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The Effect of Lime and Primary Emulsifier on the Rheological Behaviour of Palm Fatty Acid Distillate (PFAD) Biodiesel – Based Drilling Fluid

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ABSTRACT

The development of eco-friendly drilling fluid using Palm Fatty Acid Distillate (PFAD) biodiesel as a base in oil-based mud was investigated. PFAD was characterized prior to its use as continuous phase in drilling fluid. Rheology test, electrical stability and filtration were measured and the stability of the PFAD biodiesel-based drilling fluid at high temperature was characterized by evaluating the performances of the drilling fluid after aging at 275^{0}F for 16 hours. These tests were conducted for PFAD-based drilling fluid and conventional oil-based mud (mineral diesel), which will lead to the justification of the PFAD-based drilling fluid adaptability level in replacing the conventional oil-based mud. The PFAD-based drilling fluid is then tested at different weight percentage of lime and primary emulsifier in order to study the effect of each additive on its behavior. Both lime and primary emulsifier are critical in ensuring proper emulsion is achieved.

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INTRODUCTION

Oil based-drilling fluids are widely used in drilling, especially in highly technical and challenging wells because it performs better than water-based mud. Oil-based drilling mud provides good wellbore stability, good lubrication that leads to faster rate of penetration, temperature stability, reduced risk of differential sticking and low formation damage. However, the disposal of oil-contaminated drill cuttings causes environmental hazard. The industry has been replacing highly aromatic oils (e.g. diesel) with low aromatic mineral oils. Nevertheless, as environmental legislation and controls become more stringent, even the newer and less polluting mineral and synthetic oils in vogue now may be adjudged unsuitable because of their non-biodegradability. Indeed, today, in many parts of the world like the USA, United Kingdom, Holland, Norway, Nigeria and Australia, the use of diesel and mineral oil-based drilling fluids in offshore operations is already either severely restricted or banned because of their toxicity, persistency and bioaccumulation. (Dosunmu, 2010).

It is undeniable environmental protection is very important worldwide. Hence, many operators around the globe are becoming more conscious of the impact that their exploration and production activities have on the environment. In Asia, this trend is catching on. Many Asian governments are also beginning to impose tighter environmental regulations for operating companies to comply with both on- and offshore. With the establishment of these corporate and legislative standpoints, Drilling and HSE engineers and advisors in Asia are under greater pressure. Efficient and environmentally friendly ways to use non-damaging drilling fluids as well as to reduce cuttings and dispose of the waste need to be find. (Global, 2013)

In this paper, biodiesel-based drilling fluid is developed. The biodiesel used is Palm Fatty Acid Distillate (PFAD) biodiesel which satisfies both the environmental and technical criteria. Environmentally as it is biodegradable and technically as it has potential in replacing the conventional continuous phase of oil-based mud while preserving the advantages. The effect of lime and primary emulsifier on it is focused. The function of primary emulsifier is to emulsify the water inside the oil and stabilize the drilling fluid. Besides primary emulsifier, concentration of lime in drilling fluid is vital as lime is used to control the degree of acidity and

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alkalinity of the prepared system, for removing soluble carbonate ions, for controlling corrosion; and for activating fatty-acid, oil-based drilling fluids additives. Both emulsifier and lime is required to activate the fatty acid in the emulsifier to ensure proper emulsion is achieved.

Apparatus and Procedures:

Rheological parameters such as plastic viscosity, yield point, 10-min gel strength were measured with six speed rotating viscometer (Fann Multirate Viscometer). Electrical stability meter measured the relative electrical strength of drilling fluids having oil phase. Filtration was measured by the High Pressure High Temperature Fluid Loss equipment at 275°F and the oil water ratio by retort test at 950°F. The stability of the PFAD biodiesel-based drilling fluid at high temperature was characterized by evaluating the performances of the drilling fluid after aging at 275°F for 16 hours.

RESULTS AND DISCUSSION

Rheology behaviour:

The rheology behaviour of PFAD biodiesel-based drilling fluid was studied at room temperature and high temperature compared with the common based-oil used in the market as given in **Table 1**. Initially, the rheological parameter of PFAD biodiesel was relatively high as compared to other. Hence, the idea to reduce the viscosity by varying the amount of lime and primary emulsifier compared with the acceptable range in oil and gas industry, was used. Rheological parameters and mud tests results for PFAD-based drilling fluid with different formulations before and after hot rolled are given in **Table 2** and **Table 3**.

