Investigating Alternatives To Diesel In Oil Based Drilling Mud Formulations Used in the Oil Industry

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Abstract
The investigation of jatropha and groundnut oils as alternatives to diesel in oil based mud (OBM) formulations reveal comparable performance characteristics to that of diesel. The viscosity values of the mud samples from the three oils varied considerably. At the same viscometer dial speed of 600 RPM and temperature of 60°C, the viscosities were 155, 135 and 50 centi poises (cP) for jatropha, groundnut and diesel oils based mud samples respectively. The jatropha and groundnut oil based mud samples were respectively 3 and 2.7 times more viscous than diesel oil based mud. The increasing order of mud densities was 7.5 ppg, 7.9 ppg and 8.5 ppg for diesel, groundnut and jatropha oils based mud samples respectively. Gel strength values at 10 secs and 10 mins were highest for diesel based mud than for jatropha and groundnut oil based muds while the True and Bingham yield points expectedly decreased as the mud temperature was increased.
Keywords: Drilling mud, Alternatives, Oil based formulations

1. Introduction

The upstream of the petroleum industry has thrived on the few available oil based mud (OBM) especially diesel for a while now. In recent times, following the outcomes of the past researches carried out, synthetic oils are now considered more environmentally friendly than the conventional diesel or mineral oil based mud (Fadairo, et al 2012). It is established that mud is, in varying degrees toxic (Fadairo, et al 2012). It is also difficult and expensive to dispose of it in an environmentally friendly manner. It is imperative to propagate the use of environmentally friendly and biodegradable sources of oil to formulate our OBM, thereby making it less expensive and environmentally safe. It should equally carry out the basic functions of the drilling mud such as maintenance of hydrostatic pressure, removal of cuttings, cooling and lubricating the drill string and also to keep newly drilled borehole open until cementing is carried out (Adesina, et al 2012 & Yassin et al 1991). Also, Oil-based mud are used for many other reasons, including increased lubricity, enhanced shale inhibition, and greater cleaning abilities with less viscosity. Oil-based mud must withstand greater heat without breaking down. The use of oil-based mud has special considerations. These include cost, environmental considerations such as disposal of cuttings in an appropriate place to isolate possible environmental contamination. Based on these, the type of oil used must be taken into consideration when formulating OBM. Oil-based mud can be a mud where the base fluid is a petroleum product such as diesel fuel or other forms of oils. Stakeholders in the oil and gas industry have been tasked with the challenge of finding a solution to this problem by formulating optimum drilling fluids and also reduce the handling costs and negative environmental effects of the conventional diesel oil based drilling fluid (Dosunmu & Ogunrinde, 2010). Oil based mud contain oil as the continuous phase and water dispersed in it (Sáchez, et al 1999). They typically contain less than 5% (by volume) of water. Oil-based mud are usually a mixture of diesel fuel and asphalt, however can be based on produced crude oil and mud They are considered to have the most deleterious effect on the local environment (especially diesel) and so their use has been gradually phased out in the North Sea during recent years (Kjeilen et al, 1997). Alternative types of drilling fluids have been developed as a consequence of increasingly strong environmental protection legislation. These drilling fluids have been designed to have less negative impact on the environment, i.e. they are more easily degradable and less toxic than mineral oil-based drilling fluid (Cripps et al, 1998). Numerous studies of the environment around oil-based cutting piles (Gray et al.1990) have indicated significant negative impacts on the bent hic fauna and flora (Gray et al.1990). Too much toxin in the oil based drilling fluids in use today actually goes on to constitute a nuisance in the environment. Petro-diesel does not biodegrade easily, so toxins can persist for years in the environment and lead to an accumulated concentration over time with environmental impacts including: (i) decreased plant and animal growth (ii) disrupted reproductive cycles (iii) localised death of plants and animals (iv) disruption of migratory routes used by water birds and marine life (Cities for Climate Protection, 2007). Hence, we need more environment friendly oil based mud than the ones currently available. The cost of the available oil based mud is high. This however, is because of the fact that diesel is the main oil used for the drilling fluids. We need to generate or discover more affordable oil for use as a drilling mud in order to reduce the cost of production and exploration in a reservoir. With more dedication in this aspect, there should be more cost effective and environment friendly mud that would sufficiently replace diesel in the petroleum industry as the leading OBM. The team effort of Sáchez et al (1999) on environmentally safe oil-based fluids for drilling activities is one in this direction. Their work actually shed a lot of light on the fact that the OBMs in operation are not environment friendly and proffered possible substitutions to this mud. Fadairo et al (2012) took a different approach when looking at the formation of environmentally friendly oil based drilling mud, carried out comparative experiments between diesel, jatropha, moringa and some other oil based mud. Their experiments showed various results, one of which was that jatropha oil was less toxic than diesel. This makes jatropha more environment friendly as oil based mud than diesel. However, based on their viscosities and a few other properties, diesel was still found to be a better OBM than all the other drilling fluids that were put into consideration in the research. Darley & Gray (1988) discussed the functions and properties of drilling fluids as well as the fundamental principles that govern the behavior of drilling fluids and their interactions with formations exposed by the bit. And also in drilling deeper wells higher temperatures which affect the mud components are encountered. Sachez et al, (1999) formulated drilling fluids from mineral oil and palm oil and evaluated the toxicity and biodegradability of the oil-base drilling fluids compared to those formulated with Diesel. Standard procedures were performed for both tests. The results indicate that mineral and palm tree oil based fluids are not toxic while diesel showed high toxicity levels. This is why there is a continuous need to research into many other types of oils that would wholesomely give better overall performance in place of diesel.

