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Research Article

Investigating the Impact of Oil Water Ratio on Rheological Properties of Biodiesel based Drilling Mud

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Abstract

Now a days environmental regulation agencies become highly vocal on environmental issues, due to that petroleum industry especially drilling companies wants all operations safe, secure, & within the regulation limits set by these agencies. On the basis of above aspect, the drilling operations could be friendly to environment with the usage of environment friendly materials i.e. drilling fluid & cement slurry during drilling & completion activities. This study incorporates the investigation carried out regarding the prospective use of biodiesel (vegetable oils) in oil based mud formulation. The vegetable seed oil (groundnut, & soybean) was used as feedstock for biodiesel preparation by transestrification process and biodiesel was tested for physicochemical properties and compared with the standard requirements needed for base oil in drilling fluid formulation. Results show that the biodiesel met the requirements and can be used as base oil. Then both biodiesels were utilized for oil based mud preparation and formulation carried out at oil/water ratios of 60/40, 70/30, 80/20, & 90/10 and with common additives like bentonite, barite, emulsifiers etc. at laboratory scale. Then mud samples were investigated for rheological properties at normal temperature and different mud properties such as mud density, pH, and emulsion stability were determined for all the samples. Further results of mud samples were evaluated for performance in terms of cutting carrying capacity (CCI) as a hole cleaning efficiency and rheology was compared with literature and API standards of oil based mud to find out the applicability of these parameters for drilling activities and their attributes as friendly to the environment. The results showed that both biodiesel (groundnut & soybean) based mud have the highest viscosity which indicates higher lubricity and suspension of particles during flow as well as it would prevent mud losses. The overall investigation results indicate that both biodiesel based muds possess a chance for viable alternative environmentally & technically, as one of the solution to environmental problem associated with the conventional diesel oil based during drilling operations. The study also serves as a potential alternative to diesel based muds.

Keywords: *Biodiesel based mud, Oil water ratio, Water in oil, Rheology, Investigation.*

1. Introduction

Drilling mud is considered as a circulation fluid, also known as drilling fluid, used for rotary bit drilling to achieve desired or subsequent functions required drilling operation. Mud system is very much important for well drilling, having ability to perform better and withstand such a wellbore conditions. Day by day advancement in technology made it possible that the drilling of different section of well, with cost effective and highly efficient drilling fluids. The drilling fluid is considered as a blood of the drilling process, it is one of the most important elements of well design. Oil base muds are mostly used in Exploration& Production activities worldwide especially for shale formations because using water based mud has a major cause of instability in shale formations.

The usage of oil based drilling fluids become limited and an inconvenient for the environmentally sensitive regions, due to too much contaminants and its disposal(Fadairo, Orodu and Falode, 2013). Diesel content is aromatic, toxic, and poorly biodegradable; with that it is potential for polluting water supplies, might be destructive, dangerous to creature and vegetation (Agwu, Okon and Udoh, 2015),(Dardir *et al.*, 2014). Innovations and different techniques are applied to protect environment but some issues can't be solved without alternating materials with eco-friendly ingredients

Due to this serious issue, Oil industry is going towards consideration of other environment friendly approaches which does not alter or deteriorate functions of conventional drilling fluids in eco-friendly and economical limits.

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Drilling mud devotes their usage directly and indirectly to almost every operation from drilling to completion and up to depletion, due to that reason, its selection and design has a paramount importance. The oil and gas industry now a day shifting their all the operation to safe and secure technology having maximum benefit to companies and their localities, on the basis of this assumption that, main operation and very much important to an E & P company is drilling, in which company invest maximum and exist for long term.

The industry wants all operation to be carried out in environmental friendly manner, in drilling the diesel oil as base fluid is now a day's considered as highly harmful to environment and not beneficial for company in terms of cost (Agwu, Okon and Udoh, 2015). Due to environmental concern, the use of less toxic oils is preferred as a base or continuous phase (Ismail and Jaafar, 2014). The flow behavior of usual oil mud depends on the fraction of dispersed phase, and primarily on rheology of base fluid (Fakoya and Ahmed, 2018). The formulated mud from biodiesel (vegetable oil) based mud have numerous qualities in terms of better filtration and rheological behavior related to the drilling activities (Sulaimon, Adeyemi and Rahimi, 2017),(Yassin, Kamis and Abdullah, 2007).

