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High Performance Aqueous Fluids in Deepwater Operation

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Authors' contributions

This work was carried out in collaboration among all authors. Author AIO did the formal analysis, Investigation, writing- original draft, visualization, project administration. Author OMO did the formal analysis, writing- review & editing. All authors read and approved the final manuscript.

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ABSTRACT

An exploration drilling in Gambia deepwater with water depth of 965m. well total depth drilled at measured depth 3,457m, the maximum inclination angle 34.6º and the horizontal section depth 1000m. The top-hole section was drilled with seawater and Guar GUM Sweep and the conductor casing set at 1053m. After the 26'' hole was drilled with seawater and GUAR GUM sweep at TD the well was displaced to pad mud (KCl/polymer Mud) the 20'' casing run and cemented. The intermediate and landing section was drilled with High Performance Water-based mud which was provide by one of leading servicing provider. This is where it was first deployed in Deepwater operation in West Africa (Gambia) and it shows good cutting and shale inhibitive performance, good hole cleaning, and wellbore stability, it allows the MWD tools to performed at high ROP, the rheological properties were stable with little treatment, the gives good lubrication and good cutting carrying to surface. According to Pearson, J.R.A [1], that the important rheological requirements are that they should have a low an apparent viscosity as possible, consistent with drilled cutting back to the surface during circulation.

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In deepwater operation we may encountered some extremely reactive formations that can incur lot of cost, well lost hole pack off and lost of drilling tools (BHA) which will require sidetrack. Also, with the glamour for the clean energy in the world, there are a lot of environmental restriction now and high cost of waste disposal. This high-performance Water based mud is an option to address the above concerns much attractive in drilling operation.

In this study, the rheological preparties of the mud will be compare with Oil based mud to see the way they performed downhole. The hole cleaning ability and the number of cutting waste that will be generated which will translate to the cost of disposal.

This result show that high performance water-based mud is more effective in term of cost, solved environmental concern and performed as oil – based mud that is wildly used in the region.

Keywords: Inhibition; fluid loss; environmental impact.

1. INTRODUCTION

Drilling in oil and gas exploration is a huge capital investment. For a drilling operation to be successful a lot of work in planning, design, and specialized skills are involved from the drilling to completion phase for the goals to be met. However, any mistake in the design of the drilling fluids may jeopardize the operation. Drilling fluids is one the essential commodities in drilling activities. It represents one-fifth to 18% of the total cost of the well petroleum drilling and must generally comply with three important requirements: they should be i) easy to use, ii) not too expensive, and iii) environmentally friendly. The complex drilling fluids play several functions simultaneously. They are intended to clean the well, hold cuttings in suspension, prevent caving, ensure the stability of the wellbore, and form an impermeable cake near the wellbore area. Drilling fluids also must cool and lubricate the drilling tools, transfer the hydraulic power, prevent formation fluid flow into the wellbore (kick), and carry cutting from the bottom to the surface. A specialized drilling method requires some specialized formulated drilling fluids to meet these objectives.

Drilling fluids went through major technological evolution, from the first operations performed in the US, using a simple mixture of water and clays, to complex mixtures of various specific organic and inorganic products used nowadays. These products improve fluid rheological properties and filtration capability, allowing them to penetrate heterogeneous geological formations under the best conditions. According to Alderman et. al. [2] mentioned that the fluid yield stress remained essentially independent of pressure, unlike oil-based muds, where it decreases with temperature. For water-based systems, it remained constant below a characteristic temperature and then increased exponentially with inverse temperature.

The drilling fluid used should cause no side effects that could harm the well construction process. Meaning it should not damage the productive formation (reservoir), lead to risks related to the health and safety of the personnel or contaminate the environment [3].

The behavior rheological properties of the oil-based mud under temperature [4] investigated using a state of art viscometer capable of measuring drilling fluid properties up to 600 F. This shows how thermal degradation of the solid polymer and other components of the mud samples which lower the resistance of the fluid to flow.