2 Experimental Method

2.1 Apparatus: These include: Weighing scale, mud balance, sample containers, mixer, measuring cylinders, viscometer, thermometer, mixer, beakers and heaters.

2.2 Materials: Jatropha oil diesel oil, groundnut oil, bentonite and barite

2.3 Preparation of the Mud Samples: Three mud samples of the same compositions except for the base oil used were prepared. See Table 2.1 for the quantities of the various components used. The diesel oil sample was first measured in to 1 litre plastic beaker and then placed under a mixer. The specified quantities of water and bentonite were then respectively added to the oil in the beaker and kept under continuous stirring. Barite was then finally weighed and added to the mixture until it was finally well blended into a smooth consistent paste. It was then stored into a mud sample container and labeled. The above process was repeated using jatropha and groundnut oils respectively in the place of diesel oil while other components remain unchanged.

Table 1: Constituency of the Mud

Mud	Water	Oil Type	Barite	Bentonite
Sample 1	105ml	245ml	106gm	20gm
Sample 2	105ml	245ml	106gm	20gm
Sample 3	105ml	245ml	106gm	20gm

2.4 TESTS

2.4.1 Mud Weight: The test for the mud weight was carried out using a mud balance. The procedure is as follows:

- The mud balance was first cleaned up (to avoid any additions or anomalies in the mud weight reading at the end.
- The mud balance was then kept upright and the cup was filled up to the brim with the mud to be tested.
- As soon as there was a balance between the arm of the mud balance and the cup itself, the mud weight was then taken and recorded.

2.4.2 Rheology Test.

- Using a viscometer for the rheology experiment, the viscosity for each mud was tested three times at different temperatures. It was tested first at 60^{o}C, then at 80^{o}C and finally it was tested at 100^{o}C. The viscometer allows for tests at 600 RPM, 300 RPM, 200 RPM, 100 RPM, 60 RPM, 30 RPM, 6 RPM and then it was allowed to gel for 10 seconds and 10 minutes. Readings were taken and recorded. First, the mud to be tested was agitated and blended again by the mixer. Then the mud sample was heated to the temperature at which its viscosity was to be tested. The mud to be tested was then poured into the viscometer cup up to the required level and then fixed in place for the spins at the respective dial speed. After each reading was taken, the mud was stirred for a while before the next level commences. Readings were taken at 6 RPM and then the mud allowed to stir. The viscometer is then switched off and the mud allowed to gel for 10 seconds As soon as the ten seconds has lapsed, the viscometer is turned on and the first reading seen is immediately taken and recorded. The same procedure is repeated for the ten minutes gel except that the time would change to 10 minutes. The entire procedure was repeated for other samples. This experiment not only showed the different viscosities of the three oil based mud in question, it also showed the effect of temperature on the viscosity of fluids.

