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Evaluating the Effects of Additives on Drilling Fluid Characteristics

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Abstract

Drilling fluid plays a vital role in hole cleaning, suspension of cuttings, prevent caving, and ensure the tightness of the well wall. Moreover, they also help in cooling and lubricating the drilling tool, transfer the hydraulic power and carry information about the nature of the drilled formation by raising the cuttings from the bottom to the surface, using a simple mixture of water and clays, to complex mixtures of various specific organic and inorganic products as additives. These additives improve fluid rheological properties and filtration capability, allowing bits to penetrate heterogeneous geological formations. Two potassium Chloride polymers were formulated to test the effect of varying concentration of additives on the drilling fluid characteristic for water base mud. From the experimental results of formulation 1and 2, rheological properties shows that the plastic viscosities are 18 and 8Cp and yield point are 32 and 8 lb/100ft2 respectively. Also the mud weights are 8.4 and 8.3ppg, fluid loss, 11and 13 mls, and pH are 12.7and 12.5 respectively. Two oil base muds were also formulated to test the effect of additives on drilling fluid characteristic at varying concentration. From the experimental results, the rheological properties show that the plastic viscosities are 19and 13Cp and yield point are 21 and 10lb/100ft2 respectively. Also the mud weights are 9.5 and 9.0 ppg, fluid loss, 6 and 10 mls, and pH are 10.5and 9.7 respectively. Electrical stability which is the increase in voltage across a probe until the emulsion breaks and a current is established were also obtained as 400 and 340v in the oil base mud. It will vary with the amount of water - the more water generally the lower the stability; as the emulsion stabilizes the electrical stability increases..

Keywords – Drilling Fluid.

Introductions

The selection and application of drilling fluid are key factors in the success of any drilling operation. Drilling fluid is used in the rotary drilling process to clean the rock fragment from beneath the bit and carry them to the surface, exert sufficient hydrostatic pressure against subsurface formation to prevent formation fluid from flowing into the well bore, keep the borehole open until casing and cementing, cool and lubricate the drilling equipment and subsurface tubular.

To meet these design factors, drilling fluid offer a complex array of interrelated properties. Five basic properties are usually defined by the well program and monitored during drilling: Rheology, density, and fluid loss, solid content and chemical properties. For any types of drilling fluid, all five properties may to some extent, be manipulated using additive, however, the resulting chemical properties of a fluid depends largely on the types of mud chosen, and this choice rest on the types of well, the nature of the formation to be drill and the environmental circumstances of the well. (Baker Hughes 2011)

Additives used in drilling fluids

Drilling and well completion operations utilize a lot of chemicals. The only way we can create jobs and actualize the local content initiative is to make sure that most of the chemicals needed in the oil industry are manufactured in the country. Our local content contribution in the oil industry presently is not even up to five percent, the concept of the local content development is not about awarding of contracts to Nigerians with foreign counterparts, but developing and expanding the industry for the benefit of the majority. (Baroid Drilling manual Jan revised 2007)

Clay chemistry

Thus, an understanding of clay chemistry is important in the selection of a drilling fluid system and borehole stability. Most reservoir sandstones also contain some clay minerals. These may react with the fluids that contact them in such a way as to completely block the formation. Therefore, the structures and reactions of clays are important in

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the design of fluids that may be in contact with the producing zone. Clays play a significant role in drilling fluids, particularly in water base fluids. They may be added intentionally to control the viscous flow properties and to provide the colloidal properties required for filtrate loss control, or they may build up through drilling of formations in which they predominate. Commercial clays such as bentonite and attapulgite are purposely added to enhance drilling fluid properties. However, since the combination of formation clays and commercial clays frequently leads to too much viscosity, a large group of chemicals, including those described as "mud conditioning chemicals", are added to control the viscous properties. (George et al 2007)

Bentonite: - Prehydrated bentonite is used to viscosify KCl-Polymer Muds. Bentonite also provides a colloidal solid that can improve filter cake quality in freshly- prepared muds. Since bentonite will dehydrate from the high salt content of the mud and lose viscosity over time, constant additions of bentonite may be needed. When feasible, API "Nontreated" bentonite is recommended because it provides a noticeable reduction in material requirements and also provides better mud performance. (ZHANG 2011)

Potassium Chloride (KCl):- Potassium chloride is used to inhibit clay hydration. The amount of KCl actually needed for inhibition is difficult to determine. Older formations which contain nonswelling clays, require KCl levels in the 3 to 5 wt% range; whereas, younger shales containing hydratable clays, require KCl levels up to 15 wt%. (ZHANG 2011)

Caustic Potash - Caustic potash (KOH) is added for alkalinity control in a KCl-Polymer Mud rather than caustic soda because it provides pH control without introducing potentially destabilizing sodium ions. Generally, a pH range of 9.5-10.5 is considered optimum for running KCl-Polymer muds since high pH has a detrimental effect on polymer adsorption. However, in some cases, particularly in coring applications, a neutral pH (7-8) is desired. (ZHANG 2011)

Xanthan Gum - Biopolymers such as XC or XCD are used for viscosifying KCl-Polymer Muds either by replacing or supplementing prehydrated bentonite. Although KCl-Polymer Muds may display a high yield point, they may not be capable of adequately suspending barite; therefore, small quantities of xanthan gum are added to provide the required suspension properties.