Despite a lot of experiments over the years, for both oil-based mud and water-based mud there is a moderately systematic understanding of how the flow regime behavior changes based on the temperature and pressure downhole conditions. The rheology parameters change based on the temperature and pressure which makes the properties variation occur. According to Mahmood Amani et al. [5], there are various challenges and mechanical issues when comparing Oil based mud to water-based mud which has negative impact on the rheological properties.

The main focus of this research work is to show how high-performance water-based mud performs to Oil-based mud which can be used as an alternative mud system where environmental regulation does not permit oil-based mud, cost saving due to equipment cost and disposal costs in oil-based mud.

2. MATERIALS AND METHODS

The method adopted for this study is reported in this section. properties and application. This experiment firstly, it involves the formulation of the muds, using real drilling parameters to compare the rheological properties of the resulting drilling fluid. Comparing High-performance water-based mud and conventional drilling fluids in this chapter looks at each product used and their properties and how they relate to the formation. Also stating the material used in the mixing of mud and their basic properties.

2.1 Drilling Fluids Testing Equipment

Mud Balance: This equipment was used to check mud weight to avoid contaminants. It is one of the most important drilling fluid properties because it controls formation pressure, and it also helps wellbore stability.

Viscometer: This equipment is used to know the plastic viscosity, yield point, and gel strengths of the mud. The test was done at 120ºF (after API standards) by taking the dial readings on the V-G meter for all the six RPM speeds (600, 300, 200, 100, 6, and 3),

$$PV = 600RPM - 300RPM \tag{1}$$

$$YP = 300RPM - PV \tag{2}$$

Filter press: This test was done on the drilling fluids at room temperature with a top pressure of 100 psi and for a period of 30 minutes, and the resulting filter cake was inspected and measured, and the resulting filtrate was measured. This is carried out by filter paper (Whatman No. 50) at the bottom lid cell, followed by an O-ring to prevent damage and leakage. Then follow by the cell, and mud is poured into the cell about ¾ full and the top lid is placed and screwed properly. Then 100 psi pressure is applied for 30 minutes, and the filtrate will be collected in the graduating cylinder. The filtrate is measured in milliliters.

API fluid loss: There is an API filter press and cell assembly provided for each workstation. The filtration procedures is run as follows:

1. Remove the filter cell from the rack if not already removed, then disassemble the cell.
2. The bottom cover of the cell should have a flat gasket ring, a wire mesh to prevent large particles from blocking the filtration hole, and another upper gasket arranged in that order ascending.
3. Add a hardened (provided) 3½” diameter filter paper in between the wire mesh and the upper gasket. Put the cell body in place and turn clockwise to fasten it firmly.
4. Fill the cell to within 1 – 1½ inches or 3 – 4 centimeters to the brim of the cell. Cover the cell body with the regulator cap and place the assembly into the filter press stand, then turn the “T” screw on the filter press stand to hold the cell assembly in place and firmly to prevent leakage of gas.
5. Back off the “T” screw on the regulator fully but without removing the “T” screw. Place a CO_2 cartridge in the cartridge barrel and fasten to puncture the cartridge (ensure no leakage of CO_2).
6. Place a 25 ml graduated cylinder under the cell to collect the filtrate. Pressure the cell to 100psi by turning the “T” screw clockwise and pushing the red knob in. Start your timer when you push the knob in. The API filtrate should be run for 30 minutes.
7. Clean and replace the assembly after your test.
8. Record the filtrate value and observe the filter cake thickness.

Thick filter cakes increase torque, drag, and the tendency to become differentially stuck. Thin cakes are preferred. The filter cake is reported 32nd of an inch.