Results and Discussion of Results

Table 3.1: Viscosity Variations with Temperature at Different Viscometer Readings for Jatropha Oil

Viscometer Dial Setting	Viscosity Values at Varied Temperatures		
	60°C	80°C	100°C
600	155	110	60
300	105	95	40
200	70	75	25
100	40	35	19
60	25	21	15
30	17	14	11
6	8	7	6
Gel 10secs	8	8	9
Gel 10mins	10	10	10
Plastic Viscosity	50	15	20
Apparent viscosity	77.5	55	30

Table 3.2: Viscosity Variations with Temperature at Different Viscometer Readings for Groundnut Oil.

Viscometer Dial Setting	Viscosity Values at Varied Temperatures		
	60°C	80°C	100°C
600	135	85	72
300	75	50	50
200	58	38	44
100	35	20	38
60	23	15	11
30	15	9	10
6	7	5	6
Gel 10 secs	6	4	4
Gel 10 mins	7	7	7
Plastic Viscosity	60	35	22
Apparent viscosity	67.5	42.5	36

Table 3.3: Viscosity Variations with Temperature at Different Viscometer Readings for diesel oil.

Viscometer Dial Setting	Viscosity Values at Varied Temperatures		
	60°C	80°C	100°C
600	50	50	44
300	42	41	35
200	35	32	30
100	29	25	24
60	20	17	15
30	19	19	14
6	16	14	11
Gel 10secs	18	16	13
Gel 10mins	18	15	13
Plastic Viscosity	8	9	9
Apparent viscosity	25	25	22

Table 3.4: Values of Bingham and True yield Points at Varied Temperatures

Mud Sample	Test Property	Calculated Values at Varied Temperatures		
		60°C	80°C	100°C
Jatropha	Bingham yield point (lb/100ft^2)	55	45	10
	True yield point (lb/100ft^2)	41.25	33.75	7.5
Groundnut	Bingham yield point (lb/100ft^2)	15	15	28
	True yield point (lb/100ft^2)	11.25	11.25	21
Diesel	Bingham yield point (lb/100ft^2)	34	32	26
	True yield point (lb/100ft^2)	25.5	24	19.5

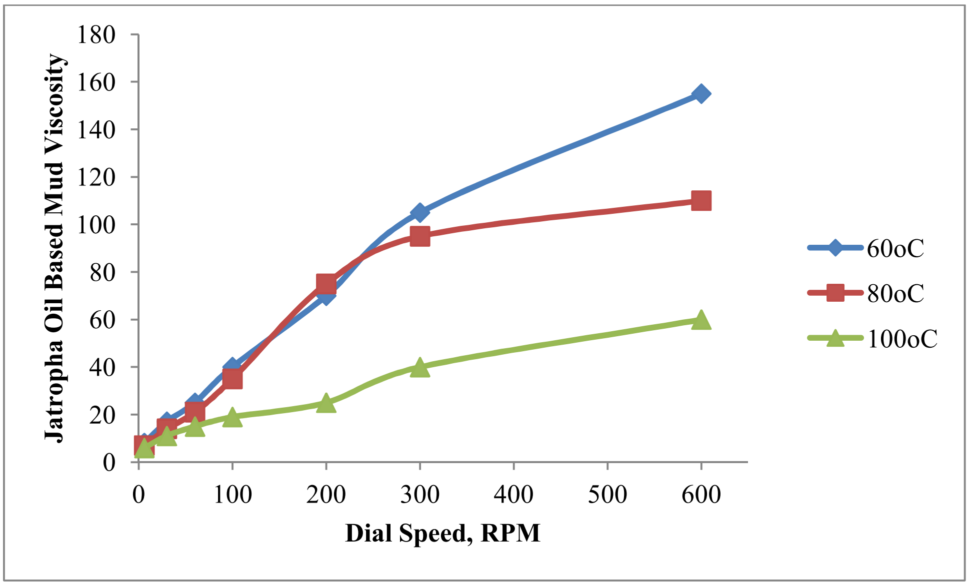

Figure 3.1: Viscosity of Jatropha Oil based mud at Different Temperatures.