Polyanionic Cellulose/Carboxymethylcellulose (PAC/CMC - Cellulosic polymers are added for filtration control. When chloride concentrations are below 50,000 mg/L, either technical-grade or regular- grades CMC are used for filtration control rather than PAC. High-viscosity CMC is generally not used because it can have a deflocculating effect; therefore, pilot testing should always be performed prior to treatment

Properties to determine

Density

The starting point of pressure control is the control of mud density. The weight of a column of mud in the hole necessary to balance formation pressure is the reference point from which all pressure control calculations are based. The required weight of the mud column establishes the density of the mud for any specific case. Fortunately, density is one of our most accurate measurements. With a simple mud balance we are able to weigh a mud to the nearest 0.1 lb. / gal, which is equivalent to 5.2 psi per 1000 ft. of mud column. Mistake (AMOCO Drilling fluids training manual)

Rheological properties

The flow (or rheological) properties of a mud are those properties which describe the flow characteristics of a mud under various flow conditions. In a mud circulating system, flow occurs at a variety of rates in conduits of different sizes and shapes. In order to know or predict the effects of this flow, we need to know the flow behavior of the mud at the various points of interest in the circulating system. To simplify the measurement procedure, we make only a limited number of measurements. When a fluid flows, it exerts a frictional drag – called the shear stress – on the surface of the conduit. The magnitude of the shear stress depends on the frictional drag between adjacent "layers" of fluid traveling at different velocities, and the difference in velocities of adjacent layers next to the wall of the conduit. The difference in velocities between adjacent layers is called the shear rate. We are interested in the effect of the flow at the wall where both shear rate and shear stress are a maximum.

Plastic Viscosity

Although calculated from measurements at relatively low shear rates, the plastic viscosity is an indicator of high shear rate viscosities. Consequently, it tells us something about the expected behavior of the mud at the bit. One of our design criteria was to minimize the high shear rate viscosity. To accomplish this, we should minimize the plastic viscosity. A decrease in plastic viscosity should signal a corresponding decrease in the viscosity at the bit, resulting in higher penetration rate. Increasing the plastic viscosity is not a desirable means of increasing the hole-cleaning ability

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of a mud. In fact, the increase in pressure drop down the drill string, caused by an increase in Plastic Viscosity, would reduce the available flow rate and tend to offset any increase in lifting ability. In general, high plastic viscosity is never desirable and should be maintained as low as practical. However, time, temperature, and agitation tend to disperse and allow hydration of the individual clay platelets, which results in increased viscosities. In order to combat the tendency of shale particles to disperse and hydrate, the "inhibitive" muds were designed. Materials such as lime, gypsum, lignosulfonate, and polymers are added to inhibit the rate of dispersion and hydration.

Plastic viscosity decreases with increasing temperature, due to thinning of water. If the mud is checked at 130°F, the PV will be about 10 percent lower than at 120°F; if it is checked at 110°F, it will be about 10 percent higher. For this reason, all mud tests should be made at the same temperature, 120°F. (Dosunmu 2003)

Yield Point

The yield point, calculated from the Bingham equation, is not the true yield stress necessary to maintain flow, but is a value which is somewhat higher. It is normally close to the value of the shear stress at annular shear rates. Anything that causes changes in the low shear rate viscosities will be reflected in the yield point. For this reason, it is a good indicator of flow behavior in the annulus and compositional changes that affect the flow behavior in the annulus. However, as the shear rate is increased, the particles are electrically attracted to one another, the effect is quite similar. At low shear rates the particles link together, increasing the resistance to flow; at high shear rates the linking bonds are broken and the fluid becomes more like water. These two effects combine to determine the yield point of a mud. The electrical interaction of solids is controlled by chemical treatment, and the mechanical interaction is controlled by adjusting the type and amount of solids or polymer in a mud. High yield points are caused by flocculation of clay solids or high concentrations of colloidal solids. Flocculation may be due to lack of sufficient deflocculent, high temperature, or contaminants such as salt, calcium, carbonates, and bicarbonate. A high solids concentration will aggravate flocculation tendencies from any cause. The yield point is primarily associated with two mud functions: the hole cleaning capability and the pressure control characteristic of a mud. A higher yield point increases the carrying capacity of a mud and increases the circulating pressure drop in the annulus. Associated with increased circulating pressure drop is increased pressure surge and swab from pipe movement. (Dosunmu 2003)

