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Performance Comparison and Optimization of Palm Fatty Acid Distillate (PFAD) Biodiesel Based Drilling Fluid

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ABSTRACT

The Palm Fatty Acid Distillate Biodiesel (PFAD) was identified and characterized as the continuous phase for the development of bio-based drilling fluid and the comparison of the formulations performances were studied. The study includes determination of physical properties of conventional oil and the blend of PFAD biodiesel with Palm olein biodiesel. The properties of the PFAD biodiesel samples are close to the conventional oil used in drilling fluid. The kinetic viscosity test result shows that pure PFAD biodiesel has the lowest kinematic viscosity value of 5 cSt compared to other mixtures of PFAD biodiesel and Palm Olein biodiesel. Subsequently the PFAD biodiesel was used as bio-based drilling fluid base oil. The PFAD biodiesel based drilling fluid has 12.0 ppg density and the samples was tested at 275F. PFAD biodiesel based drilling fluid sample with 1 ppb lime and 1 ppb emulsifier meets most number of specification requirement based on plastic viscosity, emulsion stability (ES reading) and is water free when tested in High Pressure High Temperature Filter Press (HTHP filtrate testing).

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INTRODUCTION

Drilling fluid is used to aid the drilling of boreholes into the earth. Often used while drilling oil and natural gas wells and on exploration drilling rigs, drilling fluids are also used for much simpler boreholes, such as water wells. The three main categories of drilling fluids are water-based mud, non-aqueous mud (oil based mud) and gaseous drilling fluid. Oil-based mud (OBM) can be a mud where the base fluid is a petroleum product such as diesel fuel. Oil-based mud are used for many reasons, some being increased lubricity, enhanced shale inhibition, and greater cleaning abilities with less viscosity. Oil-based mud also withstands greater heat without breaking down. Synthetic based fluid (SBM) (Otherwise known as Low Toxicity Oil Based Mud or LTOBM is a mud where the base fluid is synthetic oil. This is most often used on offshore rigs because it has the properties of an oil-based mud, but the toxicity of the fluid fumes are much less than an oil-based fluid.

In the past, the usage of oil especially diesel oil as the continuous phase of oil-based drilling mud was widespread when drilling through sensitive producing formations and troublesome shale zones. However due to the adverse environmental effects caused by oil usage, extensive legislation exists in regulating the oil pollution. Subsequently, various types of LTOBM were introduced as alternative to replace the more toxic mineral oils or diesel oil-based drilling mud (Abdullah, 2012). At present, the use of bio oil can be considered as an suitable alternative base fluid that poses no harm to the environment. The bio oil is synthesized by esterification process and have the potential of replacing mineral diesel as it is environmental friendly, good safety performance and renewable. (Wang, Sun, Shang, Fan, Liu, & Liu, 2012).

The vital factor that affects the performance of a non-aqueous fluid drilling mud is the emulsion. In order for this two liquid to coexist as an emulsion, emulsifiers are needed to be added into the drilling fluid. The role of the emulsifier is to stabilize a physical emulsion once it is formed. Therefore, the emulsifier's performance will directly affect the performance of the drilling fluid. Apart from that, the lime concentration in the drilling fluid is also significantly important as lime, calcium hydroxide, $Ca(OH)_2$ is used as a source of calcium and alkalinity in both water- and oil-based drilling fluids.

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Lime is used to increase pH, to provide excess lime as an alkalinity buffer, to flocculate bentonite slurries (spud mud) for improved hole cleaning, for removing soluble carbonate ions, for controlling corrosion; and for activating fatty-acid, oil-based drilling fluids additives. Emulsifier and lime work hand in hand as lime is needed to activate the fatty acids in the emulsifier which will react to ensure proper water in oil emulsion is achieved. Thus, this research consistsof two part. First part is development of the biodiesel to ensure its suitability used as the continuous phase of drilling part. Second part is optimization of drilling fluid formulation ensure it meets all required specifications and be on part with conventional drilling fluid in terms of performance.

Experimentation:

The experimental work includes two stages; first stage is the identification and characterization of palm fatty acid distillate biodiesel in terms of its physical properties followed by the blending of the biodiesel with pure palm oleinbiodiesel at varying ratios for economic considerations. The second stage is development of PFAD drilling fluid formulation and comparison study between formulations for further optimization and characterization.

Determination of physical properties of PFAD biodiesel and blending with Palm Olein biodiesel.