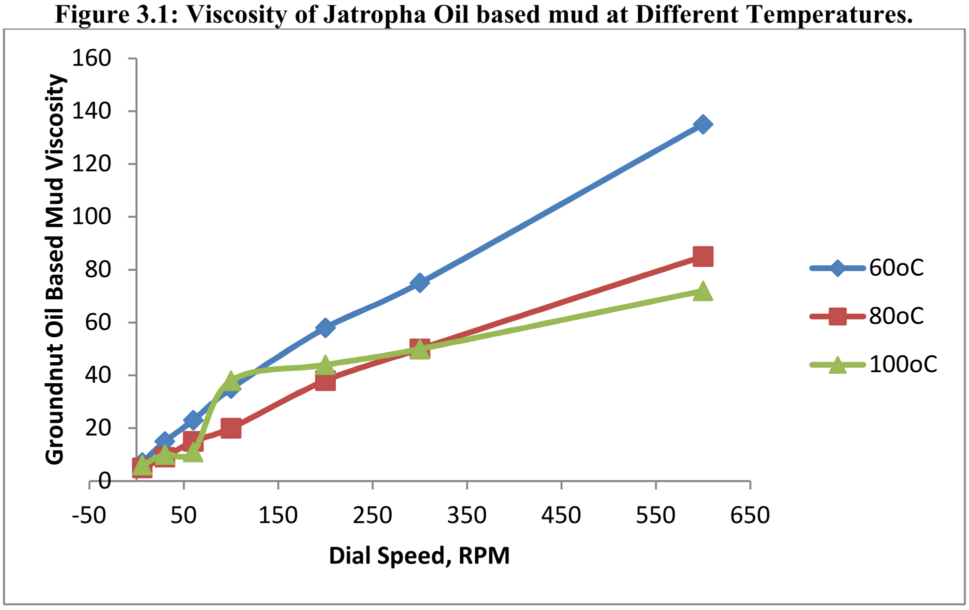

Figure 3.2: Viscosity of Groundnut Oil based mud at Different Temperatures.

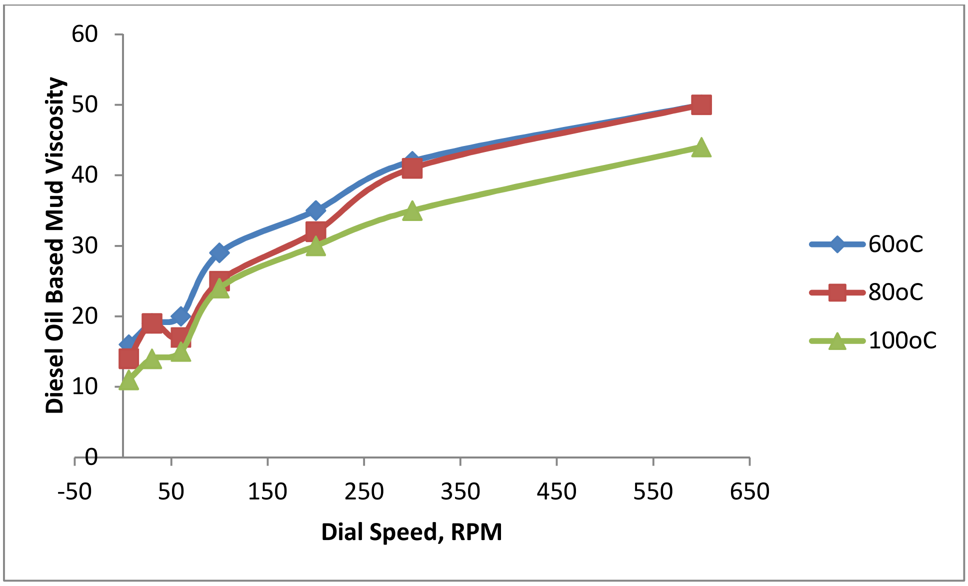

Figure 3.3: Viscosity of Diesel Oil based mud at Different Temperatures.

