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IMPROVEMENT OF RHEOLOGICAL PROPERTIES OF DRILLING FLUID USING LOCALLY BASED MATERIALS

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Abstract

Water based drilling fluid is developed using bentonite, guar gum, polyanionic cellulose PAC and gum arabic. The rheological behavior and the filtration loss property of each drilling fluid developed is measured using API recommended standard procedures. The developed drilling fluid combinations are hot rolled using Hot Air Rolling Oven and Aging Cells for 16 hours to study temperature stability of the drilling fluid additives. We observed that the developed drilling fluid system has rheological properties where fluid loss control is required for minimum performance in oil well drilling. We also noticed that Guar gum shows the highest gel strength and the most stable rheological properties with very bad filtration loss property while gum arabic had unstable rheological properties with stable gel strength and good filtration loss property. These results show that water based drilling fluid can be used as a replacement for other additives as it is readily available in commercial quantity in the northern part of Nigeria.

Keywords: Rheology; Filtration loss; Hot rolling; Guar gum; Bentonite; Viscosifier.

1. Introduction

The energy of a nation is largely conditioned by the extent of prospective, surveyed and extracted oil and gas reserves and other natural resources. Hence this is the main source of Nigeria economy. The oil and gas sector in Nigeria has many aspects where it functions; firstly, the confirmation of any natural resources on the earth crust is through drilling. Drilling is a single important aspect of oil and gas sector for without drilling, there is no access to the natural resources available below the earth crust. Drilling is a process of making a hole in the earths' surface for the purpose of creating access to the desired resource below the earth crust. Drilling process should be conducted safely least cost and minimum or no damage to the environment [1]. One of the important materials used in drilling is the drilling fluids commonly call drilling mud. The is of two types – water based mud and oil based mud and drilling fluids and design and production of these drilling fluid becomes utmost important because of its role in drilling [2,3]. Companies involved in the design and production of drilling fluids in Nigeria for the oil and gas sector have over the years imported the materials to produce mud or in some cases imported already designed and produced drilling mud. In this case, industry in this sector adjust the properties of the drilling fluid with the aid of the right types of additives which are also imported to suit the formation requirements of the area to be drilled. This has been a major challenge especially to the indigenous companies involved in the oil and gas because they have to import these materials at high costs and this has not allowed them to compete favorably with their foreign counterparts. Research into this area is thus necessary. Country like India, where cheaper substitutes for production of different goods and services are found (including the oil and gas sector and the production of drilling fluids), using their local materials. This has improved their economy with benefit of job opportunities that are created with their own natural resources which means reduction in the amount of importation [4]. Nigeria is replete with natural resources in various forms, thus research to find how our own raw materials can be used or the availability of suitable substitutes which can be develop and examined within our country for educational and technological advancement of Nigeria.

In the past, researches have been examining the possibilities of producing drilling fluids using strictly locally derived materials, this partly successful as it is discovered that Nigeria have the necessary materials to produce Locally based drilling fluids but the major problem encountered is that the gel strength of the drilling fluids produced using local substitutes is too low and the fluid loss is too high and as a result, this is not suitable for drilling processes [5,6]. Also local materials have been used in the past to produce drilling fluids but the major problem encountered is that when tested, the result is a very low gel strength, high fluid loss and therefore not good enough to be used [7]. Guar Gum is one of the locally based materials used but is not available in large quantity and the fluid loss property is high.

In this paper, we attempt to use locally derived material, Gum Arabic, which is readily available in commercial quantity in the northern part of Nigeria for the production of drilling fluids that will be suitable in the Nigeria terrain and international for all purpose of drilling processes. This research has ultimate direct impact on the Nigerian economy as the federal government under the auspices of the Nigerian national petroleum corporation (NNPC) has been encouraging the development and use of local content in the oil and gas industry [8,9,10]. Drilling fluid is now locally produced, tested and the results is analyzed and recommended. The gel strength of drilling fluid is a very important property that determines if the drilling fluid is be able to carry out its basic functions of adequately suspending the cuttings and transporting them to the surface while supporting the stability of the formation.

2. Instrumentation

The range of oil field equipments is so vast that we will limit ourselves to the equipments which are used in the course of the experiments. These equipments include;

(i) Weigh balance and measuring cylinder used to measure different samples of different chemical materials to be used in the formulation of drilling fluids. Weigh balances are often used for dry substances and the measuring cylinders are used when liquids are to be measured.