Effect of Lime and Primary Emulsifier:

In order to analyse the effect of primary emulsifier and lime on the PFAD-based drilling fluid, a chart has been built (based on data from Table 1 & 2) to give better picture on the rheological parameter of each samples and for easeof comparison.

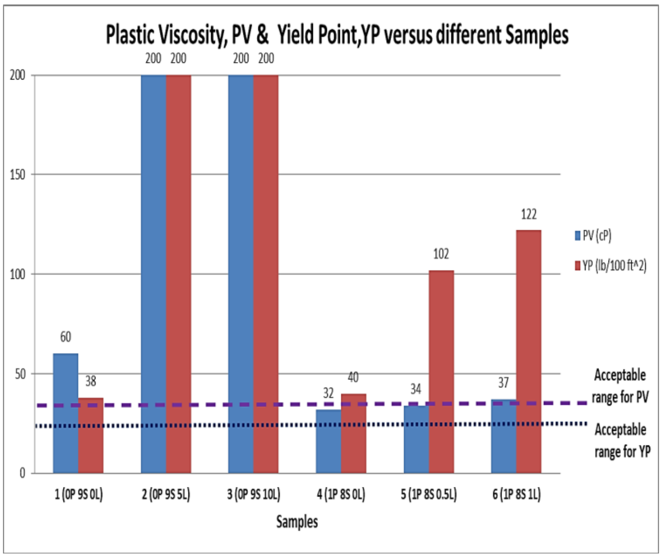

Fig.1: Plastic Viscosity (PV) & Yield Point (YP) versus different sample (*200 indicates off scale).

From figure above, there are 2 samples, 0P 9S 5L and 0P 9S 10L in which the readings are off scale. Another 4 samples are compared with the *ideal value*. In this case, the YP for all 4 sample are higher than the ideal YP. Meanwhile, for the PV, sample 0P 9S 0L yields a higher value and the other 3 values are within the tolerable range of ideal PV. The higher the value of PV and YP is most probably contributed by the higher viscosity (PV) and also presence of material suspension in the drilling fluid (YP).

[1] Acceptable range for rheological parameter in oil and gas industry

The ideal HTHP is less than 0.5 ml. However, all the sample's HTHP results are more than 0.5. To narrow the best sample to be chosen, the result which is nearest to ideal value will be selected. Nevertheless, for free water, there are 2 samples which meet the ideal standard (and 1P 8S 1L). Absence of free water indicates good emulsification of water in oil.

For the sample with no primary emulsifier (0P), the HTHP results are lower than those samples with primary emulsifier (1P). This is probably due to presence of solely secondary emulsifier in the mud composition which caused the mud to thicken. In addition, these samples consist of free water which indicates that effectiveness of water in oil emulsification due to absence of primary emulsifier.

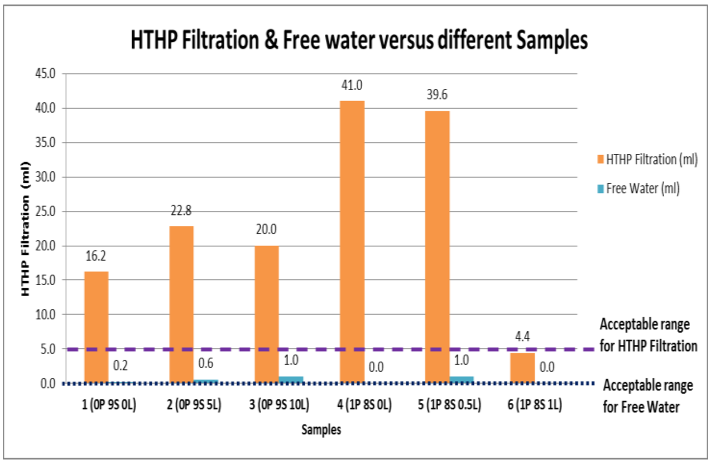

Fig. 2: HTHP Filtration & Free water amount versus different formulation of sample.

