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Determination and Comparative Study of the Effects of Temperature on the Rheological Properties of Oil Base Drilling Fluid

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Abstract

This work is to determine and compare the effects of temperature on rheological properties of oil base drilling fluid and this was carried out by formulating Oil Base Mud samples using two indigenous clay materials situated in Delta state and Edo state respectively.

Samples were produced using three varied concentrations of Oil to Water ratio. These include 80:20, 50:50 and 20:80 of Oil to Water. Each sample is tested and readings for the Mud weight, Electrical Stability, Viscosity, Gel Strength, and others were analyzed with respect to their various behaviors as temperature was varied.

From the three ratios used, the better one was the 80:20 formulation and the others which are 50:50 and 20:80, did not yield reasonable results. Meanwhile in the industry, the accepted or majorly used ratios include the 80:20. The other two were just additions to confirm the behavior of the prepared samples.

The results obtained from the 80:20 formulation shows that all the properties tested for increased as the temperature decreased, with the exception of Electrical Stability.

To further confirm this observation, various plots were made from the readings obtained. Which further confirmed that as temperature decreased, all tested properties increased with an Exception of Electrical Stability.

T-test was carried out to compare the prepared foreign betonies mud sample against Emede and Mamu samples individually to check which of these indigenous is a good match to Bentonite.

Mamu sample was accepted to be a better match to Bentonite against Emede sample for the preparation of Oil Base Drilling Mud.

Keywords: Temperature**,** Rheological, Mud, Bentonite, Properties

1.0 Introduction

Drilling fluids was used in the mid-1800s in cable tool (percussion) drilling to suspend the cuttings until they were bailed from the drilled holes.

With the advent of rotary drilling in the water well drilling industry, drilling fluid was well understood to cool the drill bit and to suspend drilled cuttings for the removal from the wellbore. Clays were being added to the drilling fluid by the 1890s. At the time that Spindle-top near Beaumont Texas, was discovered in 1901, suspended solids (clays) in the drilling fluid were considered necessary to support the walls of the borehole. With the advent of rotary drilling at Spindle-top, cuttings needed to be brought to the surface by the circulating fluid. Water was inefficient and insufficient, so muds from mud puddles spiked with somehow, was circulated down-hole to bring cuttings to the surface. Most of the solids in the circulatory system (predominantly) clays resulted from the so-called disaggregation of formations penetrated by the drill bit. The term disaggregation was used to describe what happened to the drilled clays. Clays would cause the circulating fluids to thicken, thus increasing the viscosity of the fluids [1].

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Oil based drilling fluids have become widely used in the Oil industry because of their distinct advantage over Water base drilling fluids. Unlike Water base muds, Oil base drilling fluids show significant rheological properties dependent on temperature. In this work, effect of temperature on the rheological properties of oil base drilling fluid was carried out.

2.0 Aim

This work aims at determination and comparative study of the effect of temperature on the rheological properties of Oil base drilling fluids.

3.0 Objectives

i. Formulate Oil base muds using some indigenous clay.
ii. Determine the rheological performance of these formulated samples at different temperatures.

4.0 Relevance of Study

This work helps understand the behavior of the prepared indigenous drilling fluids and the effects of temperature on the rheological properties of these fluids and how it affects drilling operation.

4.1 Classification of Drilling Fluids

Drilling fluids are classified according to this basis:-

4.2 Water Mud

Solid particles are suspended in water or brine. Oil may be emulsified in the water, in which case water is termed the continuous phase. Water itself may be used in some area as the drilling fluid. As the drilling proceeds; the drill solids will react with the water to form a natural mud.

The clay material in the drill solids is responsible for two beneficial effects [2].

i. Increase in viscosity which improves the lifting capacity of the mud to carry cuttings to the surface (this is specifically helpful in larger holes where annular velocity is low).

ii. Building a wall cake in permeable zones, thus preventing fluid loss and increasing wellbore stability.

There are two types of solids that may be present in a water based mud.

Active solids.

These are solids that will react with water and can be controlled by chemical treatment. These may be commercial clays or hydratable clays from the formations being drilled.

Inactive or inert solids.

These are solids that do not readily react with water. These may be drill solids such as Limestone, Sand and Barite.

4.3 Oil Base Mud

Solid particles are suspended in oil. Water or brine is emulsified in the oil. i.e. oil is the continuous phase [2].

Oil mud is basically (usually diesel oil) with water emulsified into it and supplemental material is added to impact viscosity, fluids loss control and oil wetting solids. A primary emulsifier is used to stabilize the emulsions and supply some viscosity and fluid loss control. The mud is to be used at a temperature above 275°F–300°F if calcium chloride water is to be added. All of the solids in an oil mud must be wet with oil to prevent aggregation of the solids and weakening of the emulsion. An oil wetting agent is used for this purpose [3].

There are two classifications of oil-based mud, namely:

4.4 Invert Emulsions and All-oil muds.

The amount of water present will describe the type of oil-based fluid. The oil used in this project is diesel from crude oil reserve.

Invert emulsions are oil muds that are formulated to contain moderate to high concentration of water. Water is an integral part of the invert emulsion and can contain a salt such as calcium or sodium chloride. An invert emulsion can contain as much as 60% of the liquid phase as water.

Special emulsifiers are added to tightly emulsify the water as the internal phase and prevent the water from breaking out and coalescing into larger water droplets. These water droplets if not tightly emulsified, can water wet the already oil wet solids and seriously affect the emulsion stability. Special derivatives or asphalties are used as the fluid loss control agents and bentonite derivatives are used to increase the viscosity and suspension properties of the system. Invert emulsions are usually tightly emulsified low fluid loss oil muds. An improvement in drilling rates has been seen when fluid loss of the system is relaxed, thus the name “relaxed” invert emulsion. Also the relaxed invert emulsion fluids do not use as much emulsifier as the regular invert emulsion systems.