HTHP Filter Press: Uses the same principle as the API filter press, but the test was performed on oil-based mud for 30 minutes at a differential pressure500 psi, with a top pressure of 600 psi and a bottom pressure of 100 psi, the resulting filtrate is recorded as double. This procedure is based on the MI SWACO [6] wellbore productivity manual.
Procedure:

1. Plug the heating jacket into a power source for preheating.
2. Close the inlet valve and invert the cell.
3. Place one circle of filter paper in the groove (Whatman No.50).
4. Place the O-ring on top of the filter paper.
5. Place the cell plate assembly over the filter paper.
6. Align all the safety locks.
7. Tighten the top screw finger and closed the discharge valve.
8. Place the groove in the preheating jacket.
9. Transfer the thermometer to the jacket wall.
10. Place CO2 cartridges in the primary and bottom pressure assemblies and tighten them until they get punctured. NOTE: Lock both pressure assemblies properly with their lock.
11. Place 100 psi pressure on both top and bottom pressure assemblies.

12. Once the temperature reaches 300° F, increase the pressure on the top cell regulator to 600 psi while the bottom regulator remains 100 psi. This will give 500 psi differential pressure.
13. Set the stopwatch for 30 minutes and close the bottom valve.
14. After 30 minutes, open the bottom valve and drain all the filtrate into a graduated cylinder.
15. Bleed off the pressures on both regulators.
16. Read the valves and multiply by two.

Retort – Liquid and Solid Content: The test was used to show the percentage of liquid and solids in the mud. It works like an oven heating up the mud until the liquid from the mud is collected in the graduated cylinder.

2.2 High Performance Water-Based Mud

The drilling fluids will be used is water-based mud. The salt used can be monovalent. This system enhances drilling giving good hole cleaning, a high rate of penetration (ROP), effective cutting transport to the surface, and excellent inhibition. The Table 1 shows the chemicals used in the formulation of the system.

2.3 Oil Based Mud

Oil-base mud was the conventional drilling fluid used in this study. It was designed with 100% oil as the base fluid and was weighted up using barite. The base fluid was blended with emulsifiers and brine (calcium chloride salt) in oil emulsion followed by filtrate reducer and organophilic clay.

2.4 Cutting Generated

The well schematic above is for OBM and HPWBM well with different hole sections but the cutting generated will be the same inrespective of the mud type used. The volume of cutting generated with HPWBM is higher than the OBM because the section drilled is longer but the same drilling bits were used throughout the drilling. The capacity of each mud skip is around 10.8 barrels.

The formula for calculating the cutting generated and the number of skips required:

Hole volume= (ID^2/1029.4) * depth drilled

Also, we have some mud that is associated with cutting generated, the hole volume is multiplied by 2 and then divided by the capacity of the skip (10.8bbls). On the field, we calculated the amount generated in metric tons.

To convert the volume of cutting generated in metric ton, the bulk density of formation in West Africa is assumed to be 15ppg.

Therefore:

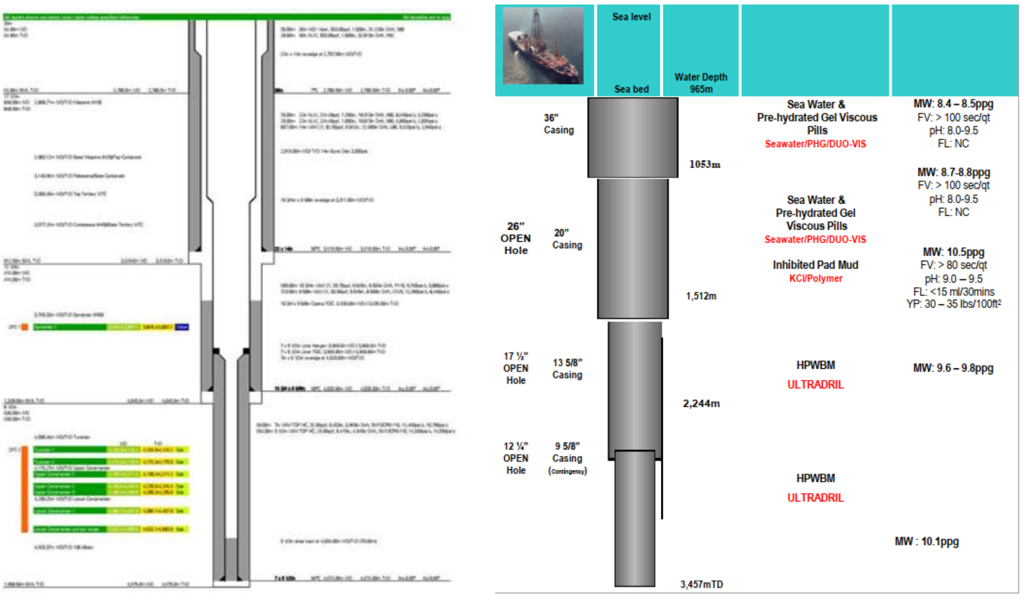
MT= (2* Hole Volume* bulk density of the formation* 42gal/bbl)/ 2205