According to review study drilling fluid components should be used to provide function as follows; 1) Base fluid must possess low viscosity & less toxic, biodegradable, 2) Primary & secondary emulsifier should be that have better stable dispersion of water in oil, 3) Viscosifier increase viscosity of mud to provide suspension of cuttings, 4) Alkalinity additives must stabilize alkalinity & emulsion of mud, 5) Brine which forms the aqueous phase of base, 6) Weighting agent have to increase mud density to prevent from blowout (Ava Drilling Fluids & Services, 1994). Water based mud are incompatible to hydratable, brittle, and dispersible shales. Stability problem could be reduced to some extent by preventing the contact of water with shaly formation, it's possible solution could be water in oil emulsion mud (Stability, no date). In recent environmental legislations throughout the world; are very much concerns on environmental issues, especially on the wastage generated by petroleum drilling operation on onshore as well as offshore. In this regard one of the example that USA environmental protection agency has limits and declare the guidelines for limit of effluents use; which allow the controlled discharge of cuttings and that must meet the specifications given by protection agencies (Mokhtar and El-sayed, 2018)(Dankwa, Ackumey and Amorin, 2018). Industry shifting their all operations to secure, safe and within the regulation limits. The biodiesel based mud possess an excellent shale stability, high lubricity, and better forbearance against contamination, having good biodegradability and less toxicity, high performance and environmental friendly (Liu *et al.*, 2016),(Ismail, Azraai and Miswan, 2012),(Ismail *et al.*, 2014),(Dosunmu and O., 2011).

This study is about characteristics, of biodiesel and biodiesel based mud and attributes of mud as an environmental friendly. The work mainly focused on the laboratory measurement of physical properties of biodiesel and rheological properties such as apparent viscosity, plastic viscosity, gel strength, yield point, pH value and mud density.

2. Methodology

The methodology of this experimental evaluation mainly focused on the biodiesel preparation from local vegetable seed oil (groundnut & soybean) as feedstock for by transestrification process and biodiesel was tested for physicochemical properties and compared with the standard requirements needed for base oil in drilling fluid formulation.Then preparation and characterization of biodiesel based mud were performed by investigating rheological & physical properties at temperatures and RPM as shown in figure 1. Then results were compared with literature and API standards.

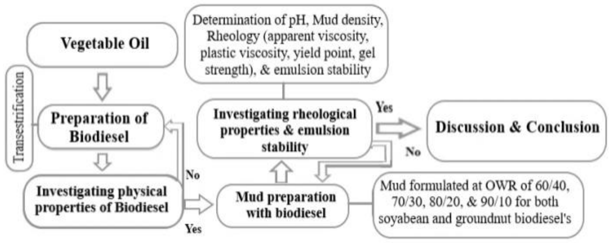

Fig.1 Methodology flow chart

2.1 *Sample collection*

The groundnut &soyabean seed oil were collected from local market and then evaluated for physical properties in laboratory; then oil samples were placed in two drying oven for removal of any moisture content if present.

2.2 *Preparation of biodiesel*

The biodiesel was prepared by transestrification process with vegetable oil (soybean & groundnut) as a feedstock. Biodiesel preparation process was described in figure 2. It could be made through a transestrification of straight vegetable oil (palm, canola, & castor etc.), waste vegetable & animal fats with main ingredients i.e. methanol, potassium hydroxide (KOH) and vegetable oil (Ferdous *et al.*, 2013),(Oghome, 2012).

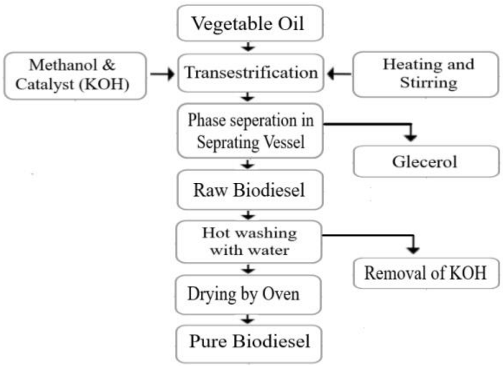

Fig.2 Transesterification of vegetable oil (preparation of biodiesel)

2.3 Measurement of physicochemical properties of prepared biodiesel

The physicochemical properties of biodiesel were determined by ASTM standard procedure and results were compared with ASTM Standard and API specification as shown in **Table 1**. According to US standard specification (ASTM 6751) for biodiesel, it is composed esters of long chain fatty acids usually made from renewable sources i.e. vegetable, seed & animal fat. It is important to know the physical properties such as flash & fire point, viscosity & density or specific gravity for further usage as a base fluid for mud formulation.(Ogbeide, 2017)

2.4 Formulation of mud samples from biodiesel

After preparation of biodiesel from groundnut and soybean seed oil by transestrification process the biodiesel was tested for physicochemical properties and compared with the standard requirements needed for base oil in drilling fluid formulation. Results show that the biodiesel met the requirements as shown in **Table 1**; here the first objective about the characterization of biodiesel was achieved. For Second objective further both biodiesels were utilized as the base oil for oil based mud formulation. After that the rheological & physical properties were evaluated with the help of API recommended apparatuses i.e. 8-Speed Rotational viscometer (OFITE) for rheology at various RPM, mud balance for mud density, Shearometer (Fann) for gel strength, and Electrical stability tester (OFI) for emulsion stability in terms of ES number(volts).

