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Evaluating the Suitability of Cocoa Pod Husk as Fluid Loss Control Agent in Water Base Mud

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***Abstract*— Drilling fluid is an important component for a successful drilling operation to be carried out in the oil and gas industry. The oil/gas industry is moving towards more environmentally friendly practices. The environmental regulations regarding drilling waste management and disposal are motivating the industry to be more efficient with drilling operations. Environmentally friendly drilling fluid additives used in drilling operations reduce not only the negative implications on the environment but also reduce costs as compared to the conventional additives. The aim of the study was to use cocoa pod husk to improve the filtration property of drilling mud. The results obtained showed that prior to the introduction of cocoa pod husk, the filtrate loss of the blank mud was 49 ml but as the 125 µm Cocoa Pod Husk (CPH) was added up to 16 g content, the filtrate loss reduced to 13.5 ml leading to a 72.45 % reduction in fluid loss. However, the conventional additives such as Polyanionic Cellulose (PAC) and Carboxymethyl Cellulose (CMC) of 1.0g content resulted in fluid loss reduction of about 80.41 % and 71.02 %, respectively. Thus, Cocoa Pod Husk (CPH) and Carboxymethyl Cellulose (CMC) compare favourably. In this connection, it can be concluded that, at considerable content (concentration), Cocoa Pod Husk can be used as fluid loss control additive in water-based drilling mud as it exhibits good filtration loss control potentials.**

Keywords*— *Cocoa pod husk; drilling fluid; filtration loss; locally-made drilling mud.

I. INTRODUCTION

An important part of drilling operations in the oil and gas industry is the drilling mud or fluid. It performs various functions including transporting drill cuttings to the surface, lubricating, and cooling the drill bit, sustaining the stability of wellbore and regulating formation pressure [1]. Therefore, success in drilling operations requires that drilling fluids possess desirable qualities which depend on their rheological and fluid filtration properties. Among these qualities of drilling fluid, satisfactory filtration control is required to avoid drilling issues that include extreme drag and torque, lost circulation, formation damage, and wellbore instability which affects well productivity.

In view of these challenges, several fluid loss agents and additives have been formulated and synthesized for various applications in invert, oil, and water-based drilling fluids [1]. Fluid loss is minimized by the creation of low permeable filter cake at the surface of the wellbore, which prevents solid particles from flowing into the pores of the formation together with the continuous phase. These solid particles tend to plug the pore spaces of the formation either by physical or chemical processes, thereby reducing the permeability and porosity of the formation and by so doing, hamper the flow of fluids through such formations to the wellbore. This is generally referred to as formation damage. Formation damage associated with drilling mud occurs when particles (such as drill solids, weighting agents and/or soft particles like polymers) invade the reservoir rock, thus plugging pores and forming internal filter cake [2].

Several types of materials are used to reduce particle invasion (filtration rate) and improve mud cake characteristics. When clays cannot be used effectively as deflocculating agents, water-soluble polymers are substituted. Polymers reduce water loss by increasing the effective water viscosity [2]. Nowadays, various polymers, which may be natural (example starch) synthetic or modified (example carboxyl methyl cellulose, CMC, polyanionic cellulose (PAC) are used in order to control the fluid loss and viscosity of drilling fluids [3]. Most of these polymers and chemicals that make up the drilling mud are costly and toxic to the environment; hence the need to encourage the use of local additives. Mohammed and Hossain [4] reported that though the technical performance of drilling fluid cannot be overlooked, the environmental impact of the mud and its additives plays an important role as it determines the application of the mud.