Table 1. HPWBM chemical

Products	Function
Dry Acrylic Acid Copolymer	Clay Hydration suppressant
Inhibitor	ROP Enhancer
Dry Acrylamide copolymer	Fluid loss and encapsulation
Caustic Soda	Alkalinity, pH
Biocide	Bactericide
Calcium Carbonate	Bridging Agent / Weighting materials
Brine (Salt)	Inhibition

Table 2. OBM chemicals

Products	Function
Olefin paraffin	Base oil
Organophilic clay	Viscosifier
Lime	Alkalinity
Liquid Viscosifier	Emulsifier
Secondary Viscosifier	Wetting agent
Barite	Weight materials
Low End modifier Viscosifier	Rheology modifier
Water	water
Calcium Chloride	Inhibition



Pic. 1. Well Schematic OBM and HPWBM

Table 3. OBM cutting calculation estimate

Hole Size (in)	Depth (m)	Depth (ft)	Hole Vol (bbl.)	Hole Vol (m3)	Estimate Skips cutting	Average m per skips
12.25	416	1365	199	32	37	11.3
8.5	630	2067	145	23	27	23.4

OSCA CUTTING BOXES IS 12 bbls and estimated based on cutting vol per skip is 10.8bbls

Table 4. HPWBM Cutting calculation estimate

Hole Size (in)	Depth (m)	Depth (ft)	Hole Vol (bbl.)	Hole Vol (m3)	Estimate Skips cutting	Average m per skips
17.5	732	2402	715	114	132	5.5
12.25	1213	3976	580	92	107	11.3

OSCA CUTTING BOXES IS 12 bbls and estimated based on cutting vol per skip is 10.8bbls

Fig. 1. Showing how cutting, and mud come from the wellbore

The Fig. 1 shows typically how cutting, and mud come from the wellbore before passing over shakers, dryers, and other solid control equipment. For it to be properly dried and has less than 6% oil on cutting that will be allowed to be discharged overboard, this has to undergo various operation to remove the oil, and this has daily cost on the equipment. Dardir M.M et al. [7] mention that additional rig equipment and modification are necessary to minimize the loss of OBM

2.5 OBM Field Properties and Losses

Table 5.12.25 OBM hole section

	Actual Mud Properties		
	Minimum	**Maximum**	**Average**
Density ppg	9.05	9.10	9.08
PV @48.9ºC, cP	23	33	28
YP, Ib/100ft2	12	21	16.50
6 rpm	9	11	10
3 rpm	8	10	9
Yield Stress (2*3Ø-6	8	9	8.50
10 sec Gel	9	14	11.50
10 mins Gel*	12	20	16
30 mis Gel	15	24	19.50
HPHT FL ml/30 mins	1.6	1.9	1.75
Salinity, % CaCl2	24.56	25.91	25.24
OWR	66/34	66/34	66/34
LGS %	2.8	3.35	3.08
Electrical stability, V	300	422	361

Table 6. 12.25'' hole section mud losses

Losses	Volume (bbls)
Mud on cuttings	109.6
Other surface	112.12
Left behind casing	54.21
interface	33.24