The drilling fluid was formulated with oil/water ratio of 60/40, 70/30, 80/20, and 90/10 with prepared biodiesel from groundnut and soybean seed oils; some basic components with mixing order i.e. base oil 60, 70, 80, & 90 percent, primary emulsifier, lime, filtration control agent, water 40, 30, 20, & 10 percent solution with salt 20 wt% respectively, viscosifier (bentonite), secondary emulsifier, weighting material (barite) were utilized for all mud samples of both biodiesel base oils.

2.5 Mud preparation

Initially the desired amount of base oil (biodiesel) was measured in dry and empty beaker and then it was poured into mixing cup. Further primary and secondary emulsifier was added and let it mix for 5 minutes. After that lime was added and it agitated for 5 minutes. Then bentonite as a viscosifier was added and mixed for 10 minutes. A solution of water & salt (brine) in other beaker in which water's quantity and salt's quantity about 20% by weight was formed and required amount of brine poured in mud sample and mixed for about 2 hours. After 2 hours barite was added and agitated for 30 minutes. After the elapsed time sample is ready as shown in fig 5. These muds were used for investigation of rheological properties.

Fig. 5: Prepared Biodiesel based mud (Groundnut & Soybean)

2.6 Determination of rheological properties of biodiesel based mud

Rheological properties were determined by 8-speed rotational viscometer with API standard procedure as follows: Initially the agitated sample was poured into the cup with adjustment of mud surface to scribed line on the rotor sleeve. Then the motor was started by placing the switch at the stirrer position and waited for a steady dial reading through indicator scale, and then position was adjusted to 600 RPM and the reading recorded at steady value. After that position was changed to 300 RPM, waited for a steady value and recorded. Further the gear positions were changed to the RPM which is desired for measurement as shown in **Table 2**. Gear positions were changed for each RPM only while motor was running. Apparent viscosity (centipoises), plastic viscosity (centipoises), and yield point (lb/100ft^2) in field units were calculated respectively: as AV: 600 RPM reading divided by two, PV: the difference between the dial readings taken at two highest speeds of 600 RPM and 300 RPM, & YP: the difference of the dial reading taken at 300 RPM and plastic viscosity (PV); as shown in equations a, b, & c respectively.

$$Apparent\ viscosity\ (cp) = \emptyset_{600}/2 \quad (a)$$

$$PV\ (in\ cP) = \emptyset_{600} - \emptyset_{300} \quad (b)$$

$$YP\ (lb/100ft2) = \emptyset_{300} - PV \quad (c)$$

Rheological properties are the mainly concerned with the flow characteristics of fluid. By taking certain measurements on a drilling fluid it is possible to conclude that the fluid will behave and flow under a variety of conditions. That include the plastic viscosity (PV), yield point (YP), and gel strength. These rheological parameters can be controlled and manage to required values with the usage of different additives i.e. viscosifier, emulsifier, and weighting agent etc.

2.7 Determination of mud density, emulsion stability, and pH.

The mud density was determined API recommended OFITE mud balance which consists of a base and a balance arm with cup, lid, knife edge, rider, level glass, and counterweight. The cup is attached to balance arm and the other with counterweight.(API Recommended Practice 13B-2, 2012) The purpose of this test is to measure the mud density which is defined as weight per unit volume of the drilling mud as shown in **Table 2 & 3**. It must be enormous to provide sufficient head pressure to prevent from formation pressures, but not to high enough to initiate loss of circulation, reduce penetration rates or damage to the drilled zone (Fadairo *et al.*, 2012).

The emulsion stability is an important only for oil based mud; it shows the emulsion characteristic of base fluid with water, it is also known as electrical stability(Li *et al.*, 2016),(AS *et al.*, 2018). Emulsion stability was investigated with the help of API recommended emulsion stability tester (OFITE); which consist of different parts electrode probe, cable, batteries, & ES meter, which gives the value in ES number that, represents emulsion stability(Ava Drilling Fluids & Services, 1994),(API Recommended Practice 13B-2, 2012). A pH meter an electronic device was used for measuring the pH of mud. A typical UTECH pH meter consist a glass electrode and a reference electrode connected to a digital meter that measures and displays the pH reading.

3. Results

The results of laboratory experiment for determining the physiochemical properties, rheological and physical properties for biodiesel samples and biodiesel based muds were evaluated for both groundnut and soyabean and presented in this section.