Diesel (AGO) is used as the base fluid in synthetic muds are non-petroleum organic compounds that act like petroleum-derived oils in drilling operations but appear to biodegrade readily in the ocean.

4.5 Properties of Drilling Fluids
Drilling optimization in oil fields is usually formulated by using mathematical models. In these models, some parameters appear to be fundamental.

4.6 Fluid Density
Density is the first parameter to consider for desired densities greater or lower than 1. Water or oil base mud can be used respectively. Oil base mud is recommended essentially for clay formations where this density should be sufficient for drilling. Generally, for water base and oil base mud, mud weight or density can be increased by adding various solids or soluble materials. Other undesirable solids issued from geologically drilled formations are not easily removed but will be reduced to finer particles, which could have some adverse effects on mud properties. The way to avoid such undesirable phenomena is to use high speed shale shakers. In additional stages, to remove finer solids down to the 1µm range, these devices are equipped with 50 – 100 mesh screens, using medium to high molecular weight flocculants. In addition, some recommendations specified the effects of size on rheology and drilling fluid performances. Solids less than 1µm have 12 times more effects on drilling rate than larger particles.

4.7 Viscosity
The second parameter to consider is viscosity. It is a general term used to define the internal friction generated by a fluid when a force is applied to cause it to flow. This internal friction is a result of the attraction between the molecules of a liquid and is related to a shear stress. The greater is the resistance to the shear stress, the greater is the viscosity.

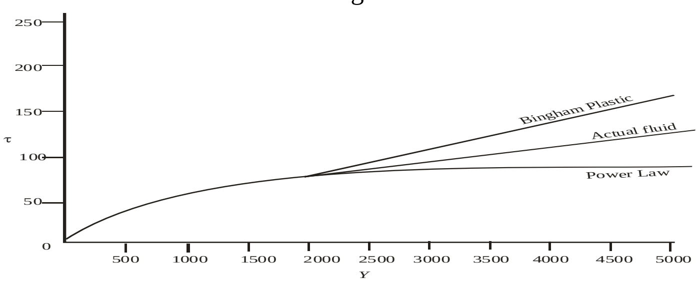

Fig. 1.0: Rheology model fits for common drilling fluid viscosity profile [4].

4.8 Emulsion Stability of Non-Aqueous Drilling Fluid
Water is dispersed as small droplets throughout the oil, emulsifiers coat the droplets, preventing them from coalescing and making the mud stable (i.e. larger water droplets will settle out and break down the emulsion). A calcium or magnesium fatty acid soap is often used as an emulsifier in an oil-based mud. The long hydrocarbon chain of the soap molecule tends to be soluble in oil while the ionic portion tends to be soluble in water when the soap is added to a mixture of oil and water. This reduces the surface energy of the interface and keeps the water droplets in the emulsion. Other types of emulsifier can also be used (e.g. Naphthenic acid soaps and soaps from free sap). The effectiveness of an emulsifier depends on the alkalinity and electrolytes present in the water phase and also on the temperature of the mud. To increase the stability, the water droplets should be small and uniform as possible. Shearing the mud with agitators does this. When oil is added, the stability increases, since the distance between droplets becomes greater, this causes a decrease in viscosity. For good mud properties there must be a balance between oil and water. The water droplets help to:
i.Support the barite ii. Reduce filter loss iii. Build viscosity and gel strength .iv. Reduce the overall diesel percentage.

4.9 Filtration
Another parameter is the loss of drilling fluid. It is generally defined as the volume of the drilling mud that passes into the formation through the filter cake formed during drilling. It is often minimized or prevented by blending the mud with additives. A number of factors affect the fluid loss properties of a drilling fluid, including time, temperature, cake compressibility, but also the nature, amount and size of solids present in the drilling fluid.
In high pressure and high temperature environments, optimization of the above mentioned three parameters is essential to lighten instability problems when drilling through shale sections. Under these conditions, selection of suitable mud parameters can benefit from analyses that consider significant thermal and chemo-mechanical processes involved in shale-drilling fluid interactions.
Nevertheless, some other factors are not taken into consideration in these mathematical models. For instance, it has been widely experienced that random factors related to soil layers, drill bits, and surface equipment, greatly affect drilling performance. Optimization layers, drill bits, and surface equipment, greatly affect drilling performance. Optimization involves the post-appraisal of offset well records to determine the cost effectiveness of elected variables, which include mud and bit types, weight on bit, and rotary speed. Stochastic models are introduced to describe such random effects. This more practical model provided a better characterization for real oilfield situations is compared with other deterministic models, and has been demonstrated to be more efficient in solving real design problems.

For drilling fluid additive evaluation, five important parameters have been proposed.

i. Main function and chemical nature.
ii. Compatibility/salt tolerance with other additives and temperature limitations.
iii. Recommended treatment range and cost.
iv. History/success of using.
v. Interference, damage and risk such as geological interpretation effects, formation damage, health, safety and environment (HSE) and waste treatment [5].

4.10 Gel Strength

The gel strength is a measurement of the shear stress necessary to initiate flow of a fluid that has been quiescent for a period of time. It is caused by electrically charged particles that link together to form a rigid structure in the fluid. The strength of the structure formed is a function of the amount and type of solids in suspension, time, temperature and chemical environment. In other words, anything which promotes or prevents the linking of particles will increase or decrease the gelation tendency of a mud. Gel strength is measured by turning the rheometer at a very low speed and reading the peak dial reflection. This represents the shear stress necessary to break the gel structure and is recorded as gel strength in lb/100sq.ft. The gel strength recorded on the mud check sheet is measured after set times of 10seconds and 10 minutes. These set times are arbitrary and have been selected simply to provide a standard basis of comparison of gel building characteristics of mud. The difference in the two measurements is an indication of the rate of gelation.

