mud giving it a pseudo plastic behavior which was absent in the work done previously.; kaolinite clay due to its abundance can be used with barite as a weighting agent to reduce cost.

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