On the hand, for sample with presence of primary emulsifier, the HTHP and amount of free water data show decreasing value with increasing amount of lime. This behaviour indicates that the performance of emulsifying water in oil is improving with the presence of primary emulsifier and increasing lime composition. However, the amount of lime should not be more than 10 in weight percentage as a very viscous mud will be formed.

Figure 3 is the summary of the overall trend based on the effect of changing the amount (by weight percentage) of primary emulsifier and lime in formulation of the drilling mud. These properties are also used in determining the best formulation of the PFAD biodiesel drilling fluid based on the response data. Table 4 below shows the comparison of optimum formulation for PFAD biodiesel drilling fluid.

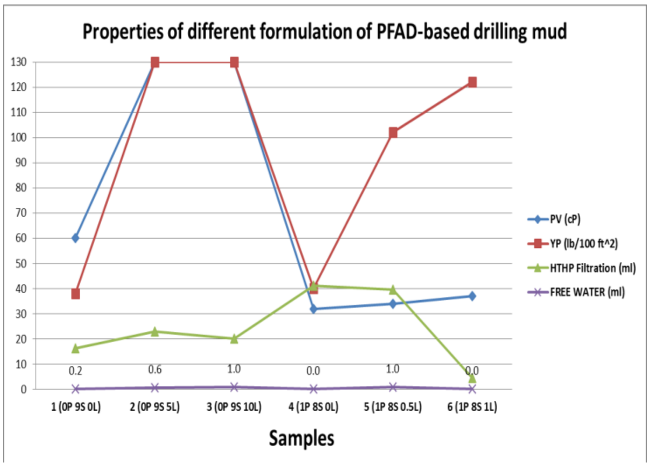

Fig. 3: Properties of different formulation of PFAD-based drilling mud.

Conclusion:

1. Based on the result, the trend of the rheological parameter is in good quality with decreases amount of lime and lower amount of primary emulsifier.
2. Samples with no primary emulsifier and increasing amount of lime yield a higher rheology reading but has a lower value in filtration and presence of free water.
3. Secondary emulsifiers are generally cannot be used alone to make a stable oil mud.
4. Samples with low amount of primary emulsifier and increasing amount of lime give a low rheology reading with decreasing amount of filtration as well as free water.
5. Hence, emulsifier set must be able to meet specifications despite being diluted. The reason behind this is different amount of emulsifier reacts differently to maintain a stable water-in-oil emulsion.

Table 1: Comparison properties of normal formulation of PFAD biodiesel based drilling fluid with common drilling fluid in market

Properties Initial	Spec Base	Sarapar 147	PFAD biodiesel Sample	Diesel Fuel	Saraline 185
Mud density, lb/gal (formulated)	12	12	12	12	12
Rheology properties at 6 RPM and 120 °F	8-12	7	196	27	9
PV, cP	< 35	21	0	29	21
YP, lb/100 ft²	15-25	9	0	38	13
Gel 10 Sec, lb/100 ft²	6-10	8	150	27	11
Gel 10 min, lb/100 ft2		12	158	33	18
ES, volts at 120 °F	>500	421	0	1267	777
Properties AHR, BHST 16 hr, (275 °F)	Spec Base	Sarapar 147	PFAD biodiesel Sample	Diesel Fuel	Saraline 185
Mud density, lb/gal (formulated)	12	12	12	12	12
Rheology properties at 6 RPM and 120 °F		4	0	10	5
PV, cP		25	0	26	25
YP, lb/100 ft²		2	0	11	7
Gel 10 Sec, lb/100 ft²		4	0	10	5
Gel 10 min, lb/100 ft2		6	0	15	7
ES, volts at 120 °F		279	0	847	530
HTHP (500 psi, 275 °F), ml /30 min		2	1.2	0.8	2.8

Table 2: Results properties of PFAD biodiesel based drilling fluid with no primary emulsifier and different amount of lime