Table 1: Physiochemical properties for Base oil and ASTM, API Specification

Items	Density, (g/cc)	Kinematic Viscosity cSt at 40°C	Flash / Fire point °C
Groundnut Biodiesel	0.895	3.091	185/205
Soyabean Biodiesel	0.889	2.72	180/200
Base Oil Requirement	N/A	2.3-3.5	>66/ >80
ASTM Standard & Other literature	0.86-0.9	1.9-6.0 4.4[c] 7.6[d]	

Table 2: Rheological properties results of Groundnut biodiesel muds at different OWR

	Groundnut Biodiesel Mud			
Parameters	60/40	70/30	80/20	90/10
600 rpm	205	185	135	77
300 rpm	125	110	82	47
200 rpm	95	86	57	29
100 rpm	57	47	35	19
60 rpm	41	33	23	13
30 rpm	27	17	13	9
6 rpm	19	13	10	6
AV (cp)	102.5	92.5	67.5	38.5
PV(cp)	80	75	53	30
YP (lb/100ft²)	45	35	29	17
Gel Strength 10sec, lb/100ft²	15	11	8	3
Gel Strength 10min,lb/100ft²	17	13	9	4
MW (ppg)	8.8	8.6	8.3	8.2
ES (volts)	638	706	870	970
PH	9.6	9.5	8.9	8.7

Table 3: Rheological properties results of Soyabean biodiesel muds at different OWR

	Soyabean Biodiesel Mud			
Parameters	60/40	70/30	80/20	90/10
600 rpm	195	163	121	65
300 rpm	117	98	72	39
200 rpm	91	69	41	25
100 rpm	52	47	30	15
60 rpm	37	28	20	10
30 rpm	19	15	14	7
6 rpm	15	11	9	5
AV (cp)	97.5	81.5	60.5	32.5
PV(cp)	78	65	49	26
YP (lb/100ft²)	39	33	23	13
Gel Strength 10sec, lb/100ft²	13	9	7	3
Gel Strength 10min, lb/100ft²	14	10	9	4
MW(ppg)	8.7	8.5	8.3	8
ES (volts)	672	815	1030	1470
PH	9.6	9.4	9.2	9

4. Discussion

Drilling fluid's rheological properties plays an important role, which contribute in an effective hole cleaning; it indicate that fluid rheology highly influences on the cutting transport, hence care must be taken while predicting optimum parameter to enhance the better hole cleaning. According to American Society of Mechanical Engineers, 2005 API specification up to 300°F the rheological properties should be in the range as follows, plastic viscosity less than 35cp, Yield point in between 15-25 lb/100ft^2, emulsion stability must be greater than 400 volts, gel strength at 10 sec would be in between 6-10 and gel strength at 10 min & 6 rpm value should be from 8-12, lb/100ft^2.

In this analysis the rheological properties of biodiesel based mud (water in oil) were evaluated with the help of 8-Speed rotational viscometer for oil water ratio (OWR) of 60/40, 70/30, 80/20, & 90/10 and further the effect of composition, & temperature on rheological and physical parameters were analyzed for both biodiesel based muds.

4.1 *Effect of oil water ratio on density of mud*

The density of both biodiesel based muds shows the decreasing trend as oil content is increasing; the density of groundnut biodiesel based mud is higher than the soybean biodiesel based mud for all OWR except at 80/20 as shown in figure 3. The decrease in mud density due to biodiesel and water content because water density is higher than biodiesel density. The density of designed mud could be increased to desired amount by adding various soluble materials or solids i.e. barite & hematite (API 13B Considerations, no date).

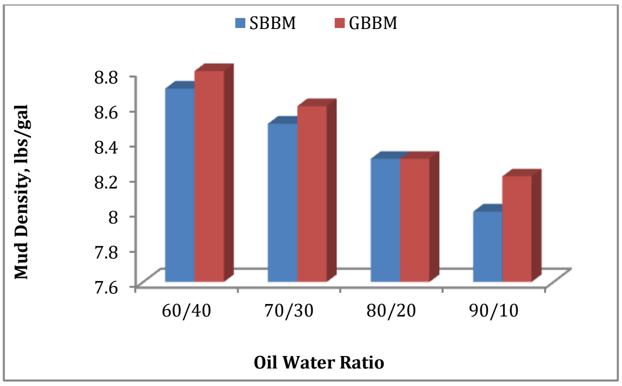

Fig.3 Effect of different OWR over density

4.2 *Effect on oil water ratio on pH*

The pH of formulated mud with various oil water ratios comes within the range of specification. According to (Ogbeide, 2017) the mud having pH from 8.3 to 9.5 considered as a prominent for wellbore stability problem in shale formation and better control on other properties, higher pH(10+) values may initiate stability problem. PH of all muds were shown in **Table 2 & 3** and represented in fig 4.