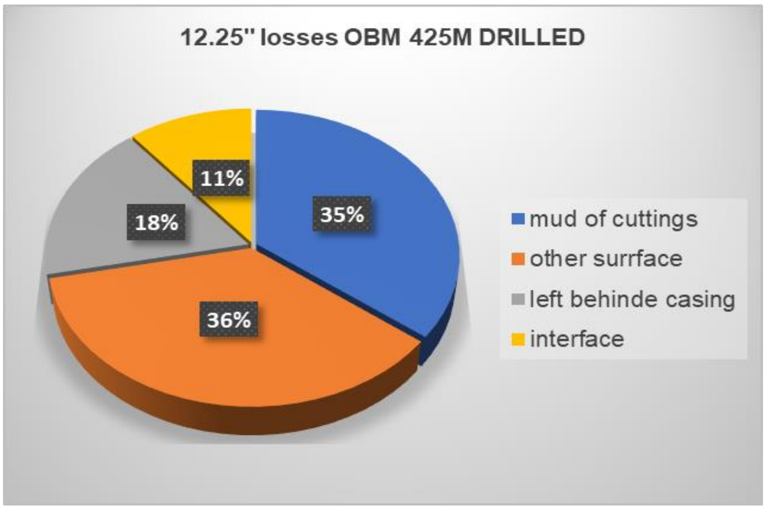


Fig. 2. 12.25'' OBM Section Mud losses

Table 7. 8.5'' OBM hole section

Actual Mud Properties			
	Minimum	**Maximum**	**Average**
Density ppg	9.25	9.50	9.38
PV @48.9ºC, cP	23	33	28
YP, Ib/100ft2	19	21	20
6 rpm	10	11	10.50
3 rpm	9	11	10
Yield Stress (2*3Ø-6	8	10	9
10 sec Gel	13	15	14
10 mins Gel*	16	19	17.50
30 mis Gel	21	24	22.50
HPHT FL ml/30 mins	1.6	1.8	1.70
Salinity, % CaCl2	22	25	23.50
OWR	67/33	68/32	67.5/32.50
LGS %	2.9	3.35	3.13
Electrical stability, V	410	524	467

Table 8. 8.5'' Hole section mud losses

Losses	Volumes (bbls)
Mud on cuttings	136
Tripping	12
centrifuge	67
Interface	52

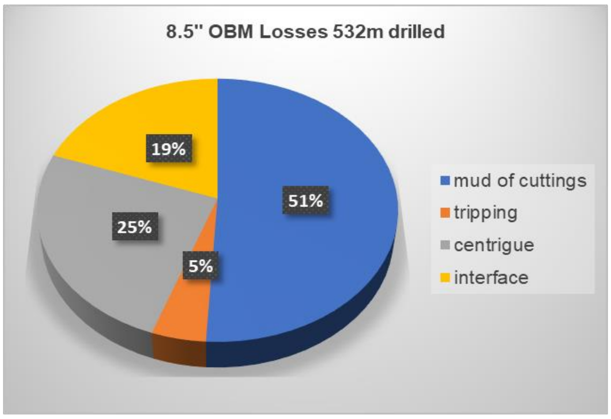


Fig. 3. 8.5'' OBM Section Mud Losses

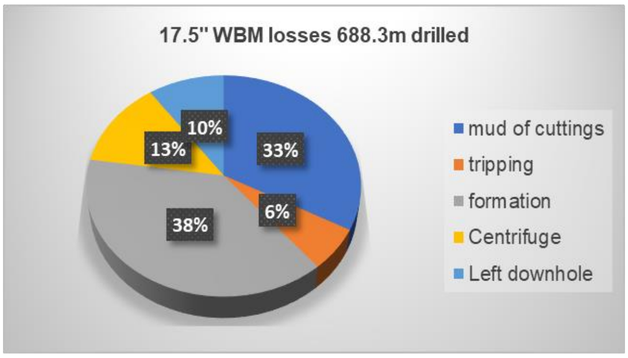


Fig. 4. 17.5'' WBM Section Mud Losses

Table 9. 17.5'' HPWBM hole section

Actual Mud Properties			
	Minimum	**Maximum**	**Average**
Density ppg	9.6	9.7	9.65
PV @48.9ºC, cP	12	37	24.50
YP, Ib/100ft2	25	38	31.50
6 rpm	8	12	10
3 rpm	8	10	9
Yield Stress (2*3Ø-6	8	8	8
10 sec Gel	8	9	8.50
10 mins Gel*	11	13	12
30 mis Gel	13	15	14
API FL ml/30 mins	3.5	3.6	3.55
Salinity, % CaCl2			
OWR			
LGS %	1.06	1.24	1.15
Electrical stability, V			