Products	Mixing time, min	1	2	3
PFAD biodiesel sample		186.32	186.32	186.32
CONFI-MUL P	2			
CONFI-MUL S	2	9	9	9
LIME	2		5	10
Properties Initial	Spec Base	1	2	3
Mud density, lb/gal (formulated)		12	12	12
Rheology properties at 6 RPM and 120 °F	8-12	144	153	18
PV, Cp	< 35	0	0	4
YP, lb/100 ft²	15-25	0	0	107
Gel 10 Sec, lb/100 ft²	6-10	130	135	31
Gel 10 min, lb/100 ft2		132	139	32
ES, volts at 120 °F	>500	881	1402	0
Properties AHR, BHST 16 hr, (275 °F)	Spec Base	1	2	3
Mud density, lb/gal (formulated)	12	12	12	12
Rheology properties at 6 RPM and 120 °F		0	172	41
PV, cP		0	0	60
YP, lb/100 ft²		0	0	38
Gel 10 Sec, lb/100 ft²		0	195	40
Gel 10 min, lb/100 ft2		0	198	39
ES, volts at 120 °F		0	1256	1690
HTHP (500 psi, 275 °F), ml /30 min		20	22.8	16.2

Recommendation:

1. Further study needs to be done by decreasing the scale of changes in the weight percentage of primary emulsifier and lime. The effect of different secondary emulsifier can also be tested as PFAD-based drilling fluid is quite a unique based.
2. Additional study should proceed with the best PFAD-based drilling fluid **[1P 8S 1L]** with respect to;

- Ability in handling shale instability
- Resistance towards contamination of sea water, cement, calcium carbonate and etc.

Table 3: Results properties of PFAD biodiesel based drilling fluid with low primary emulsifier and increasing amount of lime.

Products	Mixing time, min	1	2	3
PFAD biodiesel sample		186.32	186.32	186.32
CONFI-MUL P	2	1	1	1
CONFI-MUL S	2	8	8	8
LIME	2		0.5	1.0
Properties Initial	Spec Base	1	2	3
Mud density,		12	12	12

lb/gal (formulated)				
Rheology properties at 6 RPM and 120 °F	8-12	52	69	76
PV, cP	< 35	68	42	22
YP, lb/100 ft²	15-25	65	116	152
Gel 10 Sec, lb/100 ft²	6-10	44	59	64
Gel 10 min, lb/100 ft2		46	62	67
ES, volts at 120 °F	>500	676	692	
Properties AHR, BHST 16 hr, (275 °F)	Spec Base	1	2	3
Mud density, lb/gal (formulated)	12	12	12	12
Rheology properties at 6 RPM and 120 °F		27	60	70
PV, cP		32	34	37
YP, lb/100 ft²		40	102	122
Gel 10 Sec, lb/100 ft²		23	44	51
Gel 10 min, lb/100 ft2		26	46	61
ES, volts at 120 °F		531	1166	1689
HTHP (500 psi, 275 °F), ml /30 min		41	39.6	4.4

Table 4: Analysis of the optimum formulation of PFAD-based drilling fluid as compared to ideal standard [Best = 1, Poor = 0]

Sample/Data	1	2	3	4	5	6
PV, (cP)& YP, (lb/100 ft²)	0	0	0	1	1	1
HTHP Filtration,(ml)& Free water, (ml)	1	0	0	0	0	1
Total	1	0	0	1	1	2

From the above analysis, the most optimum sample is **1P 8S 1L**. This sample shows a great performance in PV, YP, HTHP filtration and free water as compared to standard sample. To summarize, samples with no primary emulsifier and increasing amount of lime yield a higher rheology reading but has lower value in filtration with presence of free water. On the other hand, samples with low amount of primary emulsifier and increasing amount of lime shows a low rheology reading with decreasing amount of filtration as well as free water.

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Nomenclature:

PFAD Palm Fatty Acid Distillate
HTHP High Temperature High Pressure
P* Primary Emulsifier
S* Secondary Emulsifier
L* Lime

***** *Materials obtain from Scomi Global Research and Technology Center, Shah Alam.*

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APPENDIX A

Table 4: Percentage of materials used in preparing different samples of PFAD-based drilling fluid

Materials* / Sample	Primary Emulsifier weight % (P)	Secondary Emulsifier weight % (S)	Lime weight % (L)
1	0	9	0.0
2	0	9	5.0
3	0	9	10.0
4	1	8	0.0
5	1	8	0.5
6	1	8	1.0

* Materials obtain from Scomi Global Research and Technology Center, Shah Alam.