IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 14, Issue 12, December 2024, ||Series -1|| PP 23-36

Effects Of Concentration of Polypropylene Glycol (PPG) On Rheological And Lubricity Properties of Water – Based Drill-In Fluids

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Received 11 December 2024; Accepted 23 December 2024

ABSTRACT
Drilling fluids used in drilling operations most times also serve the purpose of lubricating the moving metal parts of the drill string, drill bit and the entire drilling assembly. Oil based mud in which the base fluid is oil gives a better lubricity result than water – based mud, especially at high temperature and pressure conditions usually witnessed at the reservoir regions of the well. Hence, lubricant additives such as polypropylene glycol, monoethylene glycol, triethylene glycol, etc are normally used to achieve this lubricity effect in water – based drilling fluids.
The study examines the effects of concentration of polypropylene glycol (PPG) on rheological, filtration and lubricity properties of water – based drill – in fluids, when used in drilling reservoir region of the well.
The result of the study shows clearly that a viscosity and rheology hump was observed in drill-in fluids samples 5 and 6, which had higher concentrations of poly propylene glycol (with 4% and 5% respectively), as lubricants.
Fluid sample 4, with 3% of poly propylene glycol showed moderate and acceptable range of rheological properties with minimal risk or surge or swab effect, unlike those with higher concentrations which had a viscosity and rheology hump, which can have a negative impact in drilling efficiency due to a potential surge while tripping in or swab while tripping out, which could induce loss or even total loss of return and can result to swab effect – kick.
The result also shows that using higher concentration would lead to lower filtrate volume/ fluid loss and better filter cake formation in the course of drilling operations, while giving a lower coefficient of friction, hence a better lubricity effect.
However, considering the impact of the high concentration of polypropylene glycol on the rheological properties of the drill – in fluids studied, and the associated negative impacts (viscosity and rheology hump, potential surge or swab, swab effect – kick) in the entire drilling process, it is necessary to apply caution in adopting a particular concentration of the polypropylene glycol in preparing the drill – in fluid needed to be used at the reservoir region of the well.
KEYWORDS: Drilling Fluids, Water – Based, Lubricity, Lubricant Additives, Drill – In Fluids, Coefficient of Friction, Rheology, Viscosity, Concentration, Polypropylene Glycol.

I. INTRODUCTION

Drilling operations in the oil and gas industry involves the use of various equipment, especially rotating equipment which serve the purpose of cutting the solid formation of the earth crust in order to make a hole in the earth's crust, thereby creating the well down to the oil or gas reservoir. The ending part of these rotating equipment are usually attached with the drill bits which are made of various metal parts [1]. As they come in contact with the hard surface of the formation, friction usually occurs between the surface of the drill bits and the formation surface. These leads to the generation of heat, increase in torque during drilling operations increase in the rate of wear of the metal parts of the drill bit, drill string and the entire drilling assembly. The control of friction during drilling operation has been of great concern in the oil and gas drilling field. Several times drilling problems associated with high frictional forces during drilling operation result in high torque and drag leading to a number of drilling problems [1, 2, 3].

The use of drilling fluids in drilling operations over the years however, has served several purposes which include cooling, lubricating and supporting the drill bits, suspending and release of cuttings, removing cuttings from the wellbore, control of formation pressures, sealing permeable formations, maintaining wellbore stability, minimizing formation damage, transmitting hydraulic energy to tools and bit, control of corrosion, facilitating cementing and completion, etc [3, 4, 5, 6]. The function of the drilling fluids to lubricate the drill bits, thereby reducing the adverse effects mentioned earlier is of great importance in drilling operations. This is achieved by the use of lubricant additives, which are inevitable especially in water - based drilling fluids.

Recently, directional wells, extended-reach wells, cluster wells, deep wells, and ultra-deep wells has been gradually developed by drilling engineers [3]. These different wellbore structures have resulted in great increase in the torque and frictional forces experienced in the drilling process, which easily increase the rate of wear of drilling tools, increase the power consumption of the drilling equipment, and leading to drilling safety issues such as broken drilling and sticking [1, 2, 3]. Oil-based drilling fluid has a stronger inhibition and higher lubricity, which can effectively prevent sloughing and sticking. However, environmental pollution, affecting logging quality, and high cost are also its disadvantages. The water-based drilling fluid (mud) does not have these problems, but the poor lubrication performance and high friction have restricted its development.

Therefore, improving the lubrication performance of the water – based drilling fluid has great significance in solving the above problems [3, 7]. Adding high-quality lubricating oil into water – based drilling mud to reduce downhole friction is one of the main technical means to prevent and solve drilling safety problems at present and it is also helpful in reducing stick and slip for directional drilling works [8, 9]. The research and development of water – based drilling mud systems and corresponding lubrication treatment agents are of great significance to the wide application of water-based drilling muds in the future. Research has shown that when drilling extended, reach horizontal wells, the formation can be drilled smoothly only when the coefficient of friction (COF) of drilling mud is generally lower than 0.10. [3, 10].

In drilling operations, drilling fluid (also known as mud) serves several critical functions, one of which is lubrication as already stated earlier [4, 5]. It works through the following method:

1. Reducing Friction: As the drill bit rotates and cuts through the rock formations, heat is generated due to the friction between the bit, the drill string, and the walls of the wellbore and can cause excessive wear. Drilling fluid forms a thin protective film between these surfaces, reducing the resistance to motion and minimizing wear on the equipment.
2. Cooling: Drilling fluid helps to cool the drill bit by carrying away the heat generated during drilling. This cooling effect also reduces the chances of bit overheating, which could lead to premature failure.
3. Preventing Sticking: Drilling fluid helps to prevent the drill string from becoming stuck in the wellbore by providing a lubricating barrier. Without this lubrication, the drill string could adhere to the walls of the borehole due to friction or differential pressure, which could lead to costly stuck-pipe incidents.
4. Pressure Control: The fluid maintains pressure in the wellbore, helping to prevent the well from collapsing or allowing formation fluids (such as gas or oil) to flow into the well. This pressure control also aids in the lubrication of the bit and other moving parts by maintaining a consistent fluid flow.
5. Removal of Cuttings: Drilling fluid helps carry rock cuttings away from the drill bit to the surface, ensuring that debris doesn't accumulate and increase friction.