Filtration

Filtration occurs any time a permeable formation is exposed to a mud at a pressure higher than the formation pressure. The pressure causes filtrate to flow into the rock and deposit mud solids on the walls of the borehole. Thus, filtration causes two distinctly different types of problems-those due to filtrate invasion and those due to filter cake deposition. The problems caused by filtrate invasion are not drilling problems, but are formation evaluation and completion problems. Excessive fluid loss may cause flushing of the zone around a wellbore to the extent that logging and formation test information is incorrect. This is normally not a problem with weighted muds where filtration control is necessary for control of filter cake deposition. In clear water or low solids muds, excessive flushing may present problems. Another problem is invasion of a formation by a liquid that will greatly reduce the formation permeability. Consequently, the volume of filtrate lost is not as important as the type of filtrate. From the standpoint of the drilling operation, the filter cake is of more concern than the volume of filtrate. The filter cake has a direct bearing on such problems as differential pressure sticking, torque and drag, lost circulation, and poor primary cement jobs. Our basic aim is to minimize the thickness and permeability of the deposited cake. High solids content can cause the fluid loss to be low but result in a thick cake. (Baker Hughes 2011)

PH

The pH of a solution is a measure of its hydrogen ion concentration. At each hydrogen ion (H+) concentration, there is an equilibrium concentration of hydroxyl (OH-) ions. By measuring the hydrogen ion concentration, we are, in effect, also measuring the hydroxyl ion concentration. In pure water, the H+ and OH- concentrations are the same. This is the neutral point, or a pH of 7. When acid is added to water, the pH decreases on a scale from 7 to 0. When a base (caustic) is added to water, the pH increases on a scale from 7 to 14.

Oil mud formulations

Product requirements are listed for each company over the temperature ranges noted. These formulations are based on lab conditions and will be lower in actual field usage. The field requirement is lower because of the incorporation of drill solids, particle size of the weighting material, and longer periods of shear experienced while drilling. The formulations listed can be formulated in diesel or mineral oils with only small modifications.

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Oil Mud Properties

Mud weight of oil muds ranges from 7.5 lb/gal to over 22.0 lb/gal. Downhole density is affected by temperature and pressure more than water base muds. Temperature will decrease the density of oil muds due to expansion and pressure will increase the density due to compression of the oil phase.

Viscosity is affected by temperature and pressure, as the temperature increases, viscosity decreases. Conversely, as the pressure increases, the viscosity increases. The funnel viscosity measurement of an oil mud is greatly affected by temperature. The funnel viscosity of an oil mud is usually used as an indicator and is not normally used for treatment purposes. Rheological properties are usually made with a rotational viscometer. The plastic viscosity, yield point and gel strengths measurements (according to the Pseudoplastic Rheology Model) are made with the rheometer. More accurate descriptions of the rheology of the mud are made with the Yield-Power Law Model. Suspension of cuttings and weighting material is monitored with the gel strength (for static settling) and 3 or 6 rpm reading (for dynamic settling). The rheology of oil muds are run at the same temperature for each test. Plastic viscosity is greatly affected by temperature in which mud is normally tested; the higher the temperature, the lower the plastic viscosity.

Electrical stability (E.S.) is the increase in voltage across a probe until the emulsion breaks and a current is established. The electrical stability will vary with the amount of water - the more water generally the lower the stability. Presence of conductive solids such as hematite and insoluble salt will result in low E.S. readings. New sine wave E.S. meters are more reproducible and reliable. Falling E.S, readings and the presence of water in the filtrate indicate weakening of the emulsion. Emulsifiers and lime additions are usually required. (AMSE 2005)

HPHT filtration is run at bottom hole temperatures under static conditions to determine condition of emulsion, the filtrate volume and filter cake quality. If water is present in the filtrate, this could indicate emulsion weakening. Thick filter cakes and high fluid loss indicate excessive drill solids content. Lower the filtration rate with filtration control agents, emulsifiers and lime. Increase the fluid loss by dilution with base oil.

Experimental procedures

Mixing procedure for formulation in the lab

340 Milliliters of water was measured and poured into the mixing cup with 8 grammes of bentonite and was prehydrated for 30 minutes under stirring condition with Hamilton mixer. After 30 minutes, 1.0 gramme of Pac-R, Pac-L each and 1 gramme of xanthan gum were added to the mixing cup. These mixture was stirred for another 15 minutes before, 2.0 gramme of Caustic Soda, 10.0 grammes of Potassium Chloride was also added one after another. This was stirred for another 10 minutes. Then 10.0 grammes barite was finally added and the fluid was stirred further for another 20 minutes for homogeneity before testing.

This process was repeated with different concentration of additives as shown in table two.

Testing Procedure for Mud Density

The temperature of the mud sample to be tested was measured.

The mud balance base was placed on a flat, level surface.

Clean, dry mud balance cup was filled with the sample of mud to be tested. The cup's cap was rotated until it was firmly seated. Some mud was expelled through the hole in the cap to remove any trapped air or gas.

The cup outside was cleaned from and dry.

The balance arm was placed on the support base and was balanced by moving the rider along the graduated scale until the level bubble was centered under the center line.

The density of the mud (mud weight) was noted.

Rheology test procedure

Plastic Viscosity (PV) and Yield Point (YP)

Thermal cup was filled approximately 2/3 full with mud sample and was place on Viscometer stand

The cup was raised and stands until rotary sleeve was immersed to scribe lie on Sleeve Locked into place by turning locking mechanism

With the sleeve rotating at 600-rpm, dial reading was waited in the top window of VG meter to stabilize (minimum 10 seconds). Reading at 600-rpm dial reading was noted

With red knob in bottom position, VG meter toggle switch was flip to low position by pushing the toggle switch away from you. Dial reading was waited to stabilize (Minimum of 10 seconds). Reading at 600, 300, 6 and 3 rpm dial reading were noted.

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Fluid loss test procedure.

Low-Temperature/Low-Pressure Filtration

Air or gas pressure of 100 psi was made available.

The lid was removed from the bottom of clean and dry cell and the O-ring placed in an undamaged groove inverted to fill. The inlet was sealed with a finger preventing any mechanical damaged which could in turn prevent it from sealing.

The cell was filled with mud to ¼" of the O-ring groove and a filter paper (Whatman No. 50 or equivalent) placed on the top of the O-ring. The lid was placed on the filter paper with the flanges of the cell and turned clockwise until hand tight.

A suitable graduated cylinder was placed under the filtrate opening to receive the filtrate.

A suitable graduated cylinder was placed under the filtrate opening to receive the filtrate.

At the end of the test the valve was closed [because the normal API test runs for 30 minutes].Pressure was shut off at the source bleeding off automatically and the cell removed.

The cell was disassembled, the mud discarded and extreme care used to save filter paper with a minimum of disturbance of the cake .The cake was washed gently to remove excess mud, the thickness of the filter care measured.

PH measurement.

Procedure

PH meter was calibrated with buffer solution of pH 4, 7 and 10 before using.

After calibrations, the meter were rinsed properly before using.

The sample of fluid to be tested was allowed to reach 75±5°F (24±3°C).

Then the fluid sample was measured and the reading noted

The electrode was clean and made ready for use.

The meter was turn off and cover close to protect the instrument

Electrical stability

Procedure

Sample was heated to 120±5°F (50±2°C). 3. After inspecting cleanliness of the electrode,

Electrode was immersing into the mud and stirred for approximately 10 sec.

Direct reading electrical stability meter was taken by depressing and holding down button until displayed value stabilizes. The displayed value of electrical Stability (volts) was taken. Electrode was cleaned after use. The above procedure were repeated with an oil base mud and reading taken as shown in the table below.

Discussion

A potassium-based mud was formulated to be used in areas where inhibition is required to limit chemical alteration of shale. Potassium performance is based on cationic exchange of potassium for sodium or calcium ions on smectites and interlayer clays. The muds perform best on shale containing large quantities of smectite or interlayer clays in the total clay fraction.

The flow (or rheological) properties of a mud are those properties which describe the flow characteristics of a mud under various flow conditions. In a mud circulating system, flow occurs at a variety of rates in conduits of different sizes and shapes. In order to know or predict the effects of this flow, we need to know the flow behavior of the mud at the various points of interest in the circulating system.

The rheological properties of the water base mud in fig 1 and 2 shows that as the shear stress increases, the shear rate also increase with decrease in viscosity because of the high shear rate, as the additives increases.

The rheological properties of oil base mud in fig 6 and 7 follow the same trend as in fig 4 and 5. In order to prevent the inflow of formation fluid and lay down a thin, low-permeability filter cake on the walls of the hole, the pressure of the mud column must exceed the pore pressure. The pore pressure depends on the depth of the porous formation, the density of the formation fluids, and the geological conditions. From formulations 1-4, in fig.6 and 9. The mud weight are 8.4, 8.3, 9.5 and 9.0ppg as shown in fig, 6 and 9. For optimum design we strike a balance in other not to overdesign, fracture the formation and increase in cost.

The ability of the mud to seal permeable formations exposed by the bit with a thin, low-permeability filter cake is another major requirement for successful completion of the hole. For a filter cake to form, it is essential that the mud contain some particles of a size only slightly smaller than that of the pore openings of the formation. The rate of filtration and the increase in cake thickness depend on whether or not the surface of the cake is being subjected to

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fluid or mechanical erosion during the filtration process. When the mud is static, the filtrate volume and cake thickness increase in proportion to the square root of time. The fluid loss are 11,13,6, and 10ml are shown in fig. 6 and 9.

The pH of a solution is a measure of its hydrogen ion concentration. At each hydrogen ion (H+) concentration, there is an equilibrium concentration of hydroxyl (OH-) ions. By measuring the hydrogen ion concentration, we are, in effect, also measuring the hydroxyl ion concentration. The optimum control of some mud additives is based on pH, as is the detection and treatment of certain contaminants. The pH of formulations 1-4, are 12.7, 12.5,10.5 and9,7. As shown in fig.6 and 9.

Electrical stability is the increase in voltage across a probe until the emulsion breaks and a current is established. It will vary with the amount of water - the more water generally the lower the stability. As the emulsion stabilizes the electrical stability increases, as shown in fig.9 they are 400 and 340v for oil base mud

Conclusion

Optimized drilling involves the selection of operating conditions that will require the least expense in reaching the desired depth, without sacrificing requirements of personnel safety, environmental protection and productivity. Correct formulation of drilling fluid and its additives will be based on its relative ability to drill the formations anticipated, while affording effective hole cleaning and well-bore stabilization. Based on this, formulation 2 and 4 are preferable for cost effective and optimal design.

Appendix
The apparatus used;

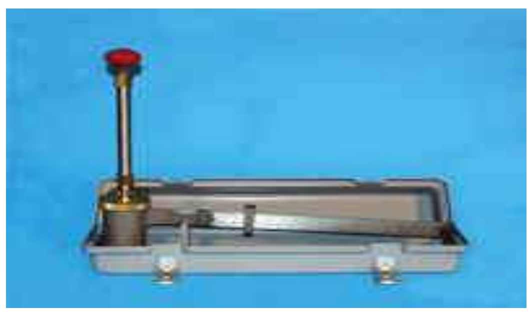

Fig.1: Pressurized Mud Balance

Fig.2: Low and HPHT Filtration cell

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Fig.3: Van Viscometer

Water base mud formulation

Table 1: Formulation 1 for water base mud

S/N	ADDITIVE	QUANTITY
1	Water	340ml
2	Soda Ash	0.5 g
3	Gel	8 g
4	XCD	1.0 g
5	Par R	1.0 g
6	Par L	1.0 g
7	Caustic Soda	2.0 g
8	Potassium Chloride	10.0 g
9	Barite	10.0 g

Table 1: RESULT

S/N	Rheological properties@	RESULT
1	600rpm	68
2	300rpm	50
3	6rpm	12
4	3rpm	10
5	PV(Cp)	18
6	YP (Ib/100ft^2)	32
7	Mud Weight	8.4ppg
8	Fluid Loss @30 mins	11 ml
9	Ph	12.7

Table 1B: CACULATED RESULT

RPM	**SHEAR RATE (RPM X 1.703)**	**DIAL READING**	**SHEARSTRESS (DIAL READING X 5.11)**	**VISCOSITY (CP)**
600	1022	68	348	0.34
300	511	50	256	0.50
6	10	12	61	6.1
3	3	10	51	17

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Table 2: Formulation 2 for water base mud

S/N	ADDITIVE	QUANTITY
1	Water	345ml
2	Soda Ash	0.25 g
3	Gel	4.0 g
4	XCD	0.5 g
5	Par R	0.5 g
6	Par L	0.5 g
7	Caustic Soda	1.0 g
8	Potassium Chloride	5.0 g
9	Barite	5.0 g

Table 2A: RESULT from formulation 2, water base mud

S/N	Rheological properties@	RESULT
1	600rpm	24
2	300rpm	16
3	6rpm	2
4	3rpm	1
5	PV (Cp)	8
6	YP(Ib/100ft^2)	8
7	Mud Weight	8.3ppg
8	Fluid Loss @30 mins	13 ml
9	pH	12.5

Table 2B: Calculated Result

RPM	SHEAR RATE (RPM X 1.703)	DIAL READING	SHEARSTRESS (DIAL READING X 5.11)	VISCOSITY (CP)
600	1022	24	123	0.12
300	511	16	82	0.16
6	10	2	10	1.0
3	3	1	5	1.7

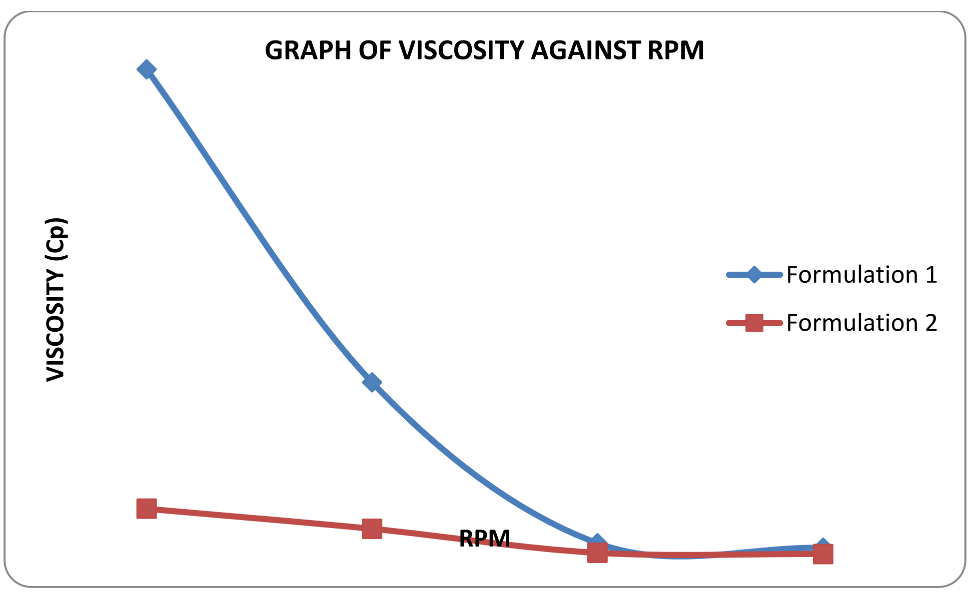

Fig 4: Graph of Viscosity against RPM in Water Base Mud

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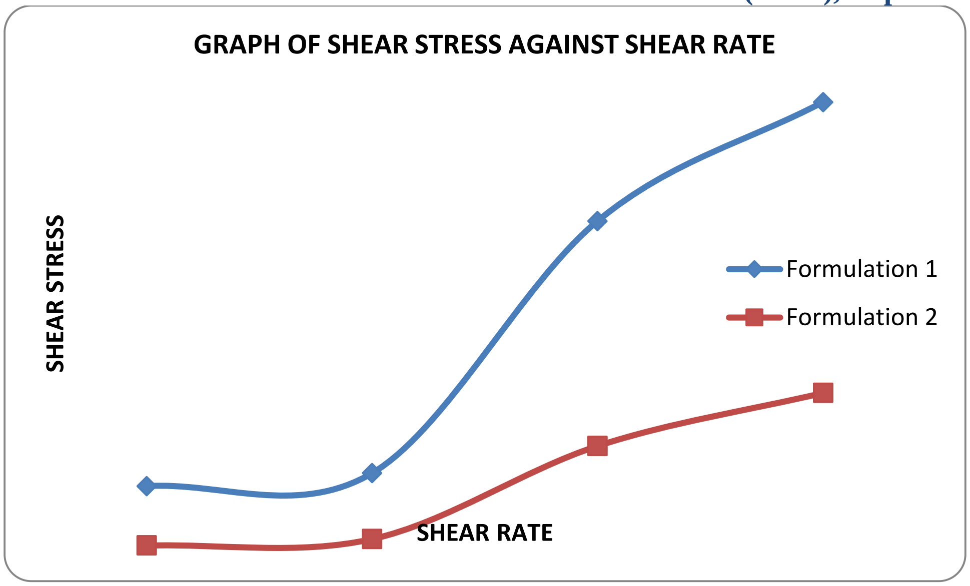

Fig 5: Graph of Shear Stress against Shear Rate in Water Base Mud

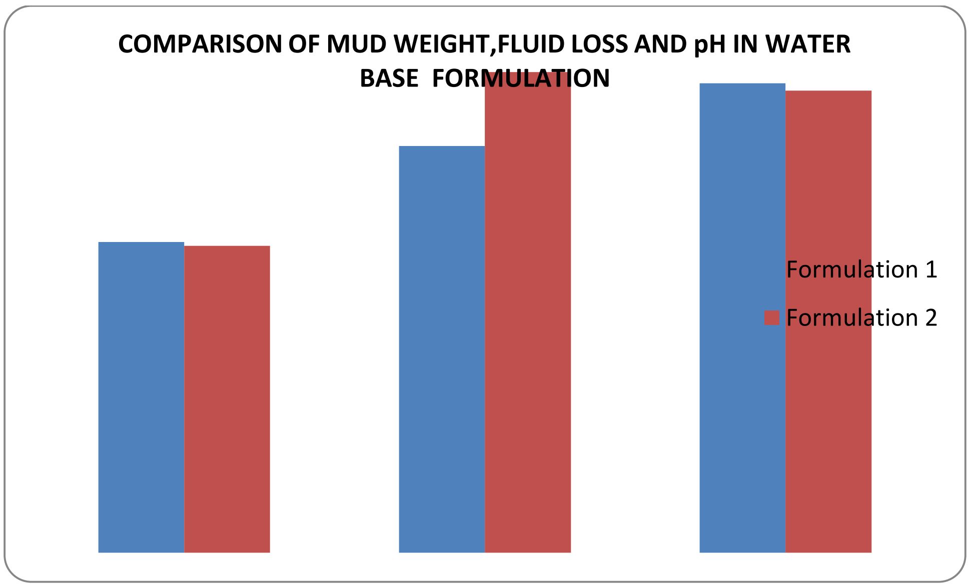

Fig 6: Comparison of Mud Weight, Fluid Loss and pH in Water Base Mud

Table 3: Oil base Mud, Formulation 3

S/N	ADDITIVE	QUANTITY
1	Base Oil	185ml
2	Organophic Clay	5.0 g
3	Lime	4.0 g
4	Secondary Emulsifier	2.0ml
5	Water	41.0 ml
6	Calcium Chloride	14.0 g
7	Barite	24.0 g

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Table 3A: Result from formulation 3

S/N	Rheological properties@	RESULT
1	600rpm	59
2	300rpm	40
3	6rpm	11
4	3rpm	10
5	PV(Cp)	19
6	YP (Ib/100f^{t2})	21
7	Mud Weight	9.5ppg
8	Fluid Loss @30 mins	6.0 ml
9	pH	10.5
10	Electrical Conductivity	400 v

Table 3B: Calculated Result

RPM	SHEAR RATE (RPM X 1.703)	DIAL READING	SHEARSTRESS (DIAL READING X 5.11)	VISCOSITY (CP)
600	1022	59	302	0.30
300	511	40	204	0.40
6	10	11	56	5.6
3	3	10	51	17

Table 4: Oil Mud Formulation 4

S/N	ADDITIVE	QUANTITY
1	Base Oil	198ml
2	Organophic Clay	2.0 g
3	Lime	2.0 g
4	Primary Emulsifier	2
5	Secondary Emulsifier	1.0ml
6	Water	20.0 ml
7	Calcium Chloride	8.0 g
8	Barite	14.0 g

Table 4A:4Result from formulation 4

S/N	Rheological properties@	RESULT
1	600rpm	30
2	300rpm	23
3	6rpm	10
4	3rpm	7
5	PV(Cp)	13
6	YP(Ib/100ft^2)	10
7	Mud Weight	9.0ppg
8	Fluid Loss @30 mins	10 ml
9	pH	9.7
10	Electrical Conductivity	340 v

Table 4B: Calculated Result

RPM	SHEAR RATE (RPM X 1.703)	DIAL READING	SHEARSTRESS (DIAL READING X 5.11)	VISCOSITY (CP)
600	1022	30	153	0.15
300	511	23	118	0.23
6	10	10	51	05.1
3	3	7	36	11.9

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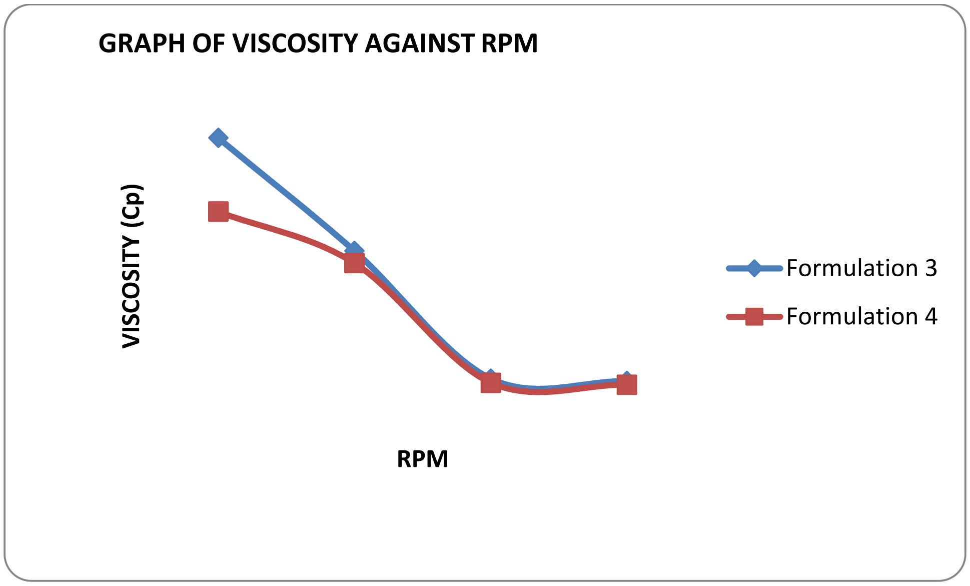

Fig 7: Graph of Viscosity against RPM in Oil Base Formulation

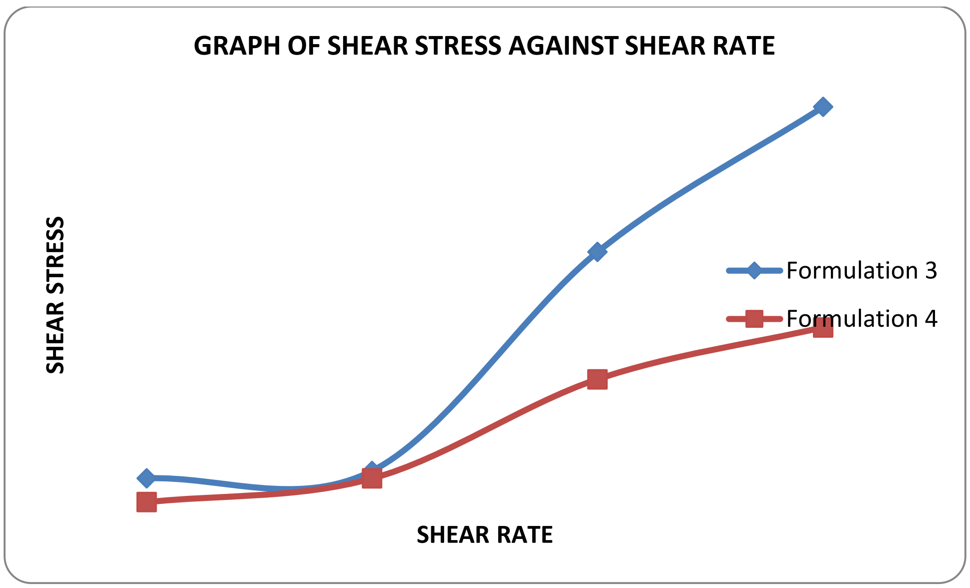

Fig 8: Graph of Shear Stress against Shear Rate in Oil Base Formulation

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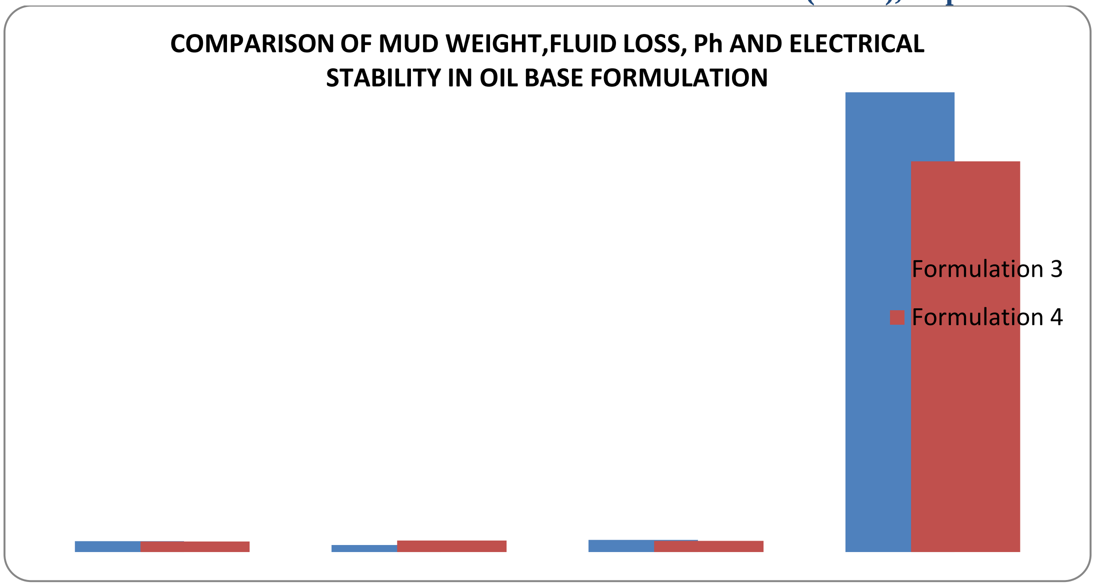

Fig 9: Comparison of Mud Weight, Fluid Loss, pH and Electrical Stability in Oil Base Formulation

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