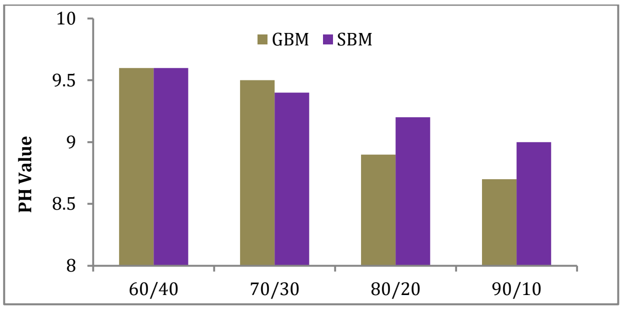

Fig.4 Effect of OWR on pH

4.3 *Effect on oil water ratio on apparent viscosity*

The apparent viscosity is greatly influenced by the change of oil water content for designed mud; both muds shows the reduction in apparent viscosity as oil water ratio increases; while the comparison carried out between both biodiesel based mud as shown in figure 5; it showed that groundnut biodiesel based mud have higher apparent viscosity but it also shows decreasing trend like soybean as OWR ratio increases.

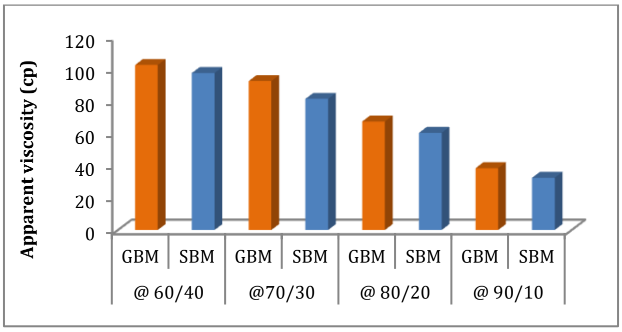

Fig.5 Effect of different OWR over apparent viscosity

4.4 *Effect of oil water ratio over plastic viscosity*

As of figure 6; the obtained plastic viscosity of all mud samples seems to be higher except at 90/10 for both biodiesel muds; while the increase in plastic viscosity were observed for both groundnut and soybean based muds as the decrease in biodiesel content 90 to 60.

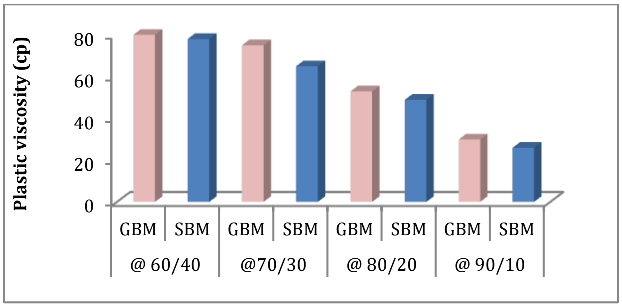

Fig.6: Effect of OWR over plastic viscosity

It may be due to the emulsion stability that influences the great change in plastic viscosity; further it could be confirmed from the emulsion characteristics.

4.5 Effect of oil water ratio over yield point

The yield point and plastic viscosity of any mud always has great importance, because mud having better PV and YP will exhibit the better ability to bear & sustain stresses created by cuttings, solid particle at higher shear rate.

Usually during circulation mud face with cutting solids or contaminated with water then yield point and plastic viscosity bear the shear stress due to solids.(Ekeinde *et al.*, 2014) The decline in yield point was observed as oil water ratio increases for both soyabean& groundnut biodiesel based mud; in other words the increasing of oil phase causes reduction of yield point as shown in figure 7. However the YP of 70/30, 80/20, & 90/10 for both mud sample comes with in the range of API standard for oil based mud.

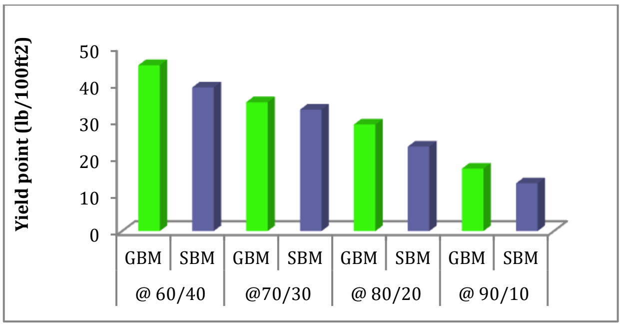

Fig.7 Effect of different OWR on Yield Point

4.6 Effect of oil water ratio on gel strength

Gel strength is an important property of mud which holds the drilled particles in suspension and mainly concerned with the base fluid used and gelling additives used.

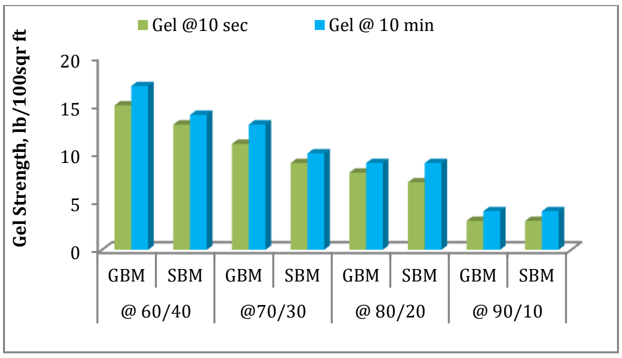

Fig.8 Effect of OWR on Gel strength

The gel strength of biodiesel based mud for 10 sec & 10 min decrease as oil water ratio increases with that groundnut biodiesel based mud has higher than soybean biodiesel based mud; as in figure 8, while both muds lies within the ranges of API standard (Dankwa, Ackumey and Amorin, 2018); which is 3-20 for ten seconds gel and 8-30 for 10 min gel.