(ii) Agitator used to ensure homogeneity in the drilling fluid system, thus they provide high speed mixing to properly incorporate all the chemical materials in to the drilling. For the digital type like the Silverson, the speed of mixing can be regulated to suit whatever experiments but the simple and portable Hamilton beach is calibrated low, medium and high with fixed standard speeds.

(iii) Mud balance used to measure the density and effectively the weight of the drilling fluid. It is measures in pounds per barrel (ppb). This is necessary because the weight of the drilling fluid is an important parameter which determines whether there will be need for weighting up or further analysis. The mud weight is taken at certain temperatures which are room temperature, at 120^{o}F and at higher temperature if necessary.

(iv) Thermometer used basically to measure the temperature of the drilling fluid at specific intervals to ensure the temperature does not drop or increase beyond the required range. Also used alongside certain equipments like the high pressure high temperature HPHT filter press.

(v) Viscometer used to measure the rheological properties of the drilling fluid. It is calibrated in revolutions per minute (RPM) and the results are in centipoises (cp). It is with this equipment we calculate values for the average viscosity AV, plastic viscosity PV, yield point and gel strengths. The rheological properties is of primary concern in the design and formulation of any type of drilling fluid, thus viscometers are very sensitive equipments and their usage has to be precise and as accurate as possible.

(vi) Low pressure filter press used to determine the behavior of the drilling fluid under low pressures such as 100psi, the filtrate gotten is further tested for formation damage analysis and pH. Basically done on water-based drilling fluids and bentonite water samples.

(vii) pH kit used to measure the pH of any drilling fluid system. The principles are as simple and basic as always. The pH of the drilling fluid is important because different formation types have different pH requirements, thus the pH of the drilling fluid has to be carefully

monitored to ensure that when the drilling fluid is used on the formulation there is a balance in properties to prevent the seeping in of formation fluids to the system.
(viii) Hot-rolling oven is a dynamic heating chamber. There different types but the basic function is to provide a means of heating the cells placed in it at a steady temperature and also constantly rolling them. This is trying to replicate the drilling effect the drilling fluid experiences as you drill down hole.
(ix) Aging cells are air tight containers which allows for convenient rolling and no pressure escape. The drilling fluid is put into these containers and tightly sealed then put into the hot-rolling oven for dynamic aging to occur which normally lasts for 16H.
(x) Retort kit used to calculate the solid fluid ratio and also the salinity. It consists of a heating chamber and condensing chamber. Depending on the size of the kit the drilling fluid is put in the retort cup and inserted into the heating chamber which has the condensing chamber connected to it. The condensate is collected through a tube and calculations are made.
(xi) Mud cups, laboratory barrels, and heating cups

3. Experimental procedure

The chemical materials used in this work are bentonite, guar gum, gum arabic and polyanionic cellulose PAC .Bentonite clay used in drilling fluid is montmorillonite [8,9]. It is added to fresh water to: increase the hole cleaning properties, reduce water seepage or filtration into permeable formation, form a thin filter cake of low permeability, promote hole stability in poorly cemented formations and avoid or overcome loss of circulation. Guar gum is a polysaccharide composed of the sugars galactose and mannose. The backbone is a linear chain of β 1,4-linked mannose [14] residues to which galactose residues are 1,6-linked at every second mannose, forming short side-branche [11]. Polyanionic cellulose PAC is used as a fluid loss reducer for fresh water and salt-water muds, but it also acts as viscosity modifier in these systems [5]. PAC is available in two types (high or low viscosity grade), both of which impart the same degree of fluid loss control but different degrees of viscosity. The temperature stability of PAC is 149 °C [15] and is not subjected to bacterial degradation [9]. Gum arabic is a complex mixture of polysaccharides and glycoproteins [12,16] that is used for various purposes including viscosity control and can be used in drilling fluid formulation. Gum Arabic in its crude form is solid with golden coloration which readily dissolves in water to form a sweet smelling gel-like fluid.