The palm fatty acid distillate used in this experiment is identified and characterized. The palm fatty acids distilled biodiesel were obtained from Biomass Processing Laboratory, CBBR, UTP Research Laboratory. The biodiesel is brown in colour and the oil is heated at 70 °C for 30 min to remove methanol from biodiesel. Physical properties such as density, specific gravity, kinematic viscosity, flash point, pour point and acid value testing were analyzedas presented in Table 1 below. This serves as a preliminary basis to rate the suitability of the PFAD sample as continuous phase for drilling fluid (Chongkong *et al* 2007). Then the properties of PFAD biodiesel was compared with the conventional diesel and minerals oils such as Saraline 200 and Sarapar 147 to observe if the PFAD biodiesel sample satisfies the criteria needed for it to be used as base fluid for drilling mud.After that PFAD biodiesel sample was blended with palm olein biodiesel in varying ratios. The kinematic viscosity of different blending of palm fatty acid distillate biodiesel and palm olein biodiesel were determined and set as the deciding factor for suitability as continuous phase to be used in drilling fluid.

Table 1: PFAD biodiesel testing method and instrument.

PROPERTIES	TEST METHOD	INSTRUMENT
Density and Specific Gravity	ASTM D4052	Anton Paar DMA 4500 M
Kinetic Viscosity (at 40 °C)	ASTM D445	Koehler Kinematic Viscosity Bath equipment.
Cloud point & Pour Point	ASTM D2500 & ASTM D97	1SL CPP 5Gs analyzer
Flash point	ASTM D92	Protest Cleveland Open Cup Instrument (CLA 5) with automated flash point analyzer
Acid Value	AOCS (cd 3d-63)	Titration of potassium hydroxide (KOH)

Development of PFAD drilling fluid and comparative study:

The drilling fluids from palm fatty acid distillate were prepared using ingredientsand were mixed in accordance to the mixing order and time as in Table 2 for 60 minutes using mud formulator equipment.The preparation of mud testing has to follow the following procedure. First, before hot roll (BHR),1 barrel of the PFAD mud formulation at 12.0ppg is mixed for 60 minutes. The rheological and gel strength properties of mud samples are recorded. Theemulsion stability (ES) reading of mud sample is recorded.The mud sample is poured into aging cell and placed in an oven for 16 hours for hot rolling a 275F. Second, after hot roll (AHR), the mud sample is taken out of the oven, cooled and stired for 5 minutes.The rheological and gel strength properties of the mud sample are measured.The ES reading of the mud sample measured. Retort test is run at 950F and HTHP test at 275F on the mud sample is carried out (Dosunmu, 2010). Then the mud sample was test according to test as outlined in Table 3 to determine their physical properties.

After the determination of drilling fluid ingredient, the effects of lime and emulsifier on the newly developed palm fatty acid distillate drilling fluid were investigated. Varying lime and emulsifier concentration are used in this study. The comparative study of the different formulations are analysed and its performance are assessed for further optimization.

Table 2: Drilling fluid ingredients data

Products	Mixing Order	Mixing Time (min)
Base Oil – PFAD sample	1	-
Primary Emulsifier – CONFI MUL P	2	2
Secondary Emulsifier – CONFI MUL S	3	2
Viscosifier – CONFI GEL HT	4	5
Fluid Loss Control Agent – CONFI TROL HT	5	2
Lime	6	2
Fresh Water	7	15

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$CaCl_2$		
Weighting Agent – Barite	8	5

Table 3: Drilling Fluild analysis.

PROPERTIES	ANALYZER
Density	Mud balance
Mud Mixing	Hamilton Beach Mixer.
Emulsion stability	ES Meter
Plastic Viscosity Gel Strength Yield Point	FANN (Model 35A) Viscometer
Fitrate Volume Mud cake thickness	High Pressure High Temperature Filter press

RESULT AND DISCUSSION

PFAD biodiesel Physical Properties and PFAD blending with Palm Olein biodiesel:

Table 4 shows PFAD biodiesel physical properties. The comparison of PFAD biodiesel properties with conventional diesel, Saraline 200 and Sarapar 147 are show in Table 4. It is observed that the PFAD biodiesel sample did not satisfy the criteria needed for used as the base fluid for drilling mud (Oilfield Glossary, 2012).Modifications are needed to improve its properties to be used as the base fluid for drilling mud application.

Table 4: Physical properties of PFAD biodiesel and conventional base fluid.