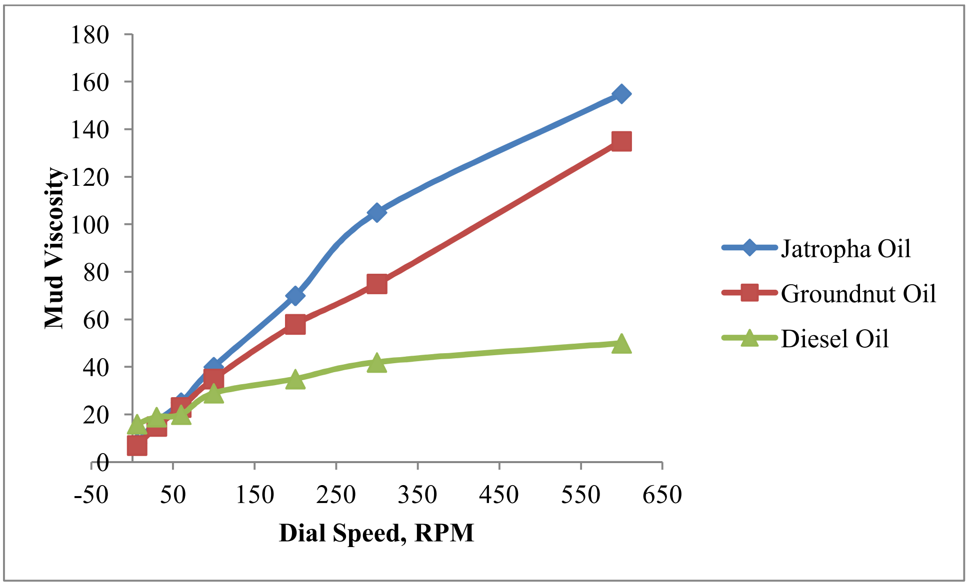

Figure 3.4: Comparative Analysis of the Viscosities of Jatropha, Groundnut and Diesel Oils At 60^{o}c

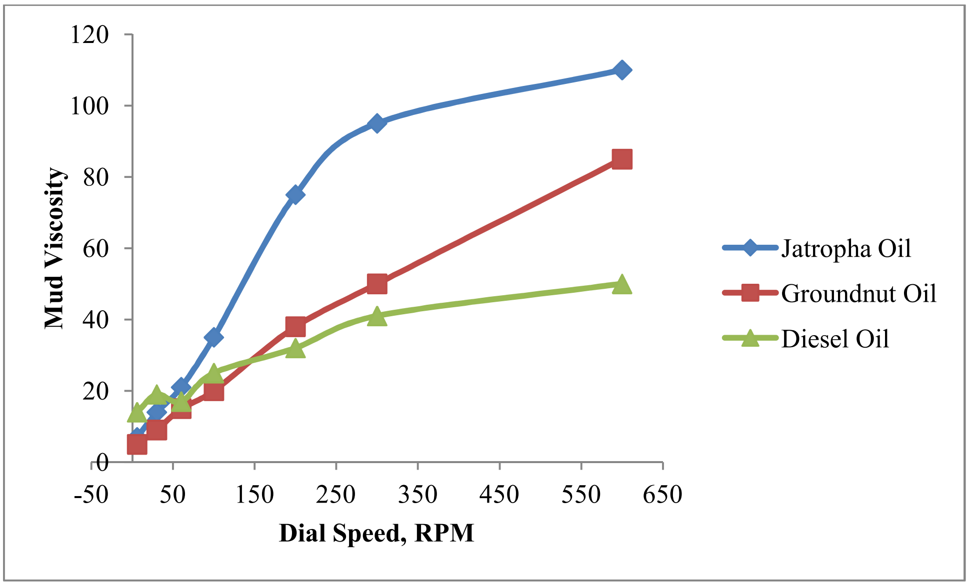

Figure 3.5: Comparative Analysis of the Viscosities of Jatropha, Groundnut and Diesel Oils At 80^{o}c