All the chemical materials (bentonite, guar gum and polyanionic cellulose PAC) used for this research are from MI SWACO except the gum arabic which was locally sourced from Kaduna. The experiment is carried out in MI SWACO laboratory in Port Harcourt, Nigeria with the following procedures;

b. 350ml of fresh water was put into a laboratory barrel under the agitator.
c. 10.5g of bentonite was measured and poured into the fresh water while agitating
d. Agitation is allowed for a minimum of 30mins
e. After homogeneity is achieved, agitation is stopped and then the temperature is checked and if necessary is heated to a temperature of 120^{o}F not above.
f. The mud weight is taken using a mud balance.
g. When the temperature is achieved the rheology is taken using a viscometer and recorded.
h. After the rheology was taken the bentonite water suspension or spud mud (spud drilling fluid) was put into aging cells and aged at a slightly increased temperature of 150^{o}F in a hot-rolling oven for 16 hours.
i. After hot-rolling the bentonite water suspension or spud mud the temperature is cooled to 120^{o}F and the mud weight is taken again then the rheology is taken all over again and recorded.
j. Then the low pressure filter press equipment was used to determine the fluid loss the drilling fluid was subjected to a pressure of 100psi for 30mins. The filtrate was collected in a measuring cylinder.
k. The pH of the filtrate was taken and recorded and the filtrate was used to analyze for formation damage.

This procedure is repeated for all the drilling fluid samples formulated adding the respective chemical material in addition to the spud mud and agitating till homogeneity is achieved, and then the same testing procedure followed all the tests.

All safety precautions are strictly adhered to as it is a prerequisite to having access to the laboratory. Most of the equipments used are very dangerous because of the high pressures which can explode if not handled properly plus chemicals and these are liable to be dangerous to the skin.

4. Results and discussions

Table 1. Rheological properties of bentonite water suspension (spud mud) at 120^{o}F

RPM	Readings (cp)
600	5.0
300	3.0
200	2.0
100	1.0
6	-
3	-
Gel 10″ (lbs/100ft^2)	-
Gel 10′ (lbs/100ft^3)	1.0
Gel 30′ (lbs/100ft^4)	1.0
Average viscosity AV	2.5
Plastic viscosity PV	2.0
Yield point YP (lbs/100ft^2)	1.0

Table 2. Rheological properties of bentonite water suspension with guar gum @ 120^{o}F

RPM	Readings at 1g of guar gum (cp)	Readings @ 2g of guar gum (cp)	Readings @ 3g of guar gum (cp)
600	47.0	44.0	73.0
300	38.0	37.0	69.0
200	34.0	32.0	62.0
100	30.0	27.0	51.0
6	22.0	17.0	25.0
3	21.0	17.0	21.0
Gel 10″ (lbs/100ft^2)	24.0	21.0	22.0
Gel 10′ (lbs/100ft^3)	35.0	30.0	23.0
Gel 30′ (lbs/100ft^4)	45.0	40.0	30.0
Average viscosity AV	23.5	22.0	36.5
Plastic viscosity PV	9.0	7.0	4.0
Yield point YP (lbs/100ft^2)	29.0	30.0	65.0

Table 3. Rheological properties of bentonite water suspension with polyanionic cellulose PAC @ 120^{o}F

RPM	Readings at 1g of PAC (cp)	Readings @ 2g of PAC (cp)	Readings @ 3g of PAC (cp)
600	64.0	61.0	101.0
300	34.0	41.0	84.0
200	26.0	33.0	70.0
100	16.0	22.0	49.0
6	4.0	5.0	12.0
3	3.0	4.0	9.0
Gel 10″ (lbs/100ft^2)	5.0	7.0	12.0
Gel 10′ (lbs/100ft^3)	9.0	12.0	20.0
Gel 30′ (lbs/100ft^4)	20.0	25.0	30.0
Average viscosity AV	32.0	30.5	50.5
Plastic viscosity PV	30.0	20.0	17.0
Yield point YP (lbs/100ft^2)	4.0	21.0	67.0

Table 4. Rheological properties of bentonite water suspension with gum arabic @ 120^{o}F

RPM	Readings at 32g of gum arabic (cp)	Readings @ 64g of gum arabic (cp)	Readings @ 96g of gum arabic (cp)
600	84.0	100.0	74.0
300	59.0	68.0	44.0
200	49.0	58.0	32.0
100	36.0	43.0	20.0
6	9.0	11.0	5.0
3	8.0	9.0	4.0
Gel 10″ (lbs/100ft^2)	10.0	10.0	6.0
Gel 10′ (lbs/100ft^3)	15.0	15.0	10.0
Gel 30′ (lbs/100ft^4)	20.0	20.0	16.0
Average viscosity AV	42.0	50.0	37.0
Plastic viscosity PV	25.0	32.0	30.0
Yield point YP (lbs/100ft^2)	34.0	36.0	14.0

Specific samples selected to be hot-rolled for 16 hours are;