Table 10. 17.5'' Hole section mud losses

losses	Volumes (bbls)
Mud on cuttings	938
Tripping	175
Formation	1093
centrifuge	367
Left downhole	280

Table 11. 12.25'' HPWBM rheology properties

Actual Mud Properties			
	Minimum	**Maximum**	**Average**
Density ppg	9.	10.1	9.65
PV @48.9ºC, cP	18	34	26
YP, Ib/100ft2	21	34	27.50
6 rpm	6	11	8.50
3 rpm	4	8	6
Yield Stress (2*3Ø-6)	2	5	3.50
10 sec Gel	6	8	7
10 mins Gel*	7	10	8.50
30 mis Gel	8	12	10
API FL ml/30 mins	4	5.2	4.60
Salinity, % CaCl2			
OWR			
LGS %	2.9	3.5	3.13
Electrical stability, V			

Table 12. Mud losses

Losses	Volumes (bbls)
Mud on Cuttings	410
Left downhole	528
Centrifuge	285
Discharge after drilling completed	8428

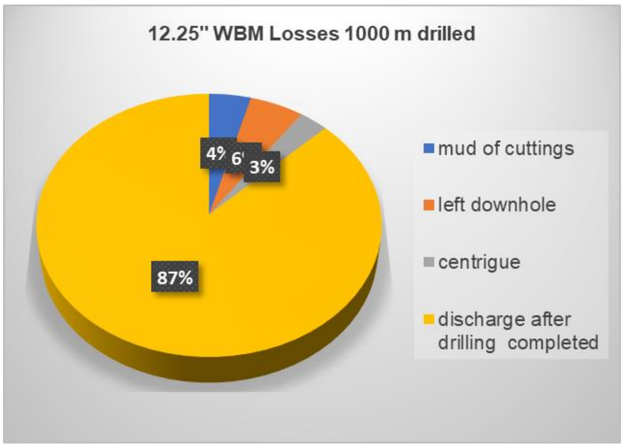


Fig. 5. 12.25'' WBM Section Mud losses

3. RESULTS AND DISCUSSION

3.1 Yield Point Comparison

Based on the field data between the Oil-based mud and high-performance water-based mud the comparison in Fig. 6. The result shows that the YP of HPWBM shows a higher value which translates to providing better hole cleaning than the OBM. The OBM has the presence of insert solid from Barite while the HPWBM uses calcium carbonate to provides weight and fluid loss materials.

3.2 Plastic Viscosity Comparison

Plastic viscosity is that part of flow resistance, which is caused by mechanical friction. This friction occurs between the solids in mud, between the solids and liquids that surround them and with the shearing of the liquid itself. The result in Fig. 7, shows that both mud system performed equally which means that HPWBM competes with OBM without any significant differences.

3.3 6rpm Rheology Properties

This is one of the most critical rheological properties that gives a prompt indication of hole cleaning. The result shows that there is little significance in the value of the field when it is deployed. Both muds have proven proper cutting removal from the wellbore. According to Merlin, the reading is one of the most important indicators for hole cleaning. The rule of thumb for effective hole cleaning is to ensure the 6-rpm value is between 1.1 to 1.2 times the hole sizes. As you can see from Fig. 8 there is not much different form the maximum and average value which show that the HPWBM performed closely to the OBM. Cuttings are transported to the surface by circulating a drilling fluid and it is vital for the drilling operator to be able to select an appropriate fluid for each individual well, including the decision of using oil-based or water-based fluids or “muds” (OBM or WBM). Each of these two fluid types has shown there is no much differences as review by Apaleke et al. [8].