4.6 Effect of OWR on emulsion Stability

The mud's emulsion stability is very much important for oil based mud; also known as electrical stability and measured in ES volts. As shown in figure the increases in oil content also increase in emulsion stability, means increase in oil water ratio that enhances the stability. The mud sample showed acceptable and better ES values. The electrical stability could be increased by addition of barite concentration in mud, according to literature(Growcock, Ellis and Schmidt, 1994), (API Test and Muds, no date) "Oil based mud having ES value greater than 500 volts are considered as good emulsion mud" will also be better sustainable against subsurface condition.

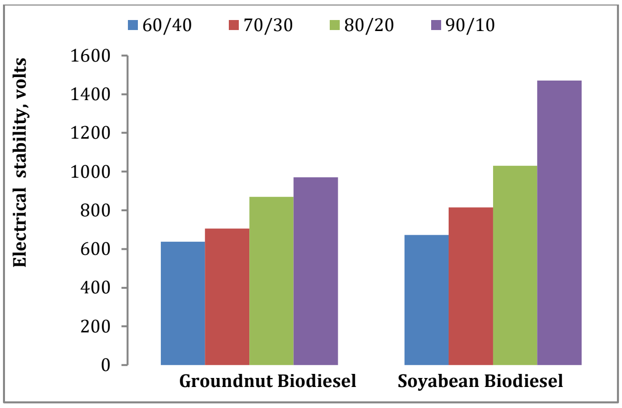

Fig.9 Effect oil water ratios emulsion stability

4.7 Effect of OWR on cutting carrying index

Rheological results obtained from experimental study can be further used to check the hole cleaning efficiency of formulated biodiesel based mud from groundnut &soyabean oils can obtained by using empirical relationship for calculating cutting carrying index (CCI) at various OWR for different temperature. Cuttings carrying index (CCI) is the capability of drilling fluid to carry drilled cuttings from the hole(Fadairo, Orodu and Falode, 2013)(Adesina *et al.*, 2015). According to ASME published book; the higher values indicates the better cleaning efficiency. Those drilling fluids shows the cutting carrying index lower values may show poor hole cleaning, may cause hole problems, while those have CCI higher values considered as an efficient drilling fluids.(Ogbeide, 2017), (Fadairo, Orodu and Falode, 2013) As shown in figure 10; results depicted that both base oil have efficient hole cleaning efficiency at normal temperature for low oil ratio, while at higher temperature and high oil ratio both base oil gives lower hole cleaning efficiency. That issue can be solved by improving the rheology while dealing at higher temperature with increasing the amount of rheology control agent like viscosifier and weighting agents. From above analysis it is observed that the groundnut biodiesel muds at OWR 60/40, 70/30, & 80/20 shows better cutting carrying capacity, while for soyabean biodiesel muds only two muds 60/40 & 70/30 gives acceptable results.

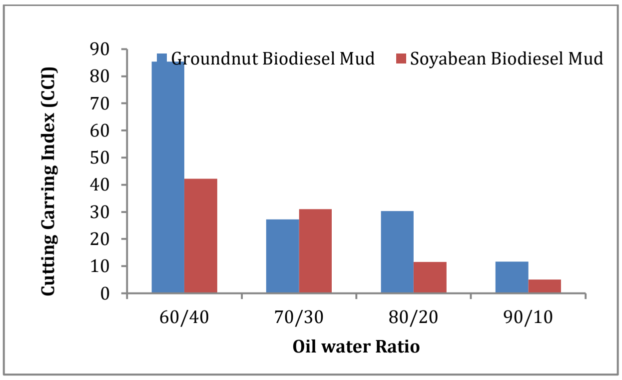

Fig.10 Effect of oil water ratios on cutting carrying index

4.8 Effect on rheological properties with addition of viscosity reducing agent

In above analysis it is observed that the prepared biodiesel based mud possess higher rheological values i.e. AV, PV and YP then viscosity reducing agent IPA was added in equal amount of 4 grams in all mud samples and further rheology were determined and compared with earlier results as well as for API specification. Here the comparison was performed only for the main parameters which were influenced due to addition of viscosity reducing agent. It could be clearly seen from figure 11 that the yield point decreased from 67 to 45 lb/100ft^2 for G-60/40, 57 to 39 lb/100ft^2 for S-60/40, 49 to 35 lb/100ft^2 for G-70/30, 43 to 33 lb/100ft^2 for S-70/30, 40 to 29 lb/100ft^2 for G-80/20, 30 to 23 lb/100ft^2 for S-80/20, 27 to 17 lb/100ft^2 for G-90/10, and 27 to 13 lb/100ft^2 for S-90/10. The plastic viscosity and emulsion stability of all mud samples was reduced with the addition of viscosity reducing agent as shown in figure 12 & 13; however both meet the API specification.