Bentonite water suspension – mix A

Bentonite water suspension with 1g of guar gum – mix B

Bentonite water suspension with 1g of PAC – mix C

Bentonite water suspension with 32g of gum arabic – mix D

Table 5. Results achieved after hot-rolling

CONSTITUENTS		UNITS	MIX A	MIX B	MIX C	MIX D
PAC R		ppb	-	-	1.0	-
GUAR GUM		ppb	-	1.0	-	-
GUM ARABIC		ppb	-	-	-	32.0
BENTONITE		ppb	10.5	10.5	10.5	10.5
WATER		ppb	322.7	322.7	322.7	322.7
PERIOD AGED		HOURS	16	16	16	16
TEMPERATURE		°F	150	150	150	150
DYNAMIC/STATIC		D/S	-	-	-	-
RHEOLOGY:	TEMP.	°F	120	120	120	120
	600 RPM	cp	17.0	52.0	53.0	26.0
	300 RPM	cp	11.0	44.0	34.0	17.0
	200 RPM	cp	9.0	39.0	26.0	15.0
	100 RPM	cp	6.0	31.0	17.0	10.0
	6 RPM	cp	2.0	16.0	5.0	5.0
	3 RPM	cp	2.0	15.0	4.0	5.0
	GEL 10″	lbs/100ft^2	4.0	15.0	6.0	9.0
	GEL 10′	lbs/100ft^3	8.0	16.0	10.0	11.0
	GEL 30′	lbs/100ft^4	20.0	22.0	20.0	20.0
	AV	cp	8.5	26.0	26.5	13.0
	PV	cp	6.0	8.0	19.0	9.0
	YP	lbs/100ft^2	5.0	36.0	15.0	8.0
FILTRATION	PRESSURE	psi	100	100	100	100
	API FLUID LOSS	mls	26.5	47.0	11.0	17.0
	PH	VALUE	9.5	8.0	9.0	8.0
	FILTER CAKE	1/32″	2.0	5.0	1.0	1.0

Bentonite water suspension is formulated as a means of ascertaining the quality and properties of the bentonite used by comparing the results achieved with the results achieved using it alongside with other materials. Bentonite is the base material of all water-based drilling fluid thus its compatibility with other materials used is very essential. Based on the API standard of 3% solid content 10.5g of bentonite is dispersed in the 350ml of fresh water and rigorously stirred or agitated for 30mins to ensure homogeneity is the system. Bentonite is normally known for its swelling property and this as expected reflects in the changes observed on addition; the water becomes more viscous on successive additions.

The rheological results achieved at 120°F, the bentonite shows low rheological properties as expected because in a drilling fluid system the bentonite is not expected to single handedly control the rheological properties but to provide a base line for other materials to work with thus it does its job well enough. After the initial rheology is taken and recorded the bentonite water suspension is hot-rolled for 16H at a slightly higher temperature of 150°F and the rheology is taken all over again.

The results achieved after hot-rolling for 16 hours, there is an improvement in the rheological properties of the spud mud (bentonite water suspension), this is evident in the graph plotted in Figure 1. This means that the bentonite used is of good quality and also gets better with increase in temperature which is what is obtainable when you go downhole in drilling. The deeper you go beneath the earth surface the higher the temperature and also pressure increases considerably. Bentonite does not loss its properties with heat; it should withstand heat because high temperatures are to be expected in the drilling process.

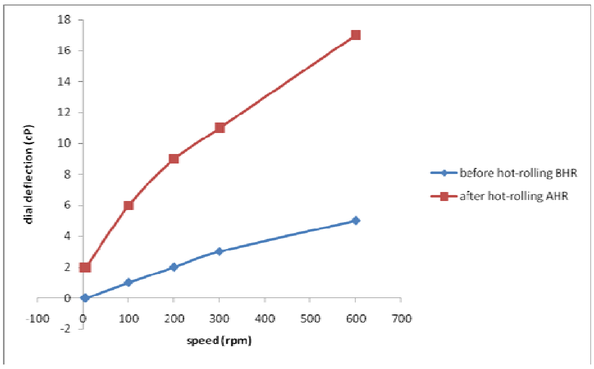

Fig. 1. Comparison of the rheological properties of bentonite water suspension (spud mud) before and after hot-rolling