The lubricating properties of the drilling fluid are primarily due to its composition, which typically includes water, oil, and various additives [11]. These additives are designed to reduce friction, prevent bit damage, and improve the efficiency of the drilling process. For example, oil-based muds or synthetic-based fluids can provide superior lubrication compared to water-based fluids, particularly in challenging conditions where high temperatures and pressures are encountered. Drilling fluids can also be formulated for specific formations and conditions to optimize its lubricating and cooling properties [12].

Lubricants used in drilling fluids are designed to reduce friction between the drill bit and the wellbore, enhance the performance of drilling equipment, improve the efficiency of the drilling process, and extend the life of the equipment [3, 12, 13]. Examples of types of such lubricants used in drilling fluids include:

1. Oil-Based Drilling Fluids Lubricants (OBM): These are often used in oil-based drilling fluids to reduce friction between the drill bit and the wellbore. Some oil-based drilling fluids inherently provide lubrication effect due to the oil content, which helps reduce friction. In these cases, additional lubricants may not be necessary, but oil-based fluids tend to provide better lubrication compared to water-based systems. Examples include: Diesel, Mineral Oils, Synthetic oils (such as ester-based or paraffin-based oils).
2. Emulsifiers: These chemicals help in stabilizing oil-in-water or water-in-oil emulsions, improving lubrication in drilling fluid systems. Examples include: Fatty acids and Amine-based emulsifiers.
3. Polymeric Lubricants (e.g., Polymeric Esters): These are synthetic polymers that are used to reduce friction in both water-based and oil-based drilling fluids. They can be tailored for specific well conditions, such as high temperature or high pressure. Examples include: Polymeric esters, Polyethylene glycol (PEG), etc.

4. Graphite and Molybdenum Disulfide: These are solid lubricants often added in small quantities to improve lubrication in high-friction environments, particularly for high-temperature drilling conditions. They help to reduce friction between the drill pipe and the wellbore. They are particularly effective in reducing torque and drag.
5. Fatty Acids: These are organic compounds which are often used to reduce friction in water-based and oil-based drilling fluids to provide lubrication for smoother drilling operations. Examples are Oleic acid, Linoleic acid or Stearic Acid. Oleic acid in particular, is a common choice because of its ability to form a thin lubricating film on metal surfaces.
6. Synthetic Lubricants: These are specially engineered (man-made lubricants often used in water-based drilling fluid systems) for use in specific types of drilling operations, including high-pressure, high-temperature (HPHT) environments. They are designed to provide excellent lubrication while being more environmentally friendly than some other lubricants. Examples include: Polyalphaolefins (PAOs), Esters, etc.
7. Wetting Agents: Surfactants or wetting agents can reduce the adhesion of drilled cuttings to the equipment, enhancing the efficiency of drilling operations. Examples include: Sodium lignosulfonates, Oleyl alcohol, etc.
8. Bio-Based Lubricants: These include naturally occurring oils, such as vegetable oils or bio-esters, which can serve as environmentally friendly lubricants in drilling fluids.

These lubricants help to reduce wear on drill bits, increase the lifespan of equipment, and enhance the overall efficiency of the drilling process [14, 15]. They are selected based on certain factors such as the type of drilling fluid (water-based, oil-based, or synthetic), temperature, pressure, and environmental regulations [16].

In water-based drilling fluids, lubricants are added to reduce friction between the drill bit, drill pipe, and the wellbore, helping to improve the efficiency of the drilling process [16, 17]. Some common examples of lubricants used in water-based drilling fluids include:

1. Fatty Acids (e.g., Oleic Acid, Stearic Acid): These natural or synthetic fatty acids help to reduce friction and enhance lubricity. Oleic acid is particularly popular in water-based systems for its ability to create a lubricating film on metal surfaces, reducing wear and tear on the drill bit.
2. Lignosulfonates: Derived from wood, lignosulfonates are used as additives in water-based drilling fluids to provide lubrication and reduce friction. They can also act as dispersants, stabilizing the mud system.
3. Polymeric Lubricants (e.g., Polymeric Esters): These are water-soluble polymers that are used to enhance lubricity in water-based drilling fluids. They are typically designed to improve the performance of the fluid under high friction conditions while maintaining fluid stability.
4. Surfactants (e.g., Ethoxylated Fatty Alcohols, Alkylphenol Ethoxylates): These compounds reduce surface tension and can improve the lubricating properties of water-based muds. Surfactants often form thin films on the metal surface, reducing friction and wear.
5. Hydroxyethyl Cellulose (HEC): Although primarily a viscosifier, HEC can also contribute to lubrication in water-based fluids, particularly in combination with other lubricating agents.
6. Vegetable Oils (e.g., Soybean Oil, Canola Oil): These oils can be used as environmentally friendly lubricants in water-based systems. When added in small amounts, they help reduce friction and improve the flow characteristics of the drilling fluid.
7. Glycerine: Glycerine is a common additive in water-based drilling fluids that acts as a lubricant, reducing friction in the system and enhancing the performance of the mud.
8. Aliphatic Alcohols (e.g., Isopropyl Alcohol): These alcohols can be used to reduce friction and provide some degree of lubrication in water-based systems, though they are typically used in combination with other lubricants.
9. Glycols and Polyols: These are dihydroxy alcohols and the polymeric alcohols, which serve as lubricants in water – Based drilling fluids. Examples include Monoethylene glycol, triethylene glycol, polyethylene glycol, polypropylene glycol, etc.