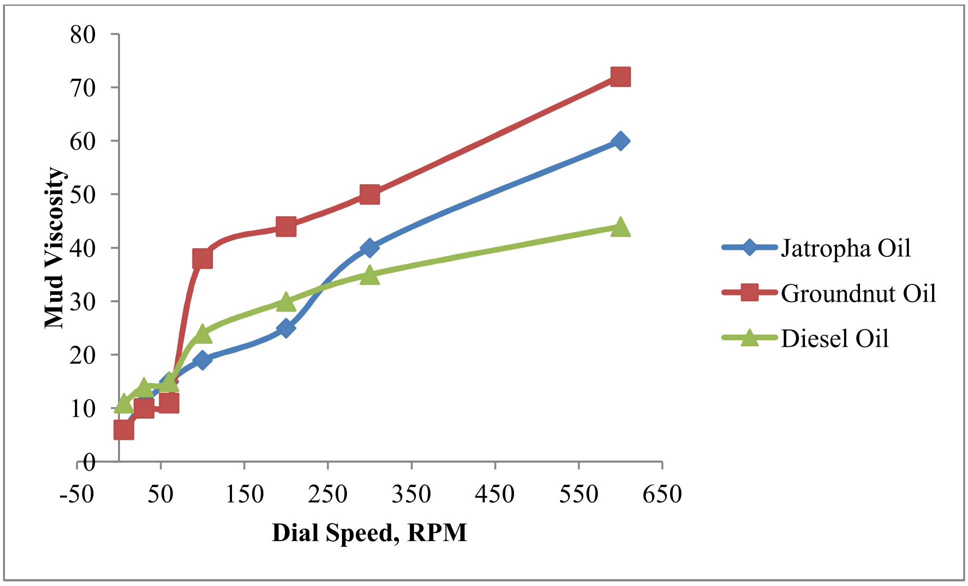

Figure 3.6: Comparative Analysis of the Viscosities of Jatropha, Groundnut and Diesel Oils At 100^{o}c

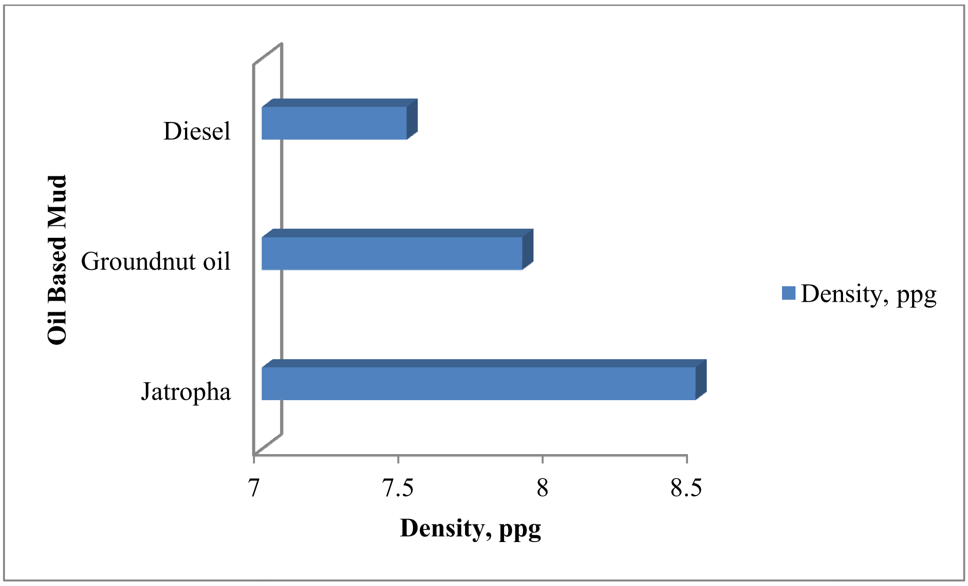

Figure 3.7: Comparative Analysis of the Densities of Diesel, Jatropha and Groundnut Oils Based Muds.