It is necessary for a weighted mud to have gel strength of about 2 to 4lb/100sq.ft in order to suspend barite. The barite will settle in a mud that has no gel strength regardless of its viscosity. A high viscosity will simply slow the rate of settling in a water-base mud that contains clay solids, the development of gel strength is a natural thing. Barite settling should never be a problem unless these clay solids have been inert by excessive chemical treatment. In such cases, addition of pre-hydrated bentonite should solve the problem. Barite suspension in oil muds is somewhat more difficult since clays solids are essentially inert in oil. Even the oil-wet clays used in some oil muds to build viscosity are not particularly good at building barite – suspending ability. It should be emphasized again that a high viscosity is not sufficient to suspend barite. A gel strength of 2 to 4lb/100sq.ft is necessary [3].

4.11 Rheology

Rheology is the study of the deformation and flow of matter. Viscosity is a measure of the resistance offered by the matter to a deforming force. Shear dominates most of the viscosity – related aspects of drilling operations. Because of that, shear viscosity (or simply "viscosity") of drilling fluids is the property that is most commonly monitored and controlled. Retention of drilling fluid on cuttings is thought to be primarily a function of the viscosity of the mud and its wetting characteristics. Drilling fluids with elevated viscosity at high shear rates tend to exhibit greater retention of mud on cutting and reduce the efficiency of high-shear devices like share shaker .

Conversely, elevated viscosity at low shear rate reduces the efficiency of low-shear devices like centrifuges in as much as particle settling velocity and separation efficiency are inversely proportional to viscosity. Water or thinners will reduce both of their effects. Also, during procedures that generate large quantities of drilled solids (e.g. reaming), it is important to increase circulation rate and/or reduce drilling rate.

Other rheological properties can also affect how much drilling fluid is retained on cuttings and interaction of cuttings with each other. Some drilling fluids can exhibit elasticity as well as viscosity. This visco-plastic fluid possesses some solid-like quantities (elasticity) particularly at low shear rates, along with the usual liquid-like qualities, (viscosity). Shear-thinning drilling fluids, such as xanthan gum-based fluid, tend to be visco-elastic and can lower efficiency of low-shear-rate devices like static separation tanks and centrifuges.

Visco-elasticity as discussed above is based on flow in shear. There is another kind of visco-elasticity however, that is just now receiving some attention, extensional visco-elasticity. As the term implies, this property pertains to extensional or elongational flow and has been known to be important in industries in which processing involves squeezing a fluid through an orifice. This property may be important at high fluid flow rates, including flow through the drill bit and possibly in high-throughput solids – control devices. High molecular-weight (HMW) surface-active polymers, such as PHPA and 2-acylam do-2-methyl-propane sulfuric acid (AMPS) – acylamide copolymer, which are used as shale encapsulators, produce high extensional viscosity. Muds with extensional viscosity – especially VW muds will tend to 'walk off' the shakers. Addition of fine or ultra-fine solids such as barite or bentonite, will minimize this effect.

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5.0 Methodology

Introduction

This section extensively lists out the equipment and material used during the project work. Also, it contains procedures or steps used in the course of the experimental work. The fluid used in this project is diesel Automotive Gas Oil (AGO).

Below are listed equipment/materials and their various functions in tabular form.

Table 1.0: Equipments Used

S/N	Equipment	Model	Functions
1.	Waring mixer	Commercial blender	It is used for mixing fluids and other additives.
2.	Measuring cylinder 500ml	Byrex, U.S.A.	It is used for measuring specific volume of fluid used.
3.	Mud balance	Fann, MB001, Singapore.	It is used for measuring the weight of fluid in different units.
4.	Phydrion pH paper dispenser		It is used to test the acidity or alkalinity nature of our prepared sample.
5.	Retort Kit	Fann,WK 098 Singapore.	It is used to get the percentage volume of water and oil in the oil based mud.
6.	Electric stability meter	FAN, ES701, Singapore.	It is used to test the emulsion stability of the oil based mud.
7.	Beaker 350Ml	Pyrox, USA	Used for measuring volume of fresh water.
8.	Spatula		For collection of samples from the bulk containers for measurement.
9.	Rheometer	Fann 355A (viscometer)	To obtain the viscosity and gel strength at various rpm and time respectively.
10.	Weigh balance (Electronic)		It is used to get the weight of each sample used.
11.	Syring.		It is used to collect liquid samples used; in ml.

Table 2.0: Formulation of Oil base mud (using Diesel oil as base fluid) along with water (dissolving agent) with various ratio by percentage in volume of 350ml.

Production	**Name**	**Formulation Ratio % of Oil water**		
Base Oil	**Percent Ratio**	**80% 20%: AGO: H_20**	**50%: 50%: AGO:H_2O**	**20%:80% AGO:H_2O**
Base-oil	Diesel	280ml	175ml	70ml
Water	Solvent	70ml	175ml	280ml
Emulsifier	Invermul	6.5ml	6.5ml	6.5ml
Viscosifirer	Geltone II	6.5g	6.5g	6.5g
Dispersant	Duratone	5.0ml	5.0ml	5.0ml
Slake lime	Calcium Hydroxide	5.0g	5.0g	5.0g
Salt	Calcium chloride	35.7g	35.7g	35.7g
Lime	Sodium hydroxide (1M)	10ml	10ml	10ml
Barite	Barium sulphate	96.5g	96.5g	96.5g
Clay	Bentonite	17.5g	17.5g	17.5g

Specific gravity of Diesel oil @ 60^0F= 0.8650

6.0 Laboratory Procedure for the Preparation Of Oil Base Mud (Obm) Using Diesel Oil

The procedures are as follows:

Step 1: 35.7g of $Cacl_2$ was weighed with the help of digital weighing balance and mixed with little portion of 70mL of fresh water in a beaker. It was stirred thoroughly until the salts were dissolved in it.