Property	Unit	Diesel	PFAD biodiesel	Sarapar 147	Saraline 200
Specific Gravity	-	0.865	0.910	0.773	0.783
Kinematic Viscosity (at 40^{o}C)	cSt	2.0	4.8	2.5	3.0 – 4.0
Pour Point	^{o}C	-17.7	16.0	12.0	-18.0
Flash Point	^{o}C	37.8	132.0	120.0	95.0

Figure 1 shows the graph of kinematic viscosity of PFAD biodiesel-Palm Olein ratio. It has found that 100 % of PFAD biodiesel shows the lowest kinematic viscosity and followed by an increasing in viscosity value as palm olein ratios increased. Generally, any fluid with a kinematic viscosity of higher than 10 cSt is not suitable to be used as a base fluid for drilling mud (Fadairo *et al*., 2012). Oil which is too viscous and has higher oil/water ratios will result in bad rheological reading. Therefore, only three blends ratios were feasible as base fluids which are, 100 % PFAD Biodiesel, 90 % PFAD Biodiesel- 10 % Palm Olein and 80 % PFAD biodiesel-20 % Palm olein biodiesel.

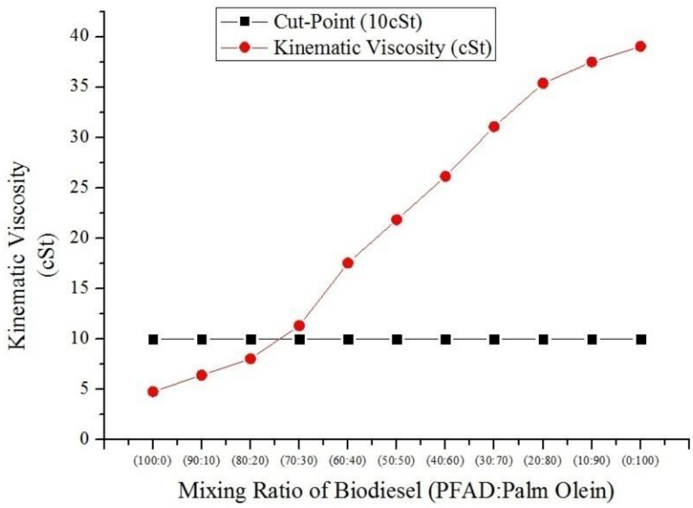

Fig. 1: Graph-kinematic Viscosity of PFAD :Palm Olein Ratio.

Palm Fatty Acid Distillate biodiesel based drilling fluid:

Since kinematic viscosity of the oil need to be below 10cSt, 100 % PFAD biodiesel is chosen as the best fraction from the three blends to be used as the continuous phase for drilling fluid. The 100 % PFAD biodiesel will be used in different formulations to assess its performance and efficiency as a bio-based drilling fluid. Table 5 shows the concentrations of Lime and Emulsifier used in PFAD biodiesel drilling fluid formulation. To facilitate the analysis of results, most criteria highlighted need to be observe.

Table 5: Mud Formulation

Mud Formulation	Lime Concentration (ppb)	Emulsifier Concentration (ppb)	
		Primary	Secondary
1	0	0	9
2	0	1	8
3	1	1	8

Figure 1 shows low end rheology results for three drilling fluid formulations. All the three formulations do not satisfy the acceptable range of the low end rheology criteria. This shows the mud is too thick at low rpm due to the viscosifier concentration (Sayed *et al*., 2011). By lowering the viscosifier concentration will help in reducing the low end rheology reading.

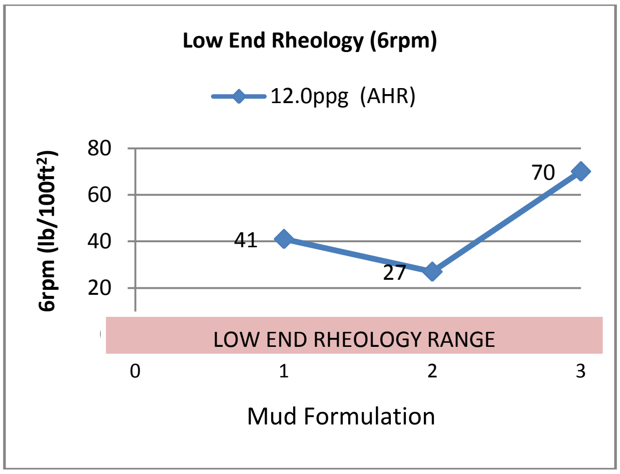

Fig. 1: Low end rheology (6rpm) results.

Figure 2 shows the plastic viscosity (PV) and yield point (YP) for 12.0ppg result for the three mud formulation. The permissible PV acceptance range is below than 35 and YP acceptance range is between 15 to 25 (Salazar *et al*., 2011). Therefore, all the three mud formulation do not satisfy the requirement for YP criteria. But for mud formulation number 2 and 3 both PV values are closed to the required criteria. In terms of YP, all formulations have values above from the acceptable range. By introducing viscosifier it will help in reducing the low end rheology reading (Salazar *et al*., 2011).