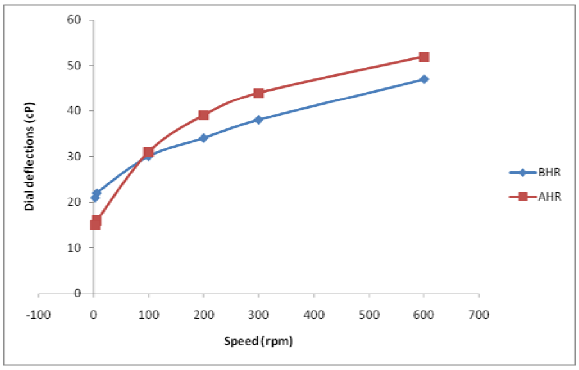

Fig. 2. Comparison of the rheological properties of bentonite water suspension (spud mud) with guar gum before and after hot-rolling

The API fluid loss test carried on this mixture indicates that the bentonite does not do too badly in retaining its fluid content at 26.5ml. Thus with increased pressure the bentonite shows amiable properties because as temperature increases the further downhole you go pressure also increases. The ability of the bentonite considerable aid this important property is important. The pH of the filtrate is also taken it is slightly basic at 9.5, this value is important for formation damage analysis which determines the penetrating effect of the drilling fluid and the amount of damage that will be caused to the environment.

Bentonite water suspension with guar gum is formulated to compare the results with that of other chemical substances that can be used in the formulation of drilling fluid but in this instance spud mud formulation. The function of guar gum in any formulation is to improve the rheological properties and hence the gel strength. Guar gum is used in both water and oil based formulation is also good for downhole properties. The further downhole the drilling goes the higher the temperature gets and pressure also. Thus the chemical material used in ensuring and maintaining the gel strength must be able to withstand high temperatures and possibly high pressures (but usually another chemical material be used to combat high pressure and fluid losses).

Before hot-rolling was done the guar gum was introduced to the system and after proper mixing was achieved the rheological properties were taken at the temperature. From the results achieved, it is obvious that the guar gum used is a very good viscofier because it sufficiently raises the gel strength of the bentonite water suspension. The yield point YP, plastic viscosity PV, average viscosity AV and the gel strengths where improved considerably from what is achieved in bentonite water suspension.

After hot-rolling for 16H at a slightly higher temperature the rheological properties were again taken at the temperature. From the results achieved, it can be seen that a slight increase in the rheological properties occurs, the point YP, plastic viscosity PV, average viscosity AV and the gel strengths are observed to increase but essentially maintained their properties as is before hot-rolling, this is evident in the graph plotted in Figure 2. This infers that an increase in temperature improves the rheological properties of this mud system. But an increase in temperature and after hot-rolling also improved the rheological properties of the bentonite water suspension, thus it means guar gum only simply maintained its properties.

The API fluid loss test that was carried out on this mud system revealed that guar gum was not good with high pressures; this was shown in the filter cake, the more the filter-cake the higher the fluid loss. The results achieved where ridiculously high, thus in a mud system guar gum should not be used in any way as a fluid loss agent but rather can be used as a viscosifier, there are other materials that can play the role of fluid loss.

The filtrate gotten from the fluid loss test is comprehensively tested to be able to ascertain the formation damage analysis. In the drilling process as you go further downhole, gases are evolved and depending on the type of formation and terrain these gases could be acidic. To combat this, the mud system has to be able to neutralize any negative effect it could have if it is allowed into the system. The pH of this system was taken as 8.0 which is slightly basic thus would be able to neutralize slightly acidic gases from the formation. But this is basically a spud mud system and if used at all in any drilling process will be for surface drilling of depths not far enough for emission of any such gases. But this gives us an idea of what would be obtainable if these materials are used in mud formulation that is to be used in drilling processes. It should also be noted that there is no standard formulation for drilling fluids; every formation to be drilled determines the properties of the drilling fluid that can be used.

Bentonite water suspension with polyanionic cellulose PAC was formulated to see the properties it would have with the bentonite in water so it can be compared to the properties of other similar functioning chemical substances. Polyanionic cellulose (PAC) is primarily a fluid loss agent in the mud system but also has a secondary function of improving the viscosity of the drilling fluid; this means it is used to control loss of fluid to the formation while the drilling process is being carried out but can also be used to improve the rheological properties of the drilling fluid. Polyanionic cellulose (PAC) is two types; the PAC-R and PAC-L, the former for the control of fluid loss while the latter for the improvement of the rheological properties of the drilling fluid.