3.1 The Effect of Oil Type on the Mud Viscosity

Figures 3.1 – 3.6 and Tables 3.1 – 3.3 all depict the variation of viscosities of the various oil based muds with temperatures. It was generally observed that the viscosity of each mud investigated was highest at 60^{o}C than at other temperatures of 80 and 100 ^{o}C. As expected the viscosity steadily decreased as the temperature was increased. Highest viscosity values were obtained for jatropha oil based mud than those of groundnut and diesel oils based muds. At the same viscometer dial speed of 600 RPM and temperature of 60^{o}C, the viscosities were 155, 135 and 50 centi poises (cP) for jatropha, groundnut and diesel oils respectively. The viscosities of the jatropha and groundnut oils based mud were noticed to be far more than that of the diesel oil based mud. While jatropha oil based mud was 3 times more viscous, the groundnut oil based mud was 2.7 times more viscous than diesel oil based mud. Even at higher temperatures, the viscosities of the vegetable oils (jatropha and groundnut oils) based mud were still higher and more stable than diesel oil based mud. This shows that in formations of very high temperatures, mud based on the these two oils would perform better than diesel oil based mud in terms of mud stability, cooling effect and enhancement of its ability to suspend and carry cuttings from formation to the surface. The comparative analyses of the three oil based mud are shown in Figures 3.3 – 3.6. Jatropha oil based mud shows consistent good premise at all temperatures except at 100^{o}C where the viscosities of the groundnut oil based mud were higher. Generally though, muds with lower viscosities at higher temperatures give better overall performance than the more viscous types.

3.2 The Effect of Oil Type on Mud Density

The densities of the three oil based muds are shown in Figure 3.7. The increasing order of densities was diesel (7.5 ppg), groundnut oil (7.9 ppg) and jatropha oil (8.5 ppg). The higher the density of the mud sample, the better it helps to maintain column or hydrostatic pressure and suspend cuttings in the mud leading to better clearing of the bore. Generally though, weighting materials are calculatedly added to mud formulations to help achieve this one important property of the drilling mud. Although, the density of the oil based mud to be used depends on the reservoir conditions. Some reservoirs require a denser drilling mud especially when faced with problems like influx of other fluids into the bore. Whereas, some other conditions like lost circulation would require a less dense fluid to regulate it. The performance of the two vegetable oils in comparison to diesel oil is quite encouraging and thus may serve as potential replacements for diesel in oil base mud formulations.

3.3 The Effect of Oil Type on Other Mud Properties.

From Tables 3.1 – 3.2, the gel strengths at 10 seconds and 10 minutes of the oil based muds (OBM) were practically unaffected at increasing temperature except for diesel oil based mud where the gel strengths marginally decreased as temperature was increased. The Gel strength for Jatropha oil at 10 secs was 8, 8 and 9, and at 10mins was 10 for the range of temperature of 60, 80 and 100^{o}C respectively investigated. For groundnut oil the gel strength was 6, 4 & 4 at 10 secs and it was 7 in 10 mins for the same temperature range. The gel strengths for diesel based mud were 18, 16 & 13 at 10 seconds and 18, 15 & 13 at 10 minutes in the same temperature range of 60, 80 and 100^{o}C respectively. The gel strengths from diesel oil doubled the values obtained from the jatropha and groundnut oil based mud. With proper gel strength solids are well suspended in the hole and allow them to settle out on the surface, excessive gel strength should not be encouraged as they can cause a number drilling problems. The plastic and apparent viscosities varied considerably with temperature for the jatropha and ground nut oil based mud but were practically unaffected for the diesel based mud. While highest values were obtained for groundnut oil based mud, diesel based mud gave the lowest values. Apparent viscosity is a reflection of the plastic viscosity and yield point combined. An increase in either or both will cause a rise in apparent viscosity.

4. Conclusion

Based on the laboratory experiments performed in this research work, the following conclusions are drawn as follows:

The viscosities of the three mud samples (diesel, groundnut and jatropha) studied steadily decrease with increasing temperature.

Highest gel strength values at 10 secs and 10 mins were obtained for diesel based mud than for jatropha and groundnut oil based mud.

The True and Bingham yield points expectedly decrease as the mud temperature increase.

At the same test conditions the True Yield Point values obtained for the three samples were lower than the corresponding Bingham yield point values.

The use of vegetable oils (groundnut and jatropha oils) to produce drilling mud compared favourably in properties and performance to the mineral diesel oil mud. Generally, vegetable oils are more environment friendly and they have the capability to replace some of the mineral based muds being currently used. The benefits derivable are enormous and attractive which; include compatibility with the environment, lower overall investment cost, readily biodegradable and less toxic to human operators.

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