$CaCl_{2(S)} + H_20_{(L)}$---------------------------$\rightarrow$ $CaOH_{(aq)} + HCl_{(g)}$

Exothermic reaction.

Step 2: 280ml of diesel (AGO) was measured into a measuring cylinder and poured into the waring mixer and stirred for 2 minutes, and 6.5g of geltone II was weighed and gradually introduced into the mixer containing the oil.

Step 3: The solution was allowed to mixed for 5 minutes and 5.0g of lime ($CaOH_2$) was poured into the waring mixer and the mixture was stirred for another 5 minutes.

Step 4: 6.5mL of primary emulsifier (invermul) was measured with the help of a 70mL syringe and it was introduced into the solution gradually and allowed to stir for 3 minutes.

Step 5: 5.0g of fluid loss additive (duratone HT) was added into the mixer and stirred continuously at high speed for 2 minutes.

Step 6: 10ml of sodium hydroxide was added into the mixture and allowed for 3 minutes.

Step 7: Then the already mixed calcium chloride solution was added and allowed to blend in for another 5 minutes.

Step 8: 17.5g of the clay (Emede) was mixed in the remaining part of the water to ensure proper dissolution before its introduction into the solution and stirred for about 5 minutes.

Step 9: This was followed by the gradual additive of 96.5g of barite. The whole mixture was allowed to mix homogenously for 10 minutes.

The above procedures were repeated in similar manner for other base fluid with various percentages by volume in composition.

NB: These processes were repeated for the second sample also which is shale.

7.0 Test Procedure on OBM Properties

7.1 Test Procedure on Density (Mud Weight).

The density of drilling mud or drilling fluid is defined as the weight of one gallon of this fluid pound. It is also expressed as the specific gravity of the fluid.

Apparatus used

Mud balance

***Procedures*:-**

1. The mud balance instrument is set on a flat level surface.
2. The temperature of drilling fluid is recorded.
3. The clean, dry cup was filled with drilling fluid to be tested. The cap was placed on the filled drilling-fluid holding cup and rotated until it is firmly sealed.
4. It was ensured that some of the drilling fluid is expelled through the hole in the cap in order to free any trapped air or gas.
5. Holding the cap firmly on the drilling fluid holding cup (with cap hole covered by a finger), the outside of the cup was washed and wiped clean and allowed to dry.
6. The beam is placed on the base support and balance was achieved by moving the rider along the graduated scale. Readings were taken when the bubble is under the centerline.
7. The drilling fluid density is read from one of the calibrated scales on the arrow side of the sliding weight. The units are specific gravity, pounds per gallon, pounds per cubic foot, or as a drilling fluid gradient in pounds per square inch per 1000ft.

7.2 Maintenance

Fill the cup with fresh water. Replace the lid and wipe dry and return to box.

7.3 Rheology (Flow Properties).

This method describes the procedure for the determination of the differential (plastic) viscosity and bingham yield stress (gel strength) of the fluid and its thixotropic property during a period of rest.

Drilling fluid is placed in the annular space between two concentric cylinders. The outer cylinder or motor sleeve is driven at a constant rotational velocity. The rotation of the rotor sleeve in the fluid produces a torque on the inner cylinder or bob. A torsion spring restrains the movement of the bob, and a dial attached to the bob in dictates displacement of the bob. Instrument constant were adjusted so that plastic viscosity and yield point are obtained by using readings from rotor sleeve speeds of 600rpm and 300rpm.

Apparatus

Direct indicating viscometer, FANN VG MODEL METER 35 SA; Stop watch and thermometer.

Procedure

1. A sample of the drilling fluid is placed in a thermostatically controlled viscometer cup. Enough empty volume was

left (approximately 50mL to 100mL) in the cup to cover for the displacement of fluid due to the viscometer bob and sleeve. The rotor sleeve was immersed exactly to the scribed line.

2. A constant shear at 600rpm was used to break the gel for 15 seconds. During the stir, the thermometer was used to get the temperature at ^{0}F.
3. With the sleeve rotating at 600rpm, the viscometer dial reading was observed carefully and when the dial got to a steady value, it was recorded.
4. The rotor speed is reduced to 300rpm. The value was taken when the viscometer dial reached a steady value. This is the 300rpm reading.
5. The bob is raised up to the midpoint and set at 3rpm and 6rpm then same procedures is repeated to obtain the viscosity values at 3rpm and 6rpm.
6. Again the bob is raised to the highest level and tightened to set it at 100rpm and 200rpm then the gear is set at low and then high to obtain the various values for the 100rpm and 200rpm reading.

Apparent viscosity (AV).

This is the effective viscosity of true or plastic fluid at 600rpm reading divided by 2.

$$\frac{600rpm\ reading}{2} = \text{Av in centipoises (cp)}$$

Plastic viscosity.

This is a measure of the internal resistance to fluid flow, expressed in centipoises (cp). This is indicative of the concentration, shape, and size of the solids in the fluid.

The plastic viscosity is calculated thus:-

$$600rpm\ reading - 300rpm\ reading = Pv\ in\ centipoise\ (cp).$$

Yield point (YP).

It is a measure of the resistance to initial fluid flow or the stress required to start fluid movement. It is measured under dynamic conditions. The attractive force is due to electrical charges located on the surface of solid particles [6].

The value of yield point is obtained thus:-

$$100rpm\ reading - plastic\ viscosity = \text{Yp in lb/100sq.ft.}$$

Gel strength

It is a measure of the amount of attractive forces set up in the drilling fluid under static conditions. The magnitude of gelation, as well as the type of gel strength is a key factor in the performance of the muds function. i.e. suspension setting of cuttings and weight materials.