These lubricants are typically selected based on factors like the temperature and pressure conditions of the well, the type of drilling fluid, and environmental regulations. Each lubricant has unique properties, and their use depends on achieving the best balance of lubricity, viscosity, and overall mud stability [17, 18, 19].

In drilling operations in which water – based drilling fluids are to be adopted, the use of lubricant additives like the glycols and polyols have become predominant [20, 21, 22]. Many drillers adopt the use of monoethylene glycol as lubricant additive in the water – based drilling fluids, whereas some use either Triethylene glycol, polyethylene glycol, polypropylene glycol, etc as lubricant additives in the water – based drilling fluids. The use of each of the above listed glycols and polyols have their various advantages and disadvantages, ranging from temperature stability, solubility, biodegradability or environmental friendliness, effect of concentration on overall fluid viscosity and coefficient of friction, etc.

This study however, focuses on the effects of concentration of polypropylene glycol (PPG) on rheological and lubricity properties of water – based drilling fluids, when used in drilling reservoir region of the well.

II. MATERIALS AND METHODS

2.1 EXPERIMENTAL DESIGN

In the course of the study, experiments were carried out using various drill – in fluid samples formulated with the lubricant additive under review. The lubricant additives used in this study is polypropylene glycol (PPG). Another drill – in fluid sample was also prepared without using any lubricant at all. This is to serve as a control drill – in fluid sample which would show if the lubricant additives used in the other drill – in fluid samples had any effect on the coefficient of friction of the drill – in fluids or not.

A total of 6 drill – in fluid samples were prepared and used for experiment/ analysis. The 1st drill – in fluid sample being the control drill – in fluid sample was prepared without using any lubricant additive. The second to sixth drill – in fluid samples were prepared using different concentrations of polypropylene glycol (PPG) as lubricant additive in the drill – in fluid. The 2nd to 6th drill – in fluid samples were prepared using different concentrations of polypropylene glycol (PPG) as lubricant additive in the drill – in fluid. The 2nd drill – in fluid sample was prepared using polypropylene glycol (PPG) as a 1% of the entire drill – in fluid formulation of 1 lab barrel. The 3rd drill – in fluid sample was prepared using polypropylene glycol (PPG) as a 2% of the entire drill – in fluid formulation of 1 lab barrel. The 4th drill – in fluid sample was prepared using polypropylene glycol (PPG) as a 3% of the entire drill – in fluid formulation of 1 lab barrel. The 5th drill – in fluid sample was prepared using polypropylene glycol (PPG) as a 4% of the entire drill – in fluid formulation of 1 lab barrel. The 6th drill – in fluid sample was prepared using polypropylene glycol (PPG) as a 5% of the entire drill – in fluid formulation of 1 lab barrel.

1% in this case represents 3.5g, 2% represents 7g of the lubricant additive, and so on.

The total amount of lubricant additive used in preparing each drilling fluid sample is relative to the concentration in percentage (%) being tested at that moment as stated above.

The Polypropylene glycol (PPG) samples were obtained from a reliable dealer.

The experiments were conducted in accordance with the standard stipulated in API RP13B-1; recommended Practice Standard Procedure for Field Testing of Water-Based Drilling Fluids/mud [1, 3]. Being a Water based drilling fluid, water was used as the base fluid throughout the study. The experimental analysis of this study, which includes; Density, Rheology, Filter cake formation and filtration test and determination of coefficient of friction of drilling fluids was conducted. All experiment was done in triplicates and the average value reported.

2.2 PREPARATION OF DRILL – IN FLUID SAMPLES

The test was carried out on drilling fluids of appropriately measured samples. It was based on the fact that 1gm/350cm³ of the sample is equivalent to 1lb/bbl (42gal) of the actual mud system [4, 5, 6]. Also 8.33cm³/350 is equivalent to 1gal/bbl (42gal) of the actual mud system.

1lab barrel = 350cm³ (final volume 1gm=1b, 1gallon = 8.33cm³). The water-based mud was formulated by adding appropriate concentrations of the materials into the base fluid (water) to obtain 1bbl (350ml) with measured mass. A Hamilton beach mixer was used to obtain a homogenous mixture. The LCMs under review formed part of the materials used in formulating the mud samples used for experiment. Below is the formula for mud samples developed for the study.

TABLE 1 FORMULA FOR DRILL – IN FLUID SAMPLES PREPARATION

S/N	MATERIALS	DFS 1	DFS 2	DFS 3	DFS 4	DFS 5	DFS 6	MIXING TIME
1	Water	350	350	350	350	350	350	1
2	Soda ash	0.5	0.5	0.5	0.5	0.5	0.5	2
3	Caustic soda	0.5	0.5	0.5	0.5	0.5	0.5	2
4	Sodium Chloride	30	30	30	30	30	30	30
5	Xanthan Gum	1	1	1	1	1	1	20
6	Drilling Starch	4	4	4	4	4	4	10
7	Sized Calcium Carbonate	250	250	250	250	250	250	30
8	Lubricant additive	-	3.5	7	10.5	14	17.5	10

PROCEDURE:

The drill – in fluid samples were prepared using the formula stated in table 1 above. The mixing order was according to the numbering and the mixing time stated above. The Hamilton Beach mixer was used for efficient mixing.

2.3 DETERMINATION OF MUD DENSITY

Mud density is used to control subsurface pressures and stabilize wellbore and it is commonly measured with a mud balance capable of +0.1lb/gal accuracy. A mud balance calibrated with fresh water at 700 + 50 should give reading of 8.3 lb/gal [6]. When we drill the wellbore, we replace a cylinder of rock with a cylinder of mud. The first critical step towards designing a drilling fluid is to establish the mud weight required to provide the correct level of borehole pressure support. Mud balance is the instrument used for drilling fluid density determination. The mud balance is designed such that the drilling fluid holding cup at one end of the beam is balanced by a fixed counter weight at the other end with a sliding weight rider free to move along a graduated scale.