Before hot-rolling was done the polyanionic cellulose PAC was introduced to the system and after proper mixing was achieved the rheological properties were taken at the temperature. From the results achieved, it is obvious that the polyanionic cellulose used is a very good fluid loss agent because it sufficiently raises the reduces the fluid loss under pressure of the bentonite water suspension and the yield point YP, plastic viscosity PV, average viscosity AV and the gel strengths where improved considerably from what was achieved in bentonite water suspension.

After hot-rolling for 16H at a slightly higher temperature, it is observed that the rheological properties of the drilling fluid remains approximately constant with the initial rheology at 600RPM dropping slightly from 64cP before hot-rolling to 53cp after hot-rolling, but the other readings remains constant with a plus or negative one difference. This explains the difference in the average viscosity AV, the plastic viscosity PV and the yield point YP. Since there is a maintenance of constant values for the rest of the rheological properties, it can be assumed that there was a slight glitch in the taking of the initial readings and if carefully taken would give approximately the same readings as the others. Figure 3 shows

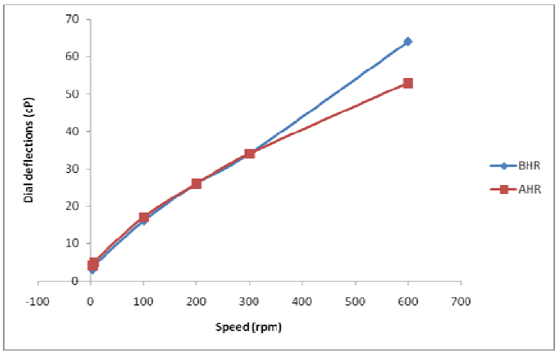

Fig. 3 Comparison of the rheological properties of bentonite water suspension (spud mud) with PAC before and after hot-rolling

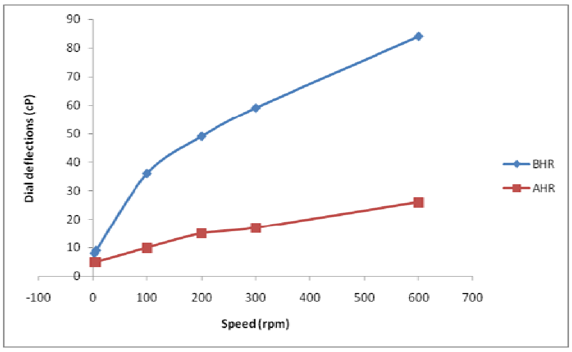

Fig. 4 Comparison of the rheological properties of bentonite water suspension (spud mud) with gum arabic before and after hot-rolling

API fluid loss test was carried out on this sample also and based on the result achieved it can be said that polyanionic cellulose PAC is a very good fluid loss agent and also the rheological properties of the drilling fluid is also considerably improved. Thus it can be said that the polyanionic cellulose used in this research work is of good quality because it not only improves the fluid loss properties of the bentonite water suspension but it also improves the rheological properties.

The filtrate gotten from the API fluid loss test was tested to enable me ascertain the formation damage analysis. In the drilling process as you go further downhole, gases are evolved and depending on the type of formation and terrain these gases could be acidic. To combat this, the mud system has to be able to neutralize any negative effect it could have if it is allowed into the system. The pH of this system was taken as 9.0 which is slightly basic thus would be able to neutralize slightly acidic gases from the formation. But this is basically a spud mud system and if used at all in any drilling process would be for surface drilling of depths not far enough for emission of any such gases. But this gives us an idea of what would be obtainable if these materials are used in mud formulation that is to be used in drilling processes. It should also be noted that there is no standard formulation for drilling fluids; every formation to be drilled determines the properties of the drilling fluid that can be used.

Bentonite water suspension with gum Arabic is formulated as the primary drilling fluid to be studied. Gum Arabic is a common material that is readily gotten locally and can be used for a variety of purposes as a stabilizer and viscosifier but there is no documentation relating it being used as a viscosifier in drilling fluids.

Gum Arabic is introduced into the bentonite water suspension and is rigorously stirred to ensure homogeneity and the rheological properties are taken. Comparing the amounts of guar gum and polyanionic cellulose PAC used, the amount of gum Arabic used is quite a lot. This can be explained because the gum Arabic is in fluid form (gel like) thus already has a considerably large amount of water in it which the guar gum and polyanionic cellulose PAC do not have as they are dry. But the rheological results achieved from the use of gum Arabic are very high, the gel strengths increased successively for the instantaneous gel strength to the 10mins and also 30mins gel strength. The plastic viscosity PV, average viscosity AV and yield point YP were also quite high which could be as a result of excess of gum Arabic being added.