The gel strength is recorded at 10 seconds and 10 minutes time intervals for the 0 minutes and 10 minutes gel strength respectively.

Procedure

1. Push the gear shift of the Fann v-g meter all the way down and press the stirring switch at high speed for 15 seconds to break the gels, then release.
2. Raise the knob to the middle point then start the stop watch and allow the desired rest time 10 seconds for the 0-minute gel. When the desired time is up, push the gear shift to 3rpm (low) speed position, note the maximum deflection of the dial before gel breaks and this is the gel strength in lb/100sq.ft.

Repeat procedures for the 10 minutes gel strength but changing rest time above to 10 minutes. This becomes the gel strength for 10 minutes in lb/100sq.ft.

Maintenance

1. Wash the rheometer cup thoroughly and wipe dry. Also use a clean damp rag to clean the rotor sleeve of the rheometer.
2. Dismantle the rotor and ensure all parts such as splash guard etc and all corners are clean before re-assembling it.

7.4 Test procedure of Electrical Stability

The electrical stability (ES) of an oil-based fluid is a property related to its emulsion stability but not necessarily oil – wetting capability. ES is determined by applying a voltage ramped, sinusoidal electrical single across a pair of parallel, flat-plate electrodes immersed in the drilling fluid. The resulting current remains low until the threshold voltage is reached, where upon the current rises very rapidly, this threshold voltage is referred to as ES of the oil-based drilling fluid and is defined as the voltage (in peak volts) measured when the current reaches 61µA. Thus a mud or drilling fluid with a high electrical stability voltage or value is considered to be stable.

Apparatus

An electrical stability meter, beaker.

Procedure

1. The equipment was first calibrated to ascertain it performance efficiency.
2. The drilling fluid sample was placed in a viscometer cup, and the temperature was measured /recorded.

3. Proper maintenance was carried out on the electrode probes. This was done by cleaning the body thoroughly with a clean paper towel. The electrode gap was also cleaned with a dry clean towel.
4. The electrode probe was swirled in the already prepared oil based mud.
5. The oil based mud was hand stirred for about 10 seconds with the electrode probe. This is done to ensured composition and temperature of the drilling fluid to be uniform. During the procedure, it was ensured that, the electrode probes was positioned so that, it did not touched the bottom or sides of the container, and also the electrode surfaces was completely covered by the sample.
6. The electrode probe of the electric stability meter was not more during the voltage ramp test.
7. At the end of the ramp test, the electric stability value of the sample was displayed on the read out device [7].

***Maintenance*.**

Rinse the probe with diesel to remove particles of drilling fluid stuck around it.

NB. Do not use xylene or toluene or any liquid chemical to rinse off probe.

Study Area.

Sample A.

The study area of sample A is Emede located in Isoko south local government area of Delta State, Nigeria. Isoko south local government area was established on the 23rd of September ; when Isoko south LGA was divided with its headquarters at Oleh. Isoko south local government area occupies a land mass of about 668 square kilometers (258 miles) with a total population of about 235,177 as at 2006 petroleum census.

Sample B.

Sample B is an Exposed Maastrichtian shale outcrop also called the Mamu shale located at the Auchi-Ighara road, Edo State, Nigeria. 07°05.07N, 006°14.8E; 162.72 m above sea level.

8.0 Results and Analysis

The formulas used in deriving/obtaining of results in this project, which was carried out in the drilling mud and laboratory of Petroleum Engineering and Geosciences Department of Petroleum Training Institute (P.T.I) were calculated strictly on standard formulas as given by American Petroleum Institute (API) in solving for various mud properties.

Table 3.0: Results for ratio 80 : 20 (OIL : WATER)

Properties	**Bentonite**	**Temp. Range 212^0F - 195^0F**		**Temp. Range 160^0F - 145^0F**		**Temperature 82^0F**	
		Emede	Mamu	Emede	Mamu	Emede	Mamu
pH	11	11	9	11	9	11	9
Mud weight (ppg)	9.50	9.90	9.90	9.98	10.00	10.02	10.05
Electrical stability (v)	440.45	1231	1024	911.5	974	705.5	925
Viscosity@ 600 rpm	110	45	63	73	81	157	240
300rpm	91.3	30	54	53	70	122	180
200rpm	70.1	23	30	44	56	107	156
100rpm	50	17	22	35	47	89	126
6rpm	32	12	15	21	38	48	79
3rpm	30	10	12	20	34	50	70
Av (cp)	55	22	31.5	36.5	40.5	78.5	120
Pv (cp)	18.7	15	9	20	11	35	60
Yp (lbs/100ft^2)	72.6	15	45	33	59	87	120
N	0.27	0.59	0.22	0.46	0.21	0.36	0.42
K	17.10	0.78	13.50	2.98	18.84	12.63	13.55
10 seconds gel (lbs/100ft^2)	23.7	8	12	25	37	41	71
10 minutes gel (lbs/100ft^2)	29.2	12	17	33	48	50	85

From Table 3.0 above it is observed that the mud weight increases gradually with a decrease in temperature, hence Sample A (Emede) and Sample B (Mamu) increases greater than that of Bentonite when comparing them. Thus it shows that when temperature increases, mud weight decreases and the drilling fluid becomes lighter in weight but as temperature decreases as seen above, the mud weight increases. This could be dangerous if the pressure exerted from the mud weight becomes greater than the formation pressure; leading to formation fracture and further problems to the formation and then disrupting drilling operations. In order to avoid these problems, the hole temperature should be checked when formulating drilling mud samples to be used.From sample A, it is observed that the Electrical Stability decreases with a decrease in temperature but the sample A and sample B readings still fall under the optimum value for a standard oil base mud which is between.