Various research works have been done on the formulation of drilling mud using locally available materials as additives. These research ranges from the use of locally available clay as a substitute for bentonite to the use of local starch as fluid loss control additive. Olatunde *et al.* [5] formulated water-based drilling fluid using bentonite, guar gum, polyanionic cellulose (PAC) and gum Arabic. The rheological behavior and the filtration loss property of each drilling fluid developed were measured using API recommended standard procedures. They noticed that Guar gum shows the highest gel strength and the most stable rheological properties with poor filtration loss property while gum Arabic had unstable rheological properties with stable gel strength and good filtration loss property. However, gum Arabic is only found in the northern part of Nigeria and not in the southern part (Niger Delta region) where major drilling operations take place. Omotioma *et al.* [6] used locally sourced cassava starch to improve the rheological properties of water-based mud. Their results showed that the rheological properties of water-based mud were improved with the addition of 4 % locally sourced cassava starch addictive to it.

Also, Ademiluyi *et al.* [7] compared local polymer (cassava starch) with an imported type in controlling viscosity and fluid loss in water-based mud. Five different cassava starches were tested as viscosifiers and fluid loss control additives in water-based mud and compared with BarazanD, an imported sample. Their experimental results indicated that at same concentration, the imported sample had higher rheological properties compared with the local samples. They also discovered that some of the newly developed local starch products (with high amylose content and high-water absorption capacity) have similar or better filtration control properties than the imported sample. However, the viscosity of the drilling fluid produced from the local starches was lower than that of the imported type.

Fig. 1. Cocoa husk profile

Cocoa *(Theobroma Cacao)* is among the most cultivated and important tropical crops in the world, and it is economically viable in the agro-pastoral systems of tropical Africa. Further, the amount of cocoa residue (cocoa pod husk) is steadily increasing due to the strong worldwide demand for chocolate products [8]. Cocoa is found in the Niger Delta region between Cross River, Akwa Ibom, Delta in the South and Ondo, Oyo, Osun, Ekiti in the West of Nigeria [9]. The people in these areas use the cocoa pod seed (cocoa bean) for chocolate production and dispose the husk as waste thereby constituting environmental pollution which is among the most serious problems facing humanity today [10]. The cocoa pod husk (CPH) is the outer part of the cocoa fruit (exocarp), which has an oval, rough, and relatively thick appearance. Cocoa pod husk comes in different colors depending on the variety, and its roughness protects it against the elements, plagues, and damage that could be caused by impact [11]. It is obtained after husking and removing the beans, and it represents 70 % to 80 % of the dry weight of the whole fruit.

Most technical application of cocoa pod husk (CPH) is in the area of agriculture using CPH for potential valorization of agro materials, agro chemical materials into high value-added product [8]. There is little or no known application of cocoa pod husk in the formulation of drilling mud available in open literature. In 2019, Wilberforce *et al.,* [1] synthesized sodium carboxymethyl cellulose (NaCMC) from cocoa pod husk (cocoa NaCMC) and was tested as a filtration agent at high temperature and differential pressure conditions. Their results showed that that filtration control performance at high temperature and low/high differential pressure was improved by decreasing particle size and increasing concentration, and and it was comparable to the industrial PAC.

This work therefore intends to use the raw cocoa pod husk as fluid control additive in the formulation of water-based mud thereby, converting waste to wealth, creating wealth and job opportunities. This will impact positively on the Nigeria economy and the environment, considering the local content policy of the Nigerian National Petroleum Corporation (NNPC) which encourages the development and use of local content in the oil and gas industry.

II. MATERIALS AND METHODS

A. *Mud sample preparation*

The cocoa pod husk was sourced and collected locally from various locations within Itam Market in Itu Local Government Area, Akwa Ibom State, Nigeria. The cocoa pod husk was cut into tiny pieces, sun-dried for about five days and then oven-dried for about 72 hours (3 days) to remove any remaining moisture. Finally, the dry husk was pulverized (milled) and sieved into the particle size of 125 microns (125 μm) with the help of the sieve shaker and used for mud preparation. Water based mud was prepared in the laboratory using bentonite and water. Based on the American Petroleum Institute (API) [12] requirement (25 g of non-treated bentonite with 350 ml of water) was prepared by first measuring 350 ml of water into a clean beaker followed by weighing 25 g of bentonite with the weighing balance. The weighed bentonite was emptied into the beaker containing the water. The sample with different concentrations was measured into the sample beaker containing bentonite and the measured fluid volumes. The sample was stirred using the stirring rod before stirring with the mud mixer for homogeneity. The mud samples were prepared for different additive content. Tables 1 and 2 show the compositions of the mud samples.