After hot-rolling also at a slightly higher temperature for 16H, the changes in the rheological properties were drastic that on first glance would be condemned but carefully studying and analyzing will give a positive outcome. The rheological properties dropped drastically, at 600RPM before hot-rolling had a reading of 84cP but after hot-rolling the reading was 26cP. This trend was followed for the other readings taken, 300RPM dropping from 59cP to 17cP, 200RPM dropping from 49cP to 15cP and for all the reading there is a consistent drop. But looking at the gel strengths from the instantaneous gel strength to the 10mins gel strength and 30mins gel strength they remained reasonably constant, this is a positive result.

It can be inferred that gum Arabic is not stable with heat as it initially showed good rheological properties at low temperature but this is lost with increase in temperature. But it maintained its gel strength properties even with heat which means that it is stable in that area. This means in the support of drilling cuttings which are to be transported during the drilling process from the down up, the same amount of cuttings that can be supported at room temperature would be the same amount supported at the increased temperature. The drastic drop in the plastic viscosity PV, average viscosity AV and yield point YP can be explained in the fizzing property of gum Arabic that is the ability to readily form bubbles and this property affects the viscometers reading while taking the rheology and also possibly a slight loss in the binding properties of gum Arabic as an organic substance would lose its some of its properties with heat. Figure 4 shows the drastic reduction in rheological properties.

API fluid loss test is carried out and surprisingly the results achieved despite the rheological differences indicated that gum Arabic is a good fluid loss agent. Unlike guar gum and polyanionic cellulose PAC which reasonably maintain their properties even with the addition of heat gum Arabic losses its rheological properties but remains stable in its gel strength and also shows good fluid loss reducing property.

The filtrate gotten from the API fluid loss test is tested to enable me ascertain the formation damage analysis. In the drilling process as you go further down hole, gases are evolved and depending on the type of formation and terrain these gases can be acidic. To combat this, the mud system has to be able to neutralize any negative effect it could have if it is allowed into the system. The pH of this system was taken as 8.0 which is slightly basic thus would be able to neutralize slightly acidic gases from the formation. But this is basically a spud mud system and if used at all in any drilling process would be for surface drilling of depths not far enough for emission of any such gases. But this gives us an idea of what would be obtainable if these materials are used in mud formulation that is to be used in drilling processes. It should also be noted that there is no standard formulation for drilling fluids; every formation to be drilled determines the properties of the drilling fluid that can be used.

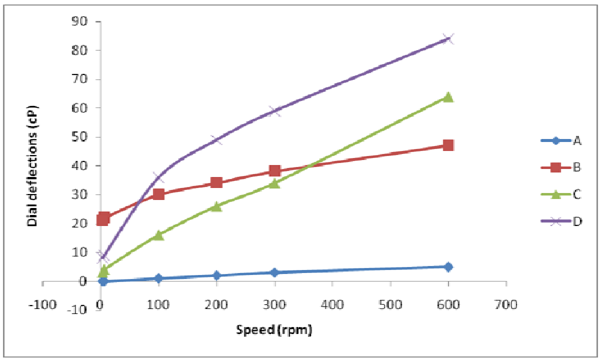

Fig. 5 Comparison of the rheological properties of A, B, C and D before hot-rolling

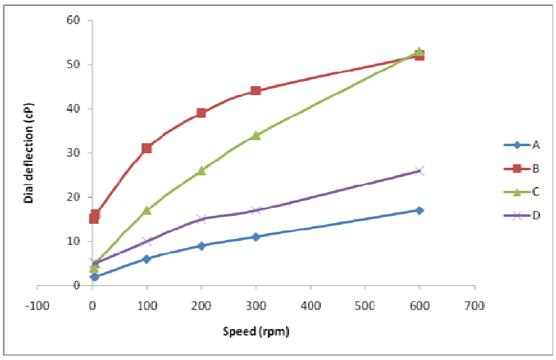

Fig. 6 Comparison of the rheological properties of A, B, C and D after hot-rolling

From the graphs plotted in Figure 5, we can deduce that bentonite water has the lowest of rheological properties (as expected) while gum arabic shows the highest of rheological properties. Polyanionic cellulose PAC has an initial high rheology but drops considerably when you get to 3rpm unlike guar gum which is relatively stable, the drop in rheological properties is minimal. Guar gum can be said to be the better of the three in maintaining a stable viscosity at this temperature (120°F).