400-1000Volts. These mud samples are stable and would not conduct electricity. Well, Emulsion Stability of a mud will not necessarily determine the stability of its conductivity, but it is quite informative in monitoring clay in the relative stability of the mud. Hence, it is good the oil base mud should be prepared with the possible water-free method, low volume filtrate (filtrate loss) at bottom hole condition of temperature.

From Table 3.0, it was observed that the viscosity values of both samples A (Emede) and sample B (Mamu) increased gradually with decreasing temperature. Viscosity being the measure to which the fluid will flow; shows that as temperature reduces, viscosity increases and the less its flow capacity. This increase in viscosity shows that the particle bombardment which occurs when temperature is increased then reduces. As this bombardment is reduced, the free and easy movement of the fluid is reduced thus drilling fluid that gets downhole may not easily be re-transported to the surface. Hole cleaning and drill cuttings transportation which are important functions of a good drilling fluid now becomes impossible due to the over viscous nature of the drilling fluid. Hence hole temperature should be properly checked when preparing drilling fluids to ensure proper functions and a smooth drilling operation.

It is observed that the Gel readings of sample A and sample B increases with a decrease in temperature but also it shows good gelation ability when compared to the column of Bentonite which tells that the mud samples are good enough to suspend cuttings while drilling operations is paused or stopped.

Table 4.0: Results for ratio 50 : 50 (OIL : WATER)

Properties	**Bentonite**	**Temp. Range 212^0F – 195^0F**		**Temp. Range 160^0F - 145^0F**		**Temperature 82^0F**	
		Emede	Mamu	Emede	Mamu	Emede	Mamu
pH	12	14	12	14	12	14	12
Mud weight (ppg)	10	10.13	10.15	10.20	10.20	10.22	10.25
Electrical stability (v)	190.5	163	192	123	201.5	205	228
Viscosity@ 600 rpm	>300	270	>300	300	>300	>300	>300
300rpm	>300	200	277	251	>300	>300	>300
200rpm	268	162	230	210	275	261	>300
100rpm	223	107	193	162	234	217	>300
6rpm	135	33	118	85	136	135	194
3rpm	120	25	103	76	120	124	158
Av (cp)	Cnd	135	Cnd	150	Cnd	Cnd	Cnd
Pv (cp)	Cnd	70	121	49	Cnd	Cnd	Cnd
Yp (lbs/100ft^2)	178	130	156	202	193	173	Cnd
N	Cnd	0.43	Cnd	0.2571	Cnd	Cnd	Cnd
K	Cnd	13.46	Cnd	50.51	Cnd	Cnd	Cnd
10 seconds gel (lbs/100ft^2)	117	29	104	62	116	75	173
10 minutes gel (lbs/100ft^2)	127	72	115	73	134	82	200

NB: CND means Can Not be Determined.

Using the viscometer which maximum dial reading is 300cp, when testing for those parameters bearing CND, the viscometer reading exceeded the maximum hence the exact value could not be determined and cannot be substituted into any of the available formulas.

9.0 Discussions of Results

From Table 4.0 which is the formulation of 50:50 Oil : Water, it was observed that the range of values of both sample A and sample B were close and is probably good enough to function well.

Table 4.0 shows that both samples A and samples B do not fall into the range of 400 – 1000Volts which is standard; hence the Electrical Stability of both samples under this ratio 50 : 50 Oil : Water is not stable.

From Table 4.0, it is observed that for the viscosity at 600rpm the viscometer which has a maximum dial reading of 300cp could not detect the exact reading of those parameters tagged CND because as the gear was turned the dial deflected greater than its maximum. This occurred to samples A and B respectively because of their highly viscous nature. For the other dials above, their viscosity values are also very high and fluids with too high viscosity cannot easily transport cuttings to the surface; hence making drilling operations unsuccessful.

Also from the results above in Table 4.0, as temperature decreases, viscosity becomes high so proper mud preparation should be done and some additives such as viscosifier could be considered.

From Table 4.0, the Gel strength is high and probably shows some traits of being able to form Gel while drilling operation is stopped.

Table 5.0: Results for ratio 20 : 80 (OIL : WATER)

Properties	Bentonite	Temp. Range 212⁰F – 195⁰F		Temp. Range 160⁰F - 145⁰F		Temperature 82⁰F	
		Emede	Mamu	Emede	Mamu	Emede	Mamu
pH	8	9	10	9	10	10	10
Mud weight (ppg)	10.3	9.5	10.4	9.53	10.45	-	-
Electrical stability (v)		1	4	1	6.5	-	-
Viscosity@ 600 rpm	37	30	25	58	54	-	-
300rpm	25	17	13	35	33	-	-
200rpm	29	19	15	28	17	-	-
100rpm	23	14	8	21	10	-	-
6rpm	25	16	40	12	41	-	-
3rpm	18	12.5	21	10	26	-	-
Av (cp)	18.5	15	12.5	29	27	-	-
Pv (cp)	12	13	12	23	21	-	-
Yp (lbs/100ft^2)	13	4	1	12	12	-	-
N	0.5653	0.819	0.943	0.728	0.710	-	-
K	0.7363	0.103	0.036	0.373	0.394	-	-
10 seconds gel (lbs/100ft^2)	110	5.5	105	8	110	-	-
10 minutes gel (lbs/100ft^2)	156	8	134	10	141	-	-

Results from Table 5.0 are unstable and even during tests at the laboratory, it showed fluctuating and inconsistent values due to the formulation ratio of 20:80 of Oil: Water volume. Due to the fact that water content is greater than oil in the formulation, it no longer appears to behave like oil base mud.

It was observed that after preparation, large amount of water which could not blend into the formulation rose above while the mixed portion of the mud went below because of their differences in density.

The electrical stability appeared too poor, proving that the emulsion stability of this formulation is too low and does not meet standard.

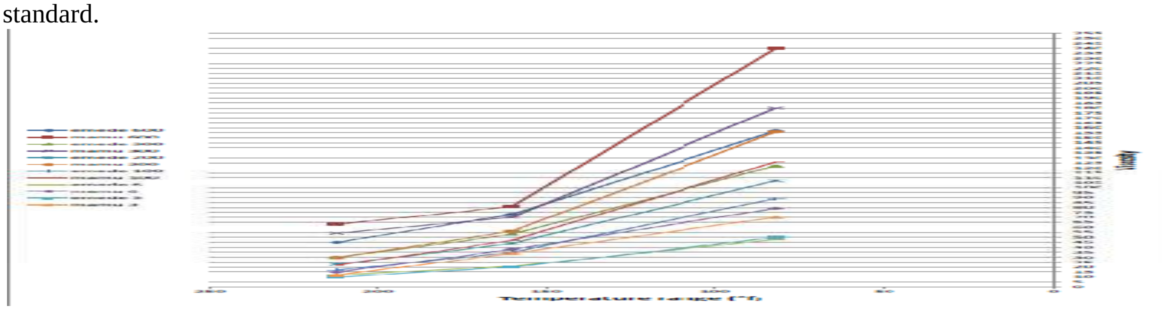

Fig 2.0: A Plot of Viscosity Against Temperature of 80:20 (o:w)

This plot confirms that as temperature reduces, the viscosity of both Emede and Mamu samples increases. This is in line with the discussion above.

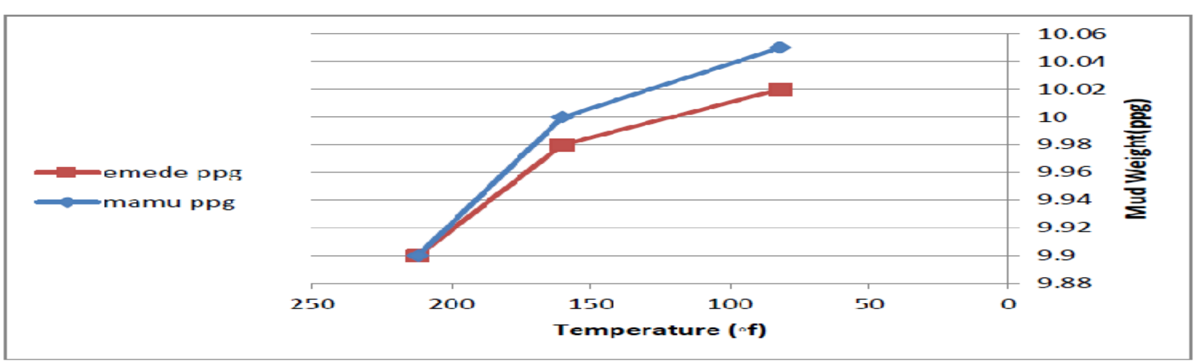

Fig 3.0: A Plot of Mud Weight/Density Against Temperature. (80:20) o:w.

This Fig3.0 shows the behaviour of both samples in terms of mud weight against temperature and also confirms that mud weight of both samples increases as the temperature decreases.

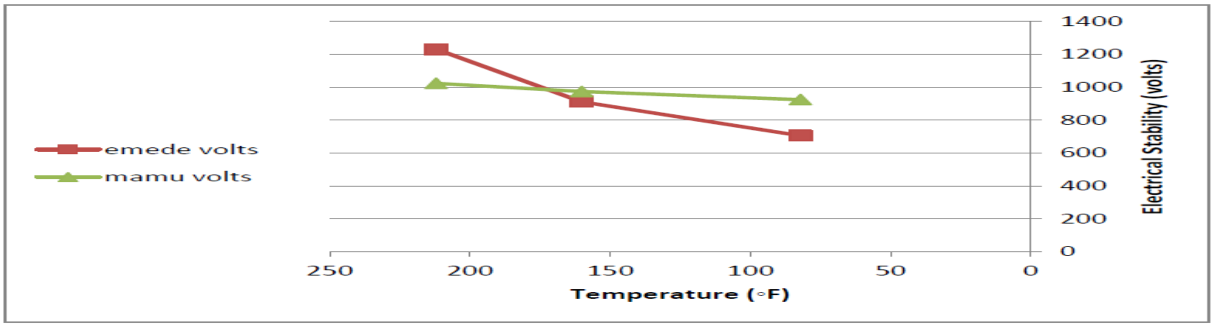

Fig 4.0: A Plot of Electrical Stability Against Temperature.

Fig. 4.0 above shows the behavior of Emede and Mamu samples respectively with respect to electrical stability. It is observed that electrical stability reduces as temperature reduces.

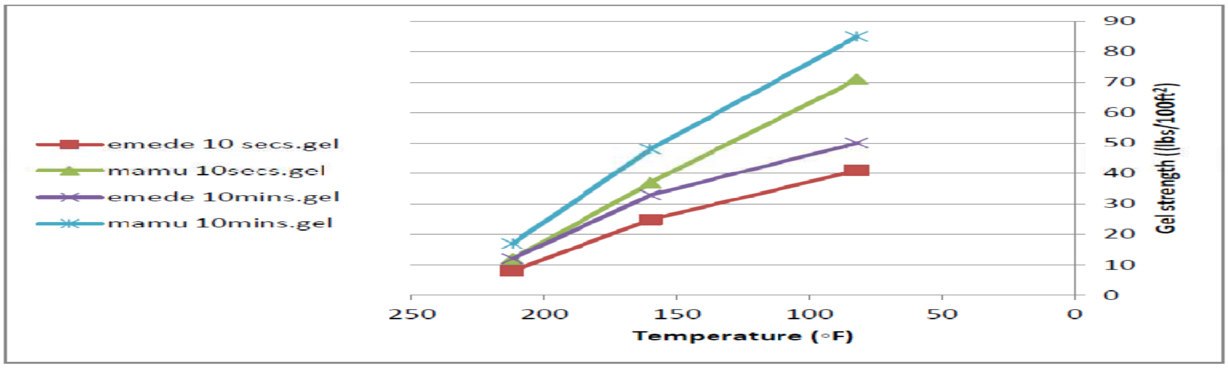

Fig 5.0: A Plot of Gel Strength Against Temperature.

Fig.5.0 above shows the behavior of Emede and Mamu samples in terms of Gel strength against temperature. It is observed that as temperature reduces, Gel strength increases. Thus the Gel strength for sample Emede and Mamu increases with a decrease in temperature.

9.1 T-Tests.

T-test was used (William Gosset , 1909) to compare between various samples of the OBM samples with Foreign bentonite sample.The results are shown in Tables 6.0 and 7.0.

We will use the viscosity readings of Emede, Mamu of temperature range 212°F -195°F against Bentonite. (80:20 formulation)

Table. 6.0: Viscosity values for Bentonite and Emede.

BENTONITE	110	91.3	70.1	50	32	30
EMEDE	45	30	23	17	12	10

Table 7.0: Results obtained.

α values	Obtained t-ratio	Table t-ratio	Status	Conclusion
0.10	2.874	1.812	O.T.R > T.T.R	Not pass
0.05	2.874	2.228	O.T.R > T.T.R	Not pass
0.01	2.874	3.169	O.T.R < T.T.R	Pass

NB: O.T.R – Obtained T-Ratio.
T.T.R – Table T-Ratio

Calculations on how these values and results were obtained are contained in the Appendix section.
There is a significant difference between Bentonite sample and Emede sample in comparison of suitability for preparation of Oil base mud.

Table 8.0:Viscosity values for Bentonite and Mamu

BENTONITE	110	91.3	70.1	50	32	30
MAMU	63	54	30	22	15	12

Table 9.0: Results obtained

α values	Obtained t-ratio	Table t-ratio	Status	Conclusion
0.10	1.974	1.812	O.T.R < T.T.R	Not Pass
0.05	1.974	2.228	O.T.R < T.T.R	Pass
0.01	1.974	3.169	O.T.R < T.T.R	Pass

NB: O.T.R – Obtained T-Ratio.
T.T.R – Table T-Ratio.
Calculations on how these values and results were obtained are contained in the Appendix section.
There is no significant difference between Bentonite sample and Mamu sample in comparison of suitability for preparation of Oil base mud.

10.0 Conclusion

Looking at the rheological data from 4.1, 4.2, 4.3 obtained from the different formulations of diesel with water in ratios of 80:20 (O:W), 50:50 (O:W), 20:80 (O:W) of Oil Base Mud. It was concluded that:-

- From this three formulations; the 80:20 (O:W) is the best formulation to be used since it does not appear to be too viscous as compared to the 50:50 (O:W) and does not appear less quality and immiscible as the 20:80 (O:W) formulation. Also because all values for each parameter tested for for the 80:20 formulation were obtained as compared to others.
- From the plots and data obtained; it is obvious that all the rheological properties tested for which included Mud Weight, Electrical Stability, Viscosity, Gel strength all increased as temperature decreased with exception of Electrical Stability which decreased as temperature decreased. Hence temperature plays a key role in the behavior and nature of our drilling fluid and in the rheological properties of OBM.

From the T-Test carried out on the samples A and B, it is concluded that sample A (Emede), when compared with Bentonite does not measure up to the standard set by the T-Test analysis. Thus Emede clay is not accepted as good match to Bentonite.
For sample B (mamu) which passed two out of three of the analysis for the T-Test, proving to be a good match to Bentonite and that there is no significant difference between Bentonite and Mamu samples with respect to being used for the preparation of Oil Base Mud. Hence Mamu/ Maastrichtian shale is a so far considered to be a good sample to be used in preparing Oil Base Mud.

11.0 Recommendation

It is recommended that the 80:20 (O:W) formulation should be used as against 50:50 (O:W), 20:80 (O:W) in preparation of standard OBM.
It is also recommended that test temperatures should not go below 195°F as seen in Table 4.0.

13.0 Appendix

Formulas.

Apparent viscosity (AV).

$\frac{600rpm\ reading}{2}$ = Av in centipoises (cp)

Calculation of Apparent viscosity (AV) cp

AV = $\frac{63}{2}$ = 31.5 cp

Plastic viscosity.

$$600rpm\ reading - 300rpm\ reading = Pv\ in\ centipoise\ (cp).$$

PV = 600rpm – 300rpm
= 63 – 54 = 9 cp

Yield point (YP)

$100rpm\ reading - plastic\ viscosity$ = YP in lb/100ft^2

YP = 300rpm – PV
= 54 – 9 = 45 cp

Power law – n

n = 3.32log $\frac{600rpm}{300rpm}$
= 3.32log $\frac{63}{54}$
= 3.32log 1.167
= 3.32 x 0.067
= 0.222

Consistency index

K = $\frac{600R}{1022}n$
= $\frac{63}{4.665}$= **<u>13.50</u>**.

Calculation of Apparent Viscosity and other parameters in sampel B, where rheolmeter readings for 600rpm and 300rpm exceeded 300, i.e, 0ff scale,

PV = 300rpm – YP
YP = (2 x 100rpm) – 200rpm.

This formular was also stated in chapter 2, under Bingham plastic fluids discussion, and it was used to calculate for viscosity in chapter 4, table 4.2

12.0 References

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