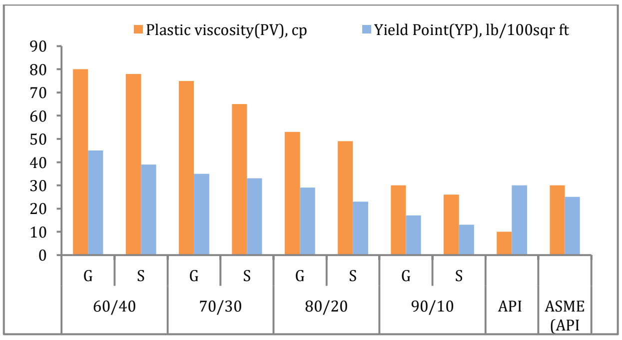

Fig.11 Comparison of PV and YP without addition of viscosity reducing agent

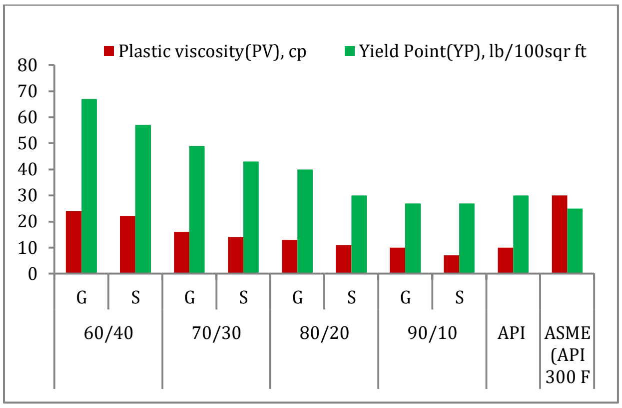

Fig.12 Comparison of PV and YP with addition of viscosity reducing agent

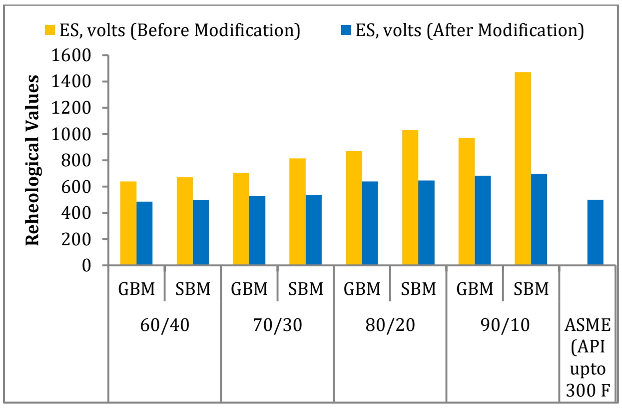

Fig.13 Comparison ES with & without addition of viscosity reducing agent

4.9 Effect of temperature on rheological properties

In this analysis the effect of temperature on rheological properties i.e. apparent, plastic viscosity, yield point, and gel strength were evaluated and presented in figures 14, 15, 16, & 17 respectively. The both biodiesel based mud revealed a consistency in reduction of AV as oil water ratio increased; while the plastic viscosity at 60/40, 80/20, and 90/10 for both biodiesel muds has shown similar trend except at 70/30. It means the 70/30 oil water ratio muds would be more efficient at that temperature. The figure 16 shoes that the yield of groundnut biodiesel based mud for 60/40 initially decreased as function of temperature then remain unchanged up to 60^{o}C; though for 70/30 & 80/20 oil water ratio muds initially remain unchanged and then slightly reduced; while the yield of soyabean biodiesel based mud was reduced as temperature increased from 40 to 60 ^{o}C.. The gel strength of both groundnut and soyabean biodiesel based muds at oil water ratio of 60/40, 70/30, & 80/20 and 60/40, 70/30 fall within the range of API specification at temperature limit of maximum 80 ^{o}C.