TABLE I. MUD FORMULATION FOR FRESH MUD

Materials	Quantity
Water	350 ml
Bentonite	25 g

TABLE II. MUD FORMULATION FOR 125MM COCOA POD HUSK

Materials	Quantity
Bentonite	25 g
Water	350 ml
Cocoa Pod Husk (g)	4, 8, 12, 16

B. *Rheological and fluid loss properties determination*

The effectiveness of the additive was determined in terms of rheological and fluid loss properties of water-based mud at different particles sizes.

Plastic Viscosity - Fann V-G meter was used to determine the Plastic Viscosity of the muds. The Fann V-G meter cup was filled to the 350 cubic centimeter (cc) mark and the table adjusted until the mud surface was at the scribed line on the rotor sleeve. Motor switched on and at a steady indicator; the dial reading at 600 rpm (θ600) and 300 rpm (θ300) were taken respectively. Hence, the difference of these reading at 600 rpm and 300 rpm gives the value for the Plastic Viscosity in centipoise (cP) expressed in Equation 1;

$$\text{Plastic Viscosity (PV)} = \theta600 - \theta300 \qquad (1)$$

Apparent Viscosity - This was determined mathematically as expressed in Equation 2 in units of centipoise (cP);

$$\text{Apparent Viscosity} = \theta600/2 \qquad (2)$$

Yield Point - This was determined mathematically in pounds per hundred feet square (lb/100ft^2) given by Equation 3;

$$\text{Yield Point (lb/100ft}^2\text{)} = (\theta300 - \text{PV}) \qquad (3)$$

Gel Strength - The gel strength of the muds in lb/100ft^2 was determined with the aid of Fann V-G meter. After the muds were thoroughly stirred at 600 rpm, the gear of the Fann V-G meter was set to a neutral position with the motor turned off. By turning the gel knob located below the gear shift knob counter clockwise, after 10 seconds, the dial reading was recorded and was taken to be the gel strength for 10 seconds. However, the act was repeated for 10 minutes to obtain the 10 minutes gel which is the maximum.

Mud Density - Densities of the muds were determined with the aid of mud balance in pounds per gallon (ppg) as follows; at first, the mud balance was calibrated using distil water and the instrument base set up so that it was approximately levelled, then freshly prepared mud was poured into a clean, dried mud balance cup. The lid placed on the cup and set firmly but slowly with twisting motion.

Mud pH - The pH of the mud was determined with the use of a pH meter.

Fluid Loss - In determining the filtration behaviour of the mud samples using a low pressure-low temperature filter press, the samples were simultaneously poured into a cell leaving 13 mm of empty space at the top. The volume of filtrate collected in the graduated cylinder after 7.5, 10 and 30minutes were recorded to the nearest 0.1cc as API filtrate. Hence, the air flowing into the test cell was shut off by slowly closing the regulator T-screw and pushing the relief valve in.

Wall Cake Thickness - From the fluid loss test carried out above, the CO_2 pressuring assembly was removed from the cell cap and the relief valve pulled out. The T-screw was slowly opened to allow any remaining pressure to escape and the CO_2 cartridge discarded. The frame was disassembled, and the cell removed. Excess mud on the filter paper was washed with water to obtain mud cake. Hence, the mud cake thickness built, was recorded with the use of a vernier caliper.

III. RESULTS AND DISCUSSION

The results of different sample distribution obtained are shown in the table and details of the result obtained during the experiments are also presented using Tables 4 to 6, while Table 3 presents details of the compositions of the formulated water-based mud.