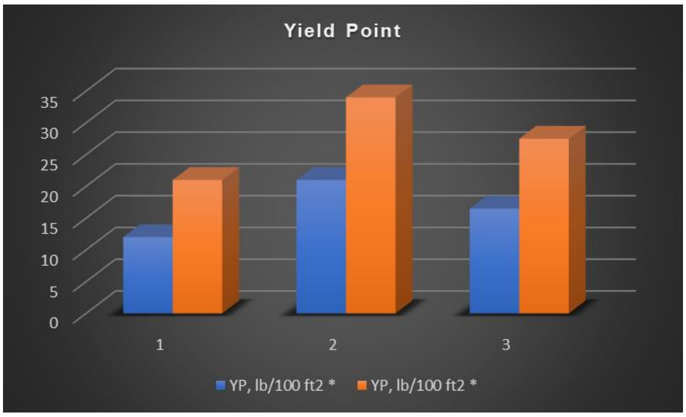


Fig. 6. Comparison OBM vs WBM Yield Point

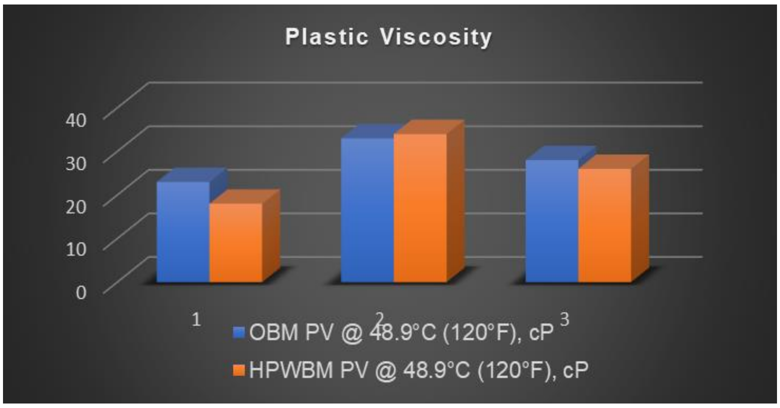


Fig. 7. Comparison OBM vs WBM Plastic Viscosity

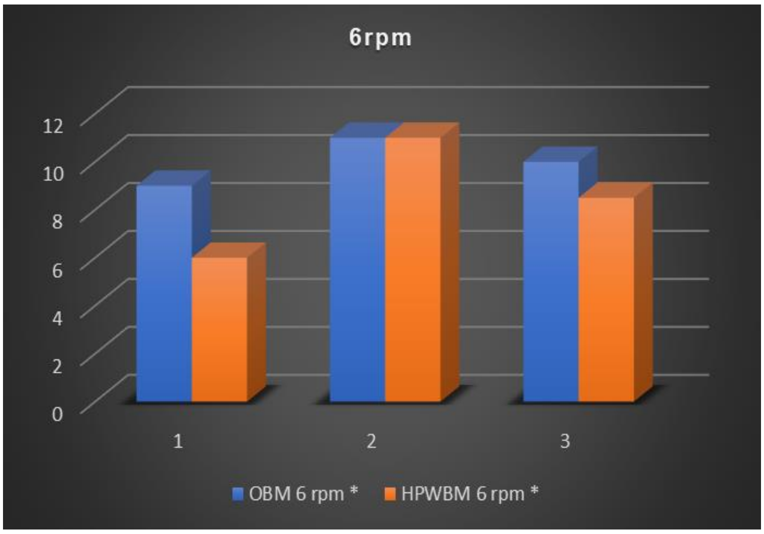


Fig. 8. Comparison OBM vs WBM 6rpm Reading

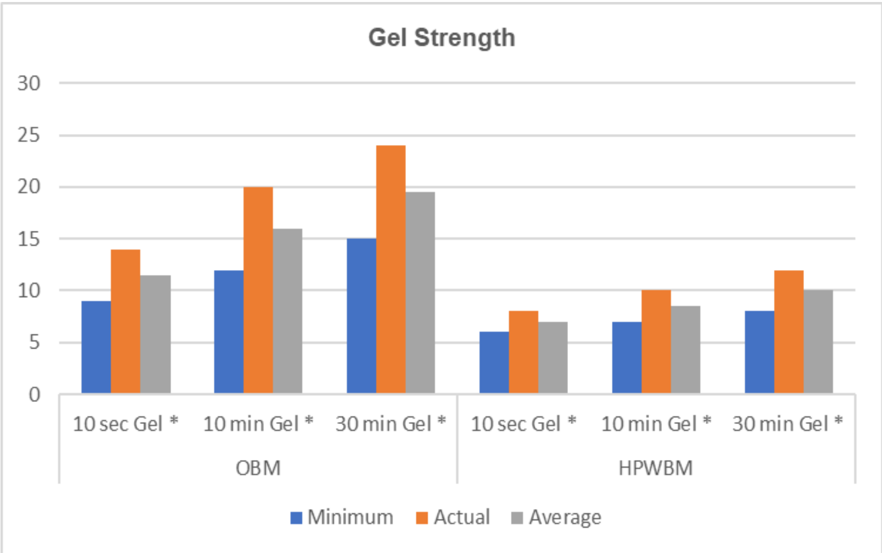


Fig. 9. Comparison OBM vs WBM Gel Strength

3.4 Gel Strength

Gel strength is the shear stress measured at the lower shear rate after the mud is at calm for a period (10 sec. 10 min and 30 mins) as per API standards procedures. It can be seen that in HPWBM values are closed because there is no excessive solid in the mud that caused high gelation which will lead to flocculation. However, there is a wide difference in the 10-second and 10-minute reading in HPWBM which means progressive gel. When there is high gel strength, It makes it difficult for logging operation to be achieved, there will be huge cutting in the wellbore (improper hole cleaning), there will high equivalent during tripping and there is possible to entrapped gas/air in the mud.

3.5 Cutting Disposal

Table 2 and Table 3 show the amount of cutting generated during the drilling operation. In OBM drilling there is a need to have some equipment on the rig such as a dryer, compressor, and skips. Before cutting can be discharged overboard there is a need for the oil of cutting to be less than 6% in the West Africa region. The cost associated with this is enormous, which can also treat waste in town. However, HPWBM is economically friendly to the environment and will not require cutting transportation, no skip required, and no compressor. This reduced drilling costs significantly, lowered the cost of maintenance of equipment to the servicing company, and the safety of the personnel handling such equipment.

4. CONCLUSION

The recent remarkable success in deepwater operations with HPWBM jobs is anticipated to be a real incentive for wide implementation of the HPWBM application in the intermediate and landing sections on the field and other nearby areas**. HPWBM** is ecofriendly inventive alternative system to invert emulsion mud for environmental consideration while keeping and delivering superior bore hole stability with enhanced fluid capability and improved drilling performance.

ECONOMIC AND ENVIRONMENTAL SUPREMACY

These are high-performance water-base drilling fluids where the operator will no longer have to compromise performance to meet environmental and economic objectives. This system delivers performance characteristics that closely mimic premium Oil and synthetic-based drilling fluids.

Benefit:

- Excellent inhibition.
- High drilling rate.
- Superb hole cleaning.
- Meets all environmental standards.
- Lower drilling waste (management costs).
- Maintain wellbore stability.
- Minimizes dilution cost.
- Reduce drilling costs.
- Improve HSE profile.

Features:

- It provides near OBM and SBM performance characteristics.
- It gives a triple inhibition methodology.
- Inhibition encapsulating cuttings.
- Ultra-low toxicity level

Triple Inhibition:

- **Superior clay inhibition:** this prevents stuck pipe and washout for shales that tend to be sloughing and swelling.
- **Cutting Encapsulation:** This encapsulates cuttings with a thin polymer coating that virtually eliminates shale dispersion.
- **Protected metal surface:** This creates the ability to coat the bit, BHA, and drill pipe with an accretion-inhibitive coating. It reduces bit balling which keeps the cutting structure clean and effective, resulting in higher ROP.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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