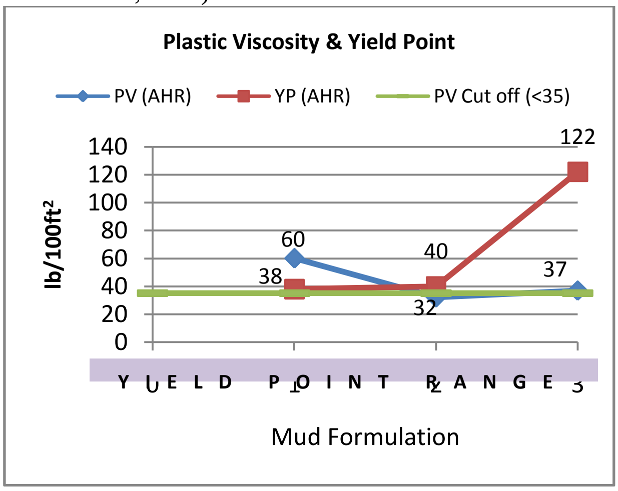

Fig. 2: Plastic viscosity (PV) and Yield Point (YP) for 12.0ppg.

Figure 3 shows the Gel Strength at 10 seconds for 12.0ppg (AHR). Based on the results, none of the formulation satisfies the acceptable range (10 seconds: 6-10 lb/100ft^2) of the gel strength criteria. The gel strength demonstrates the ability of the drilling mud to suspend drill solid and weighting material when circulation is ceased. If the mud has the high gel strength, it will create high pump pressure in order to break circulation after the mud is static for long time. For this gel strength, 10 sec is the acceptance value. By lowering the viscosifier concentration will lower the gel strength values of the mud formulations (Dosunmu *et al*., 2010).

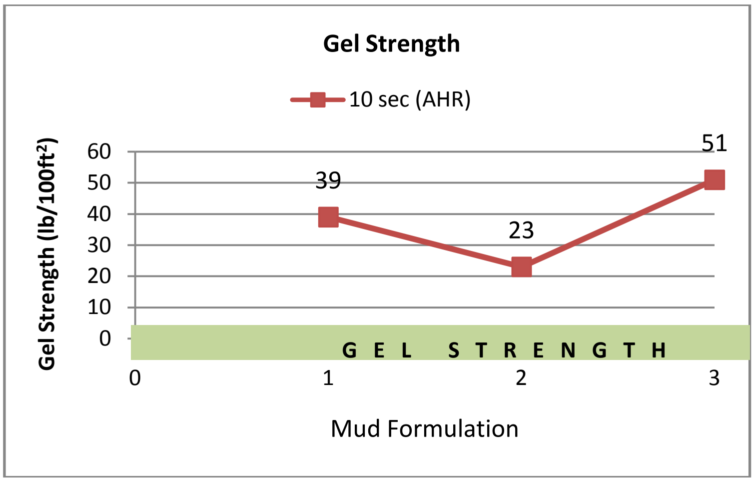

Fig. 3: Gel Strength 10sec for 12.0ppg (AHR) results.

Figure 4 shows the graph of emulsion stability for 12ppg (AHR) results. Based on the results, all mud formulation satisfies the requirement of the Emulsion Stability criteria in which the acceptable range is more than 500 volts. This means the emulsifier is compatible with the base oil and provides stable water in oil emulsion (Zanten, 2012). The emulsion stability test basically records the amount of voltage needed to pass electricity from one electrode to the other. As oil is a non-conductor, the water droplets suspended in the oil will help to conduct the electricity from both electrodes.

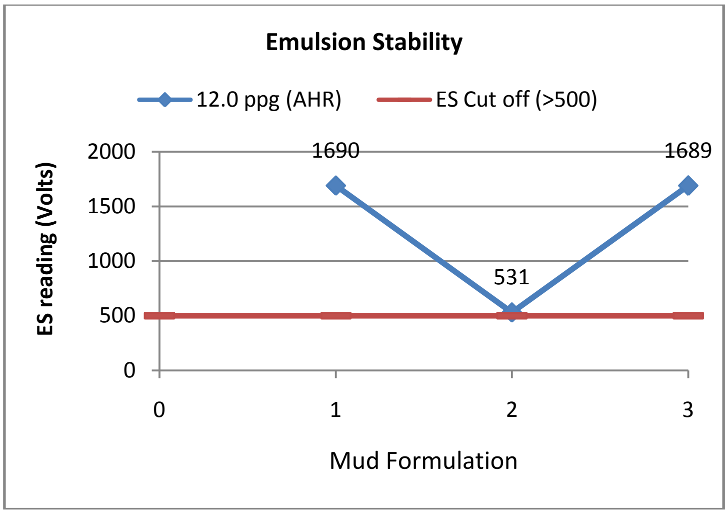

Fig. 4: Graph –Emulsion stability for 12ppg (AHR) results.