TABLE III. COMPOSITION OF FORMULATED WATER BASED MUD

Mud Composition	Contents		
	CMC Mud	*PAC Mud*	*CPH Mud (125µm)*
Water (ml)	350	350	350
Bentonite (g)	25	25	25
CMC (g)	0.25, 0.50, 0.75, 1.0	----------	-----------
PAC (g)		0.25, 0.50, 0.75, 1.0	
CPH (g)	-------	____	4, 8, 12, 16

TABLE IV. CARBOXYMETHYL CELLULOSE (CMC) TEST RESULTS

	Drilling Mud Sample + CMC (g)			
CMC Mud Properties	*0.25*	*0.50*	*0.75*	*1.00*
pH	11.18	11.41	11.43	11.44
Density (ppg)	8.60	8.65	8.70	8.72
Viscosity (cP) @600rpm	21.00	41.00	53.00	67.00
Viscosity (cP) @300rpm	14.00	29.00	37.00	50.00
Plastic viscosity	7.00	12.00	16.00	17.00
Apparent viscosity	10.50	20.50	26.50	33.50
Gel strength (Ib./100ft^2) @10sec.	5.00	10.00	12.00	19.00
Gel strength (Ib./100ft^2) @10min.	6.00	13.00	18.00	27.00
Yield point (lb./100ft^2)	7.00	17.00	21.00	33.00
Fluid loss (mL) @7.5 min	11.40	10.60	8.20	5.60
Fluid loss (mL) @10 min.	10.00	9.40	7.00	6.40
Fluid loss (mL) @30 min.	20.40	18.00	16.80	14.20
Wall cake thickness (mm)	0.30	0.45	0.60	0.70

TABLE V. POLYANIONIC CELLULOSE (PAC) TEST RESULTS

	Drilling Mud Sample + PAC (g)			
PAC Mud Properties	***0.25***	***0.50***	***0.75***	***1.00***
pH	11.23	11.32	11.33	11.39
Density (ppg)	8.60	8.65	8.70	8.73
Viscosity (cP) @600 rpm	21.00	33.00	49.00	71.00
Viscosity (cP) @300 rpm	14.00	22.00	35.00	52.00
Plastic viscosity	7.00	11.00	14.00	19.00
Apparent viscosity	10.50	16.50	24.50	35.50
Gel strength (Ib./100ft^2) @10sec.	0.00	3.00	5.00	15.00
Gel strength (Ib./100ft^2) @10min.	1.00	6.00	14.00	17.00
Yield point (lb./100ft^2)	7.00	11.00	21.00	33.00
Fluid loss (mL) @7.5 min	7.5	5.8	5.6	4.20
Fluid loss (mL) @10 min.	8.80	6.5	6.2	5.4
Fluid loss (mL) @30 min.	15	11.00	10.80	9.60
Wall cake thickness (mm)	0.25	0.45	0.60	0.70

TABLE VI. COCOA POD HUSK (CPH) TEST RESULTS

	Drilling Mud Sample + CPH (g)			
CPH Mud Properties	***4***	***8***	***12***	***16***
pH	10.44	10.49	10.53	10.58
Density (ppg)	8.62	8.70	8.90	9.20
Viscosity (cP) @600rpm	16.00	23.00	27.00	31.50
Viscosity (cP) @300rpm	11.00	15.00	16.00	19.00
Plastic viscosity	5.00	8.00	11.00	12.50
Apparent viscosity	8.00	11.50	13.50	15.75
Gel strength (Ib./100ft^2) @10sec.	3.00	7.00	8.50	10.00
Gel strength (Ib./100ft^2) @10min.	5.00	10.00	13.00	17.00
Yield point (lb./100ft^2)	6.00	7.00	5.00	6.50
Fluid loss (mL) @7.5 min	22.15	13.00	10.00	8.50
Fluid loss (mL) @10 min.	24.00	15.00	11.50	10.00
Fluid loss (mL) @30 min.	33.50	23.00	16.00	13.50
Wall cake thickness (mm)	0.50	0.70	0.75	0.83

Mud density of drilling fluid system is one of the most important drilling fluid properties because it controls formation pressure and it also helps wellbore stability. Additionally, an increase in mud density increases the capacity of the mud to carry and sustain drilled cuttings when circulation stops. As presented in Table 6, the cocoa husk mud density value increased from 8.62 lb/gal to 9.20 lb/gal which falls within the API mud density value range.