With the increase in temperature from 120°F to 150°F and rolling for 16 hours, the rheological properties of the gum arabic sample dropped abysmally which says that it is not heat resistant as the rheology of the samples containing guar gum and PAC where observed to have improved with the increasing in temperature. The gel strength of gum arabic was also observed to remain relatively constant even with the drop in other rheological properties. Figure 6 illustrates this.

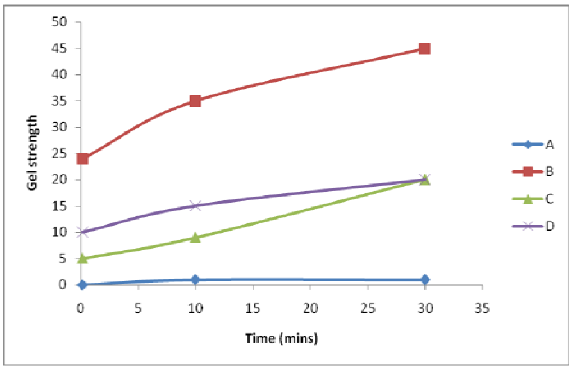

Fig. 7 Comparison of the variation of gel strength with time of A, B, C,D before hot-rolling

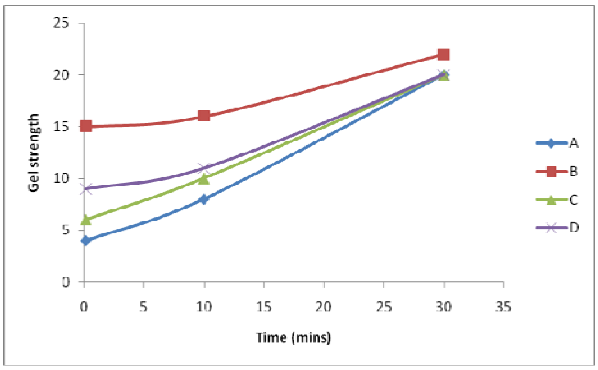

Fig. 8 Comparison of the variation of gel strength with time of A, B, C, D after hot-rolling

The gel strength of all the samples when compared against each other, it is observed that guar gum has the highest gel strength, gum arabic follows next with slightly higher gel strength than PAC, Figure 7 illustrates this. After an increase in temperature and hot-rolling, the changes observed still indicates guar gum as having the best gel strength and the rest follow in same order, with gum arabic, PAC and bentonite having roughly the same initial values. Figure 8 illustrates this graphically.

5. Conclusions

The analysis and the discussion of the results made the following conclusions;

The bentonite sample used is of good quality and can be used for any water based drilling fluid for all types of drilling surface and downhole drilling of large depths. Cost wise, it is imported and as such will be considerably more expensive than if it is gotten locally.

The guar gum used is also of good quality and it performs the duties expected of it which is to primarily viscosify and improve the rheological properties of the drilling fluid. Guar gum can be used in the formulation of both water based and oil based drilling fluid and for all types of drilling processes where temperatures and pressures would likely be on the increase. Guar gum is available in Nigeria but not in reasonable commercial quantities and because of poor processing and production might not be of standard quality.

Polyanionic cellulose PAC performs the function of retaining fluid under high pressure and also improving the rheological properties of the drilling fluid. The polyanionic cellulose PAC used performed all of these functions and also did not loss any of these properties under high temperature and pressure. Thus it is good for use in all types of formulations of drilling fluids for any drilling process.

Gum Arabic being the new material used here is compared and analyzed with the other materials used and from the results achieved gum Arabic is a good stabilizer not necessarily a good viscosifier because of its fizzing property. It also has good fluid retaining properties. Thus gum Arabic can be used as a stabilizer and a fluid control material in the formulation of drilling fluids. It has the advantage of being readily available locally in large commercial quantities and is very cheap compared to importing materials.

Nigeria is replete with so many varied raw materials which be used for a variety of purposes which will improve the economic situation of the country and also encourage indigenous technology development, thus support and encouragement of purposeful research is necessary. Gum Arabic used for this experiment is readily available but in its unprocessed form, thus the errors and problems encountered are as a result of its crude and unprocessed state. Thus further processing of gum Arabic should be researched into. This will make it easy to use and would improve the export value. Also guar gum although present in the country but not in commercial quantity can be made available in commercial quantity by encouraging the planting of its tree in large quantity.

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