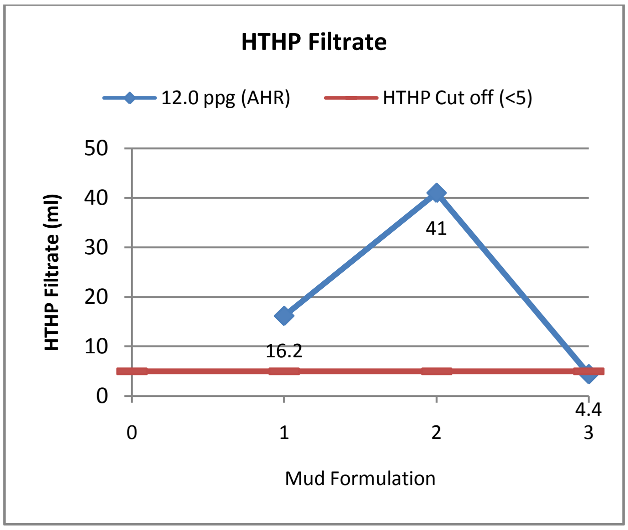

Fig. 5: Graph-HTHP fluid loss.

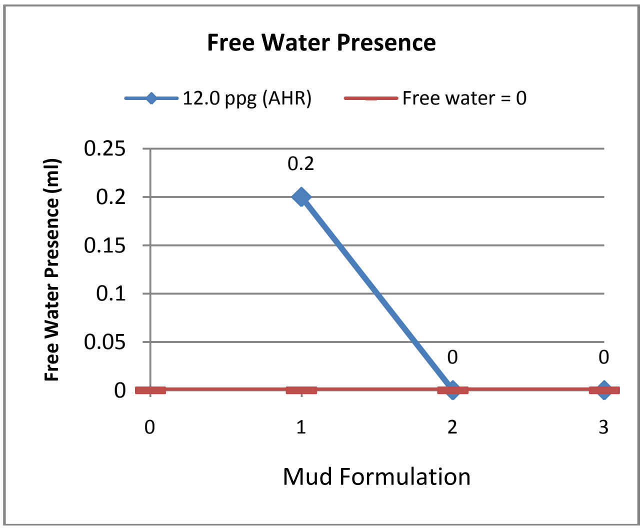

Fig. 6: Graph- Free water.

Figure 5 shows the Graph of HTHP fluid loss. Based on the results, only the mud formulation 3 satisfies the requirement for the HTHP Fluid loss criteria in which the acceptable range is below than 5 ml. The mud formulation of 1 and 2 did not satisfy the required criteria as excessive filtrate was produced during the test. However, mud formulation 2 does not have free water visible in the filtrate as shown in Figure 6 which means it has emulsion stability. Mud formulation 1 has very little visible free water. This can be due to the absence of primary emulsifier in the formulation (Growcock, 1994). The failure of both formulations can be caused by the fluid loss control agent concentration. By increasing the fluid loss control agent concentration will reduced the filtrate produced by the formulation (Rife *et al*., 2011).

Conclusion:

The development and performance of bio-based drilling fluid was performed using PFAD as base oil and others additives for drilling fluid formulation. The influence of PFAD and blending of PFAD with palm olein as base oil, and concentration of LIME and emulsifier on properties and performance of drilling fluid formulation was investigated. Based on the comparison of the three formulations, the following conclusions can be drawn:

1. Sample 1: PFAD sample with 0 ppb LIME and 0 ppb CONFI-MUL P (primary emulsifier) has a high ES reading of 1690.
2. Sample 2: PFAD sample with 0 ppb LIME and 1 ppb CONFI-MUL P (primary emulsifier) has a low Plastic Viscosity value of 32, has a high ES reading of 532 and has zero free water in HTHP filtrate.

3. Sample 3: PFAD sample with 1 ppb LIME and 1 ppb CONFI-MUL P (primary emulsifier) has a relatively low Plastic Viscosity value of 37, has a high ES reading of 1689, has a low HTHP filtrate produced of 4.4 ml and has zero free water in HTHP filtrate.

Based on the comparison, formulation of sample 3, PFAD sample with 1 ppb LIME and 1 ppb CONFI-MUL P (primary emulsifier) meets the specifications for drilling fluid formulation based on performance of PV, ES, HTHP filtrate and free water properties.

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