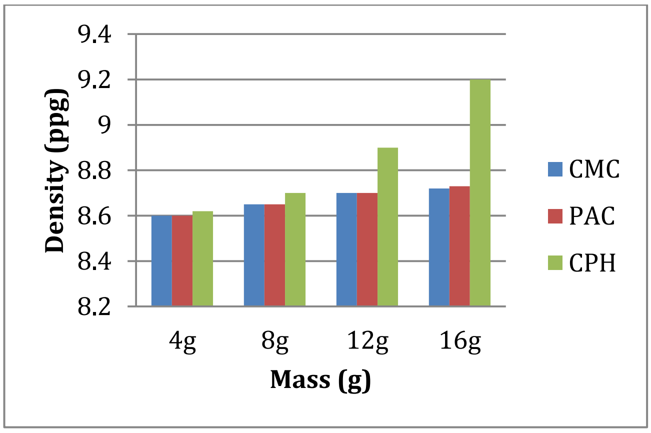

Fig. 2. Density values

The gel strength is another important drilling fluid property, as it demonstrates the ability of the drilling mud to suspend drill solid (drilled cuttings) and weighting material when mud circulation is ceased. Figs. 3 and 4 depict the gel strength of the formulated mud. As can be seen in Table 6, the gel strength of the mud sample increase with increase in the quantity of the additive. The 10 seconds and 10 minutes gel strength for the mud are within the API recommended range, they exhibit a flat gel structure, meaning that the mud will remain pumpable with time if left static in the hole.

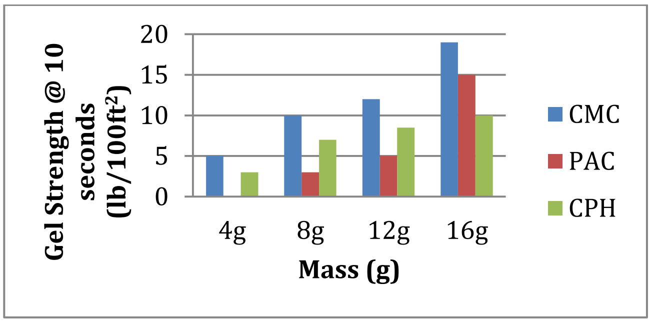

Fig. 3. Comparison of 10 seconds Gel Strength

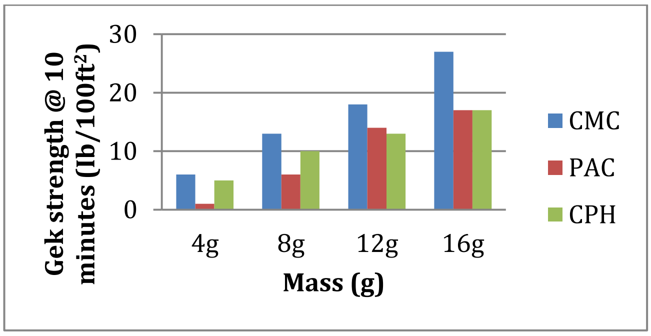

Fig. 4. Comparison of 10 minutes of Gel Strength

Filtration rate is an important property of a drilling fluid, especially when drilling an unconsolidated or permeable formation where the hydrostatic pressure exceeds the formation pressure. Proper monitoring and control of filtration can prevent or minimize wall sticking which is the primary cause of pipe stuck and drag, and in some areas improve borehole stability. Table 6 and Fig. 5 show the filtrate volumes from the formulated muds (with a 4 g of the additives) collected after 7.5, 10 and 30 minutes, respectively. Comparing the results of this test with API standard values for filtration testing (15 mL/30 min/100 psi), it is observed that the additive gives a fluid loss measurement value at 16 g content that falls within the American Petroleum Institute (API) recommended range, as can be seen in Fig. 6.

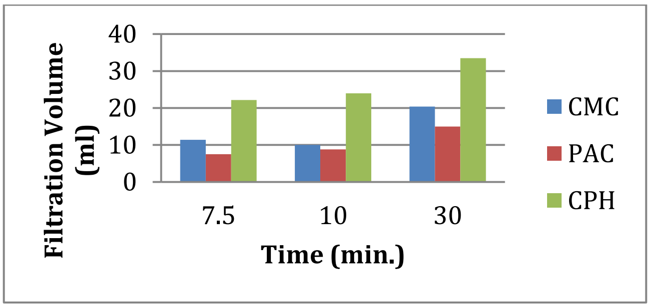

Fig. 5. Fluid Loss Profile for 4 g of the Additives

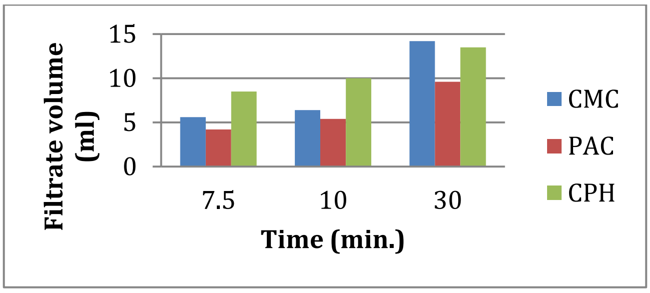

Fig. 6. Fluid Loss Profile for 16 g of the Additives

The result showed an increased in mud cake thickness with increasing quantity of local additive. The rate of increase in filter cake thickness with concentration is plotted graphically as given in Fig. 7 and is also presented in Table 6. The filter cake thickness increases from 0.50 mm to 0. 83 mm. The cake characteristics for the local additive was generally soft and thin in texture. From the above results, cocoa husk filter cake thickness met the API standard for thin filter cake, which states that the filter cake must be less than 2 mm (American Petroleum Institute, 2010).

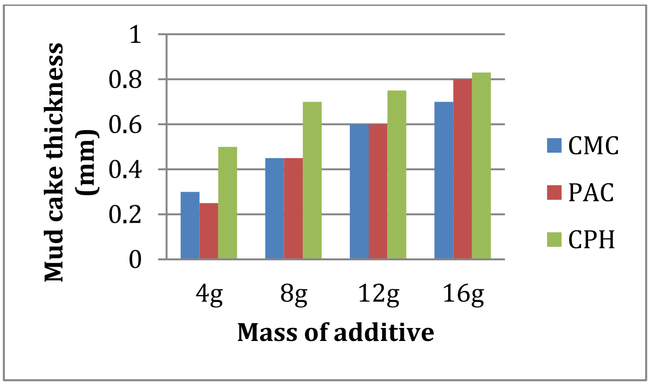

Fig. 7. Comparison of Mud Cake Thickness

IV. Conclusion

Water based mud are very sensitive to borehole environment and when used to drill through formations with high permeability, excessive filtrate loss occurs, hence the need to add fluid loss control material to improve the filtration property of the mud system. The results of this experimental work reveal that the addition of cocoa pod husk to pure mud (i.e. mud with bentonite and water) result in increase in density as the mass content is increased. It was also observed that the higher the mass content of the cocoa husk, the greater the filtration loss control. Additionally, Cocoa pod husk has a potential as a fluid loss control agent in water-based mud and to be used in oil and gas drilling operations. Cocoa Pod Husk is therefore recommended for use as fluid loss control material. Further research work is recommended to be performed under High Temperature-High Pressure (HTHP) conditions in both water-based and oil-based drilling mud.

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