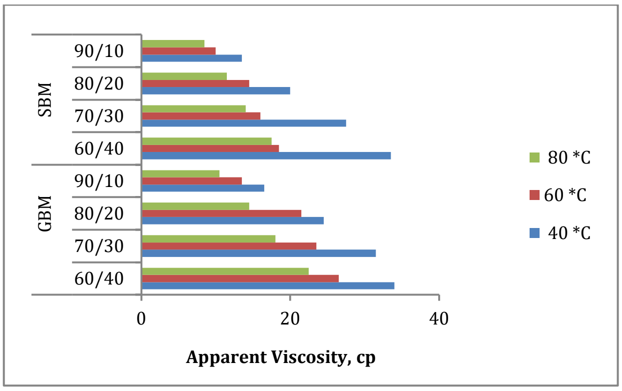

Fig.14 Effect of temperature on AV at OWR

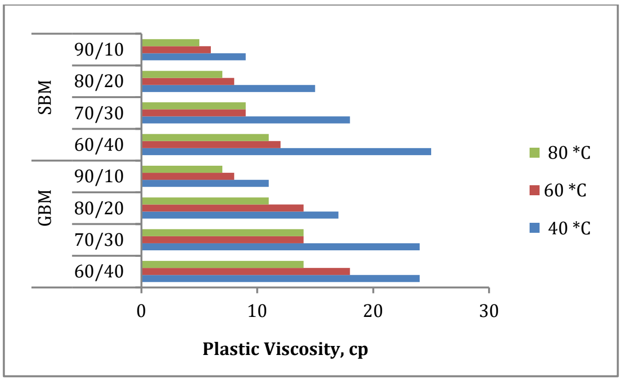

Fig.15 Effect of temperature on PV at OWR

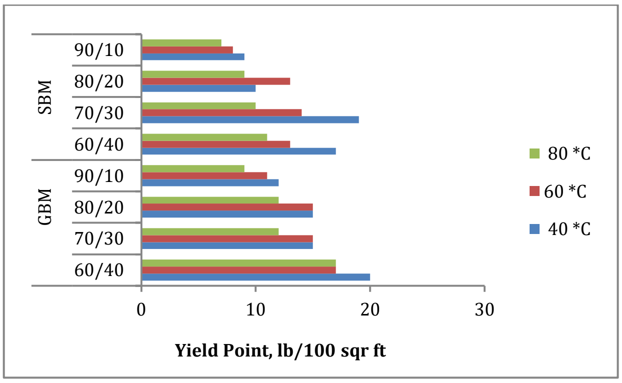

Fig.16 Effect of temperature on yield point at OWR

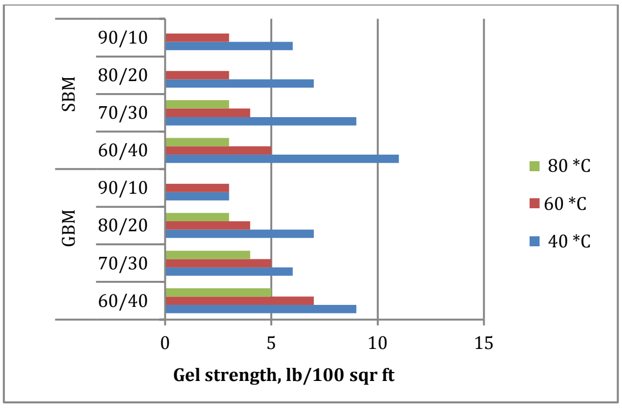

Fig.17 Effect of temperature on gel strength at OWR

Conclusion

From above study it was concluded that:

- Used vegetable oil meets the API standard requirements as base oil and holds a potential to replace other toxics base fluid for mud formulation.
- Mud formulated with varying oil water ratio gives depth knowledge of important rheological properties like plastic viscosity and yield point, & gel strength; for these parameters both biodiesel base muds has shown initially higher values then meet the requirement with addition of viscosity reducing agent.
- Emulsion stability of all mud samples meets the requirement at initial formulation, while ES for both mud system decreased after addition of viscosity reducing agent, though all mud samples retains the better emulsion stability, which is mainly required for oil based mud.

The biodiesel base mud formulated with soyabean and groundnut vegetable oil has potential to be used as oil based mud due to better rheological properties that meets the API standard and it also confirmed from study of toxicity by various researchers that both biodiesel based mud meet with in the regulations set by environmental agencies.

So the utilization of these vegetable oils at large scale, as base oil for mud preparation, will be beneficial for country and operating company in terms of secure, safe, environmental friendly and economically attractive for drilling activities. On the basis of this evaluation, used vegetable oil for rheological investigation may be planned for increasing the ability of designed mud system.

The higher cost of base oil (biodiesel) prepared from groundnut and soyabean oil could be offset by the superior properties of biodiesel based mud especially lower cost of cutting handling & disposal and it also reduces liabilities due to environment favorable materials used for mud formulation.

Future work

Further these biodiesel based mud can be analyzed for higher pressure and temperature and simulation study can be performed using these experimental results.

The rheological analysis could be performed for confirmation of hydraulic parameters like Equivalent circulation density (ECD), Equivalent static density ESD and swab or surge calculation.

These biodiesel based mud could be investigated for the other parameters like filtration and loss calculations.

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