PROCEDURES:
1. The cup of the mud balance was filled to the brim.
2. The filled mud cup was covered with the cap to allow excess mud and air out of the cup.
3. The mud balance was cleaned of any excess mud while holding the cap tightly to the cup.
4. The mud balance was made to balance on the provided knife edge using the rider.
5. When balanced, the reading on the scale as indicated by the arrow was recorded.

2.4 DETERMINATION OF WATER BASED DRILLING FLUID RHEOLOGY

The Mash Funnel and the Graduated mud Cup was used to determine the Funnel Viscosity. The FANN 33 viscometer was used to measure the plastic viscosity (PV), yield point (YP), and gel strength. Rheological properties measured with a rotational viscometer are commonly used to indicate solid buildup flocculation or deflocculation of solids, lifting and suspension capabilities, and to calculate hydraulics of drilling fluid. A rotational viscometer is used to measure shear rate or shear stress of drilling fluid from which the Birmingham Plastic parameters; plastic viscosity (PV) and yield point (YP) are calculated directly. The instrument was also used to measure gel strengths. The plastic viscosity is due to the physical size and presence of any solids or emulsified droplets in the fluid. The PV should be as low as possible and to reduce the PV we need to reduce the solids as well. The yield point is the viscosity due to the chemical attraction between the particles and to increase the YP, we need to add products with attractive forces. The Gel strengths refer to the increase in viscosity at zero shear rates. It is a measure of the attractive forces under static conditions. The equations to calculate the rheological properties, plastic viscosity and yield point are stated in equations below. The gel strength was read directly from the viscometer.

Plastic viscosity (PV) = $\Theta 600 - \Theta 300$ (1)

Yield point (YP) = $\Theta 300 - PV$ (2)

PROCEDURES: Place the VG Meter cup containing the sample on the VG Meter platform and raise the platform until the mud level reaches the scribed line around the VG Meter sleeve.
1. Tighten the screw to hold the platform in place while using the VG Meter.
2. Pull the red knob up or push it down only with the meter running.
3. Toggle the switch in the high-speed position, the sleeve will be turning at 600rpm. The first reading will be taken at 600rpm. Record the reading.
4. Toggle the switch to the low-speed position with the red knob still all the way down. This will shift the sleeve to 300 rpm where the second reading is taken. Record the reading.
5. Push the toggle switch off for 10 seconds. After 10seconds push the switch back on to the low-speed position while watching the dial. The dial turned to a high number and then fell back to a lower value. The highest dial value is taken before it dropped back as the 10sec Gel strength.
6. The VG meter cup is turned off again without changing the position of the red knob for 10mins. After 10mins the toggle switch is pushed low while watching the dial. The highest value reached before the dial falls back is the taken as the 10mins Gel strength.
7. The procedure is repeated for with all the LCM mud samples.

2.5 DETERMINATION OF FILTRATE VOLUME AND MUD CAKE THICKNESS

This test determines the rate at which fluid is forced through the filter paper under specified conditions of time, temperature and pressure. The test is conducted at 100psi and the filtrate volume is read and recorded after 5mins, 10mins, 15mins, 20mins 25mins and 30mins. The thickness of the solid filter cake deposited 32nd of an inch is measured after the test.

PROCEDURE:
1. Mount the API filter press apparatus on the work table.
2. Remove the cell from the rack if not already removed disassemble the cell.
3. Fill the cell with mud sample to 3-4cm to the brim of the cell.

4. Cover the cell body with the regulator cap and place the assembly into the filter press stand.
5. Back off the T screw on the regulator fully but without removing the t-screw. Place the CO_2 cartridge in the cartridge barrel and fasten to puncture the cartridge (ensure no leakage of CO_2).
6. Place a 25ml graduated measuring cylinder under the cell to collect the filtrate.
7. Pressurize the cell to 100psi by turning the T-screw clockwise and pushing the red knob in.
8. Start the timer and run the test for 30mins. Values of mud filtrate were taken at 0-5th mins, 5th – 10th mins, 10th- 15th mins, 15th – 20th mins, 20th – 25th mins and 25th – 30th mins.
9. The filtrate volumes were recorded and the filter cake thickness observed.

2.6 DETERMINATION OF COEFICIENT OF FRICTION OF DRILLING FLUID SAMPLES

The coefficient of friction of a drilling fluid sample can be tested using a Lubricity Evaluation Monitor (LEM). The LEM is a versatile instrument that measures the coefficient of friction by pressing a wellbore or casing sample against a rotating steel bob while immersed in a test fluid. The LEM uses the torque on the bob, the side load applied to the contact area, and the radius of the bob to calculate the coefficient of friction.

The coefficient of friction is the frictional force of the load or the force perpendicular to the surfaces. It is independent of the apparent areas of contact as long as this area is not so small as to break through the film. Ofite Lubricity Tester was used for this experiment.

PROCEDURE:

1. Check and confirm that the instrument has been calibrated using deionized water.
2. Thoroughly clean the ring, block, block holder, and sample cup with acetone.
3. Turn on the power and let the machine run for 15 minutes.
4. Place the test block in the holder. Do not let the ring and block touch.
5. Mix the test fluid for at least 10 minutes.
6. Set the motor speed to 60 rpm.
7. Fill the cup with the fluid and place it on the stand.
8. Raise the cup up until the ring and block assembly are fully submerged. Tighten the thumb screw.
9. Wait for the torque reading to stabilize. Then zero the torque reading on the Control Panel.
10. Position the torque arm so it is inside the torque arm clamp.
11. Turn the torque adjust handle so the gauge reads 150 in-lb.
12. Zero the time on the control panel.
13. Let the machine run for 5 minutes.
14. Record the torque reading from the display screen.
15. Release the pressure on the ring and block.
16. Lower the cup and discard the fluid.
17. Thoroughly clean the ring, block, block holder and sample cup with acetone.
18. Calculate the Coefficient of Friction (Lubricity Coefficient) using the formula:

$$Coefficient\ of\ Friction = \frac{\text{Meter Reading x Correction Factor}}{100}$$

III. RESULTS AND DISCUSION

The results of the experiments for the measurement of the already stated properties of the 6 formulated mud samples are presented here. All the experiments were done in triplicates and the average values were reported. These results are hereby presented and discussed.

3.1 ANALYSIS OF WATER BASED FLUID

Drilling fluid samples were formulated according to standard API procedure.

The results of the analyses carried out on the prepared mud samples are presented and discussed below. They include mud density/ weight, funnel viscosity, plastic viscosity, yield point, gel strength, fluid loss or filtrate test and mud/ filter cake thickness and methylene blue test.

3.2 DRILLING FLUID DENSITY

Drilling fluid density is a very important property of the drilling mud because it is important in controlling the formation pressure while drilling and very important in maintaining the wellbore stability.

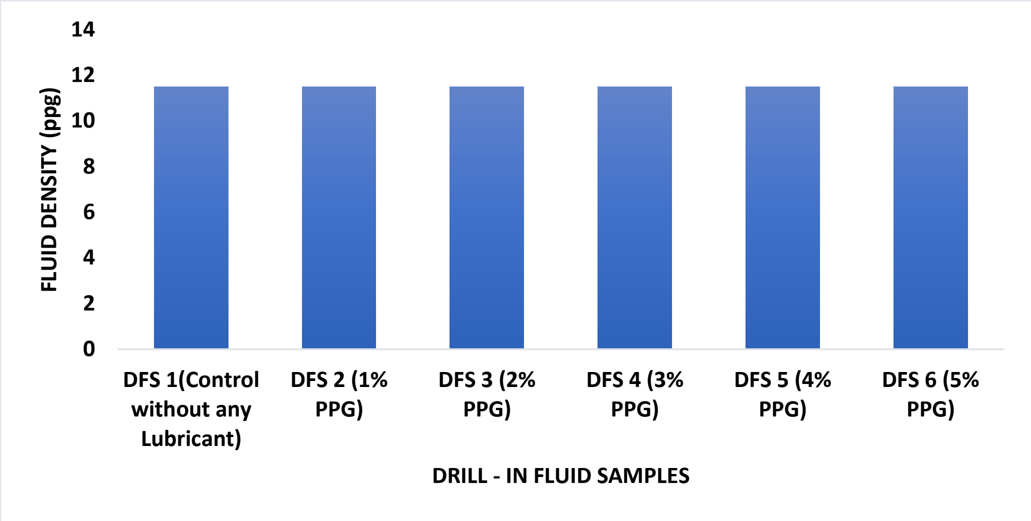

FIGURE 1 DRILLING FLUID DENSITY

From the result above, the fluid density of all the samples maintained the same value of 11.5ppg. This shows that slight changes or increase in the concentration of polypropylene glycol used in preparing the drill – in fluid samples had negligible or insignificant effect on the fluid density across the various samples prepared. Also, all samples had good fluid density which capable of maintaining wellbore stability and controlling formation pressures.

3.3 RHEOLOGY PARAMETERS

The FANN 35 viscometer was used for the experiment and the result of the VG meter readings were used for calculations to generate the values for the Plastic Viscosity, Yield Point, Low Shear Rate Yield Point and Gel Strength, while the funnel viscosity was determined using the Marsh funnel and graduated mud cup. The results are presented in figure 2 to 6 below.

3.3.1 FUNNEL VISCOSITY

Funnel viscosity is defined as seconds for one quart of mud to flow through a Marsh funnel. It is a measure of the resistance of flow observed in a suspension, without considering the underlying interactions. Funnel viscosity quantifies the flowability of the drilling fluids. It is not a true viscosity but serves as a qualitative measure of how thick the mud is. The unit is sec/qt.

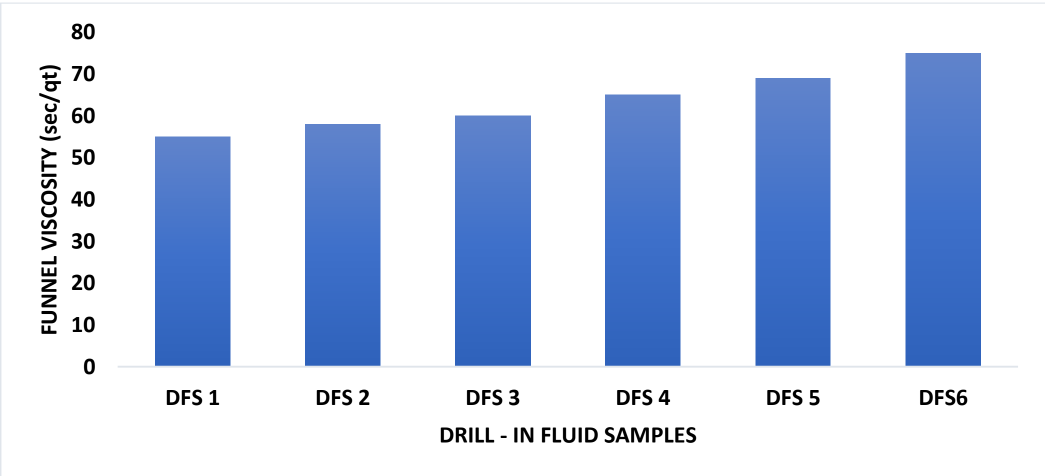

FIGURE 2 FUNNEL VISCOSITY

From the result in figure 2 above, fluid sample 6, with 5% of polypropylene glycol had the highest funnel viscosity of 75 sec/qt, followed by fluid samples 5 and 4, which had 69 and 65 sec/qt, respectively. The fluid sample 1 being the control sample had the least funnel viscosity of 55 sec/qt.

The result of the funnel viscosity above shows an increase in funnel viscosity from the control to the drill – in fluid samples in which polypropylene glycol was used as a lubricant additive. Also, there was a general increase

in funnel viscosity, with increase in the concentration of polypropylene glycol used as lubricant additive in the various fluid samples from sample 2 to sample 6. This shows that an increase in the concentration of polypropylene glycol used to formulate the drill – in fluids will lead to a consequent increase in the funnel viscosity.
Hence, care should be taken while increasing the concentration of propylene glycol being used in preparing drill – in fluids used in drilling operations, especially considering the impact of higher viscosity in drilling operations.

3.3.2 PLASTIC VISCOSITY

Plastic viscosity PV is a combination of resistance to flow caused by the friction between the suspended solids and the base fluid in the drilling fluid. A high PV may be caused by viscous base fluid and excess solids. A high plastic viscosity is associated with wellbore problems, while the low plastic viscosities at high temperature indicate that the mud formulations are lubricious and are capable of a fast rate of penetration (ROP). Drilling fluid formulations that retain their rheological properties and have low PV at high temperatures are suitable for use as drilling fluids.

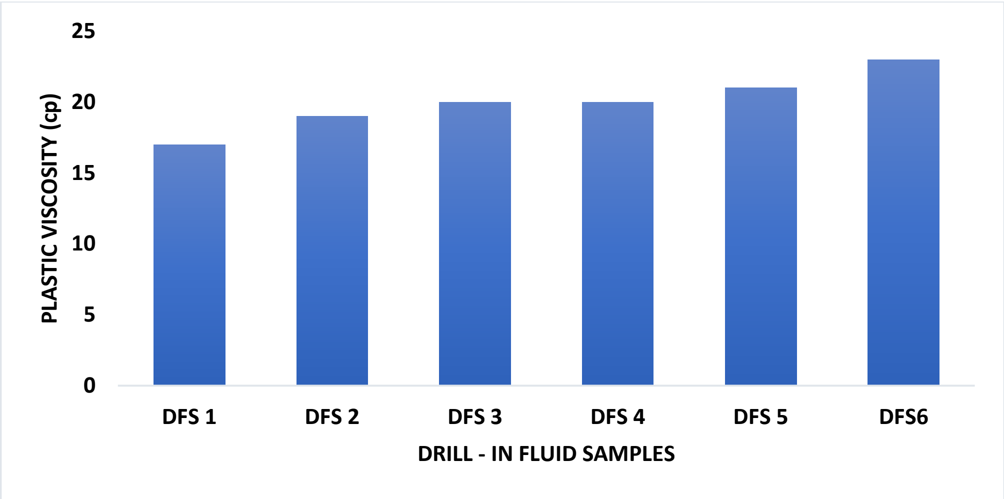

FIGURE 3 PLASTIC VISCOSITY

The result in figure 3 shows that fluid sample 6 had the highest plastic viscosity PV of 23cp, followed by sample 5 with PV of 21cp. The control sample had the least PV of 17cp. Generally, the plastic viscosity increased as the concentration of polypropylene glycol increased across the samples. However, sample 3 and 4 (2% and 3%) had the same PV of 20cp. In the preparation of drilling fluids used in drilling operations, care must be taken to control the plastic viscosity as this can have some adverse effects on the entire drilling process.
Therefore, serious consideration should be made in relation to concentration, while using polypropylene glycol as a lubricant additive in drill – in fluids.

3.3.3 YIELD POINT

Yield Point YP shows an indication of the drilling fluid to suspend weight materials and remove cuttings from the wellbore. It reflects the resistance to initial flow or the stress required to initiate fluid movement. A fluid with higher yield point will carry cuttings better than the one with lower yield point, even if both have the same fluid density.

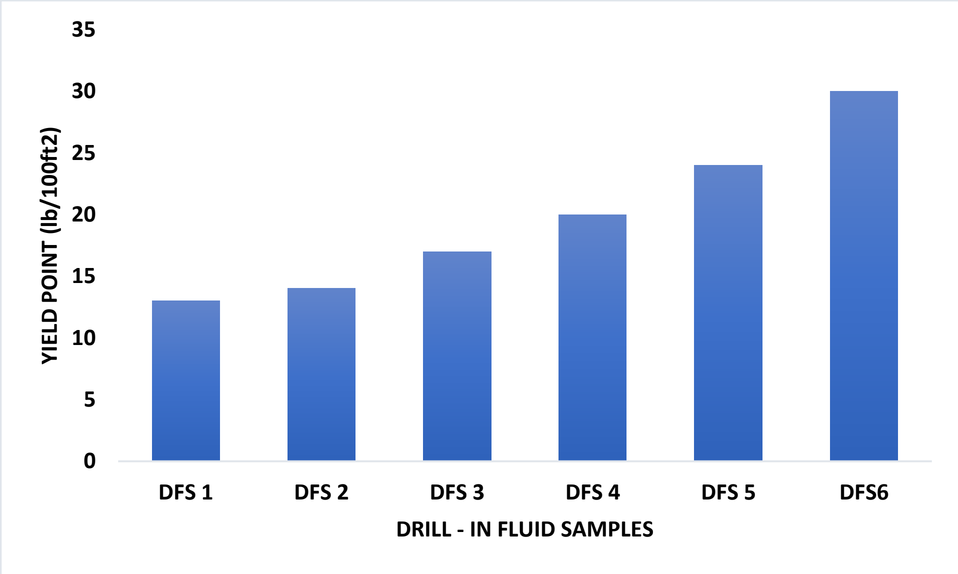

FIGURE 4 YIELD POINT

From figure 4 above, it can be seen that fluid sample 6 with 5% of polypropylene glycol as lubricant additive had the highest yield point of 30 lb/100ft^2, followed by fluid sample 5 and 4, which had yield point of 24 and 20 lb/100ft^2, respectively. Fluid sample 1 being the control sample had the lowest yield point of 13 lb/100ft^2. Generally, there is an observed increase in the yield point of the fluid samples as the concentration of polypropylene glycol used in the fluid samples increased.

This shows that concentration of polypropylene glycol used in formulating drill – in fluids has a significant impact on the yield point of the fluid. Hence, as much as the lubrication impact of polypropylene glycol is important, the concentration of polypropylene glycol being used in the preparation of drill – in fluids should be carefully monitored to ensure a fluid that will not lead to more drilling problems due to higher yield point.

3.3.4 LOW SHEAR RATE YIELD POINT

Low shear rate yield point is a measure of the viscosity and rheological properties of a fluid, particularly drilling fluids, at low shear rates. It represents the minimum stress required to initiate flow in a fluid at low shear rates. It is a critical parameter in evaluating a fluid's flowability, pumpability, and settling characteristics. It helps to predict fluid behaviour during static conditions e.g in the annulus. It also helps to optimize drilling fluid formulations and ensures effective hole cleaning and suspension of solids. A good LSRYP value indicates reduced settling ability and improved suspension ability. While a higher value indicates increased viscosity, greater settling tendency and reduced flowability.

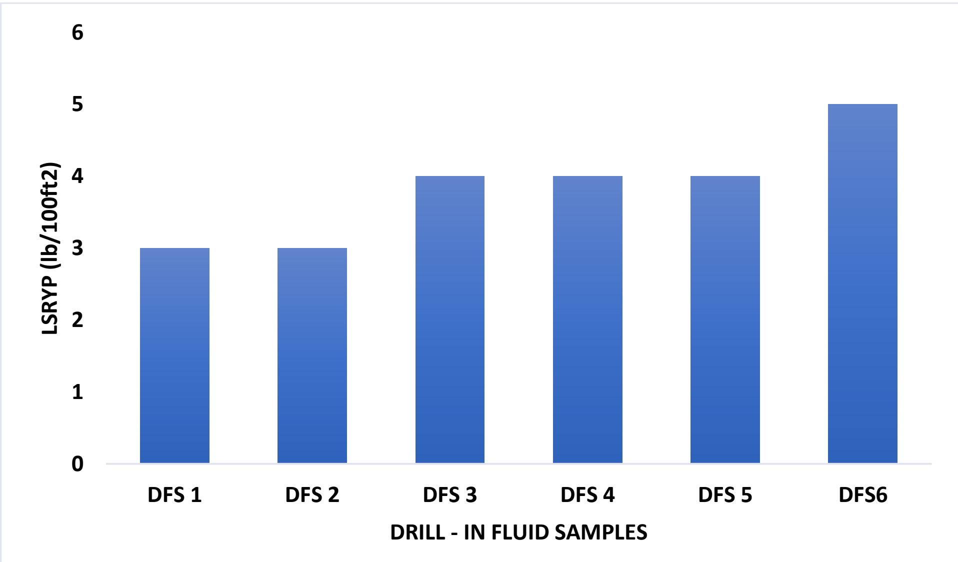

FIGURE 5 LOW SHEAR RATE YIELD POINT

The result shows that fluid sample 6 had highest value of 5 lb/100ft^2, while sample 1 and 2 had the least values of 3 lb/100ft^2 each. The values of the various fluid samples show a good ability to suspend solids and ensure proper hole cleaning.

Generally, the results shows that the LSRYP increases with increase in the concentration of the polypropylene glycol used in preparing the drill – in fluids.

This indicates that care should be taken while increasing the concentration of polypropylene glycol being used in preparing drill – in fluids, as this will likely lead to an increase in the viscosity of the fluid and a higher value of the LSRYP, leading to some other drilling problems.

3.3.5 GEL STRENGTH

Gel Strength is a property of mud that enables it suspend cuttings when pumping or circulation has been stopped. It measures the attractive forces of mud particles under static conditions for 10 seconds and 10 minutes. It also helps to determine if cuttings would settle in the wellbore under static conditions. The ability to maintain the proper value of gel strength depends on effective solids control. A reasonable gel strength is vital to prevent immediate settling of solids when circulation has stopped.

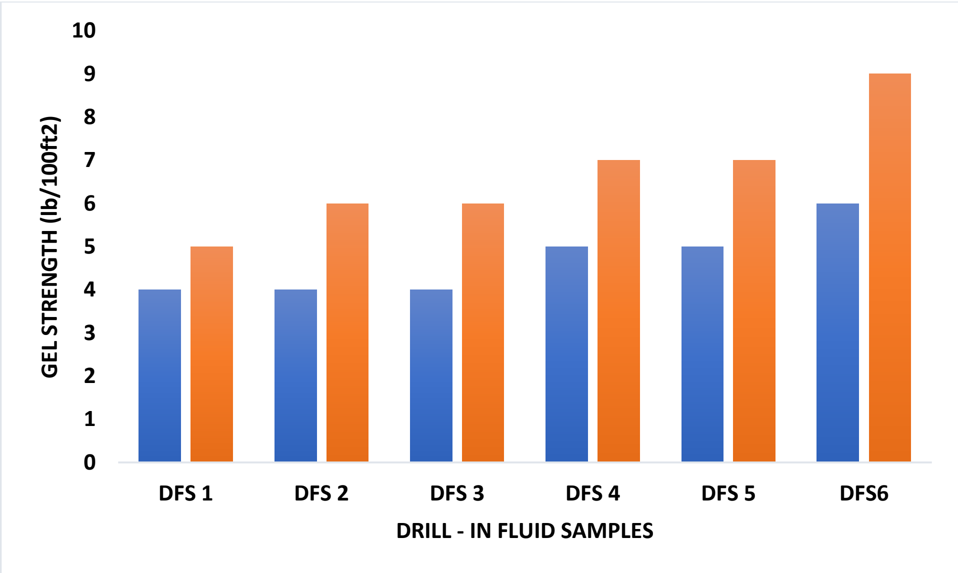

FIGURE 6 GEL STRENGTH

The result of the study shows that drill – in fluid sample 6 had the highest Gel Strength (6 lb/100ft^2 and 9 lb/100ft^2, for 10 sec and 10 min Gel respectively), followed by sample 4 and 5 which had the same values (5 lb/100ft^2 and 7 lb/100ft^2 for 10 sec and 10 min Gel respectively) each. Sample 1 being the control sample had the least Gel Strength (4 lb/100ft^2 and 5 lb/100ft^2 for 10 sec and 10 min Gel respectively).

It is observed that gel strength increased with increase in the concentration of polypropylene glycol used in the preparation of the drill – in fluid samples.

3.4 FILTRATION TEST

3.4.1 FLUID LOSS WITH RESPECT TO TIME

The term Fluid Loss or mud filtrate is used to refer to the fluid of drilling mud that filters into the formation in the process of drilling. It is the liquid part of mud which passes through a medium and become separated from the mud cake or filter cake. Reducing the volume of filtrate in drilling operations can reduce several problems associated with drilling.

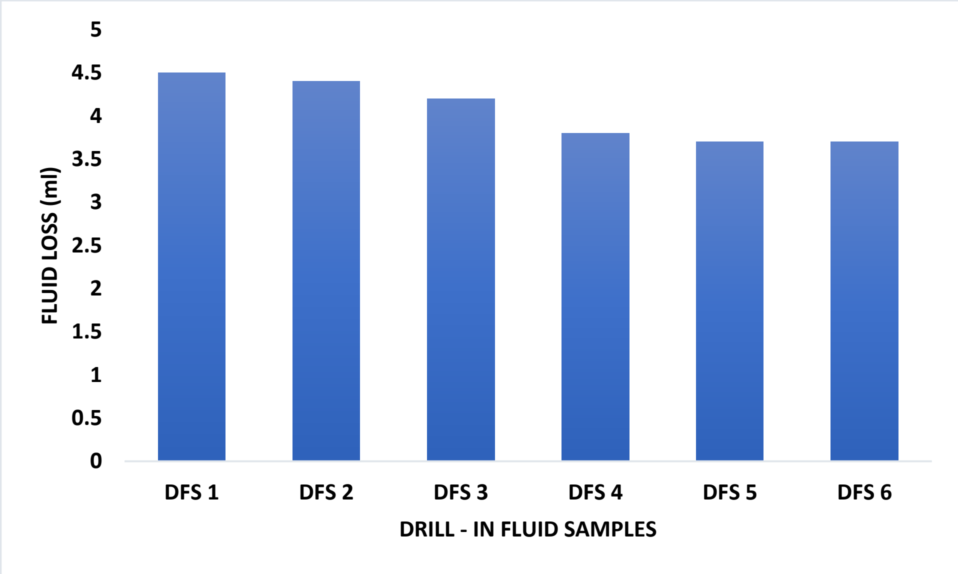

FIGURE 7 FLUID LOSS

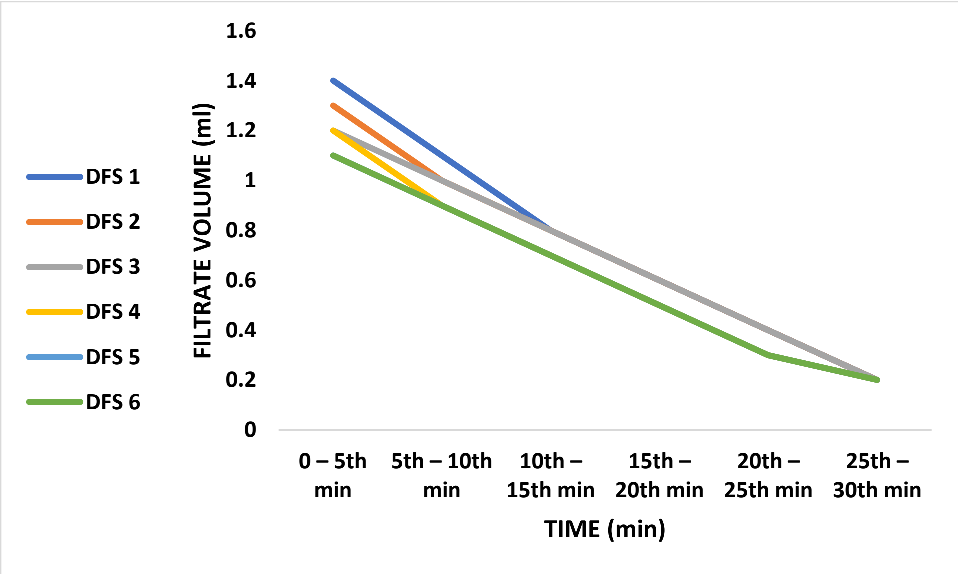

Figure 8 FLUID LOSS WITH RESPECT TO TIME

The result in figure 7 shows the fluid loss of the various samples. It shows that sample 1 being the control sample, without any lubricant additive (PPG) had the highest fluid loss of 4.5ml, followed by sample 2 and 3 which had 4.4ml and 4.2ml respectively, over a period of 30 minutes, when the API Filter press was used to determine the filtrate volume of the fluid samples at 100psi. Samples 5 and 6 being the samples with 4% and 5% polypropylene glycol respectively had the least fluid loss of 3.7ml each.

From the result, fluid loss tends to reduce with increase in the concentration of the polypropylene glycol used in the samples. This shows that the higher the concentration of polypropylene glycol used as lubricant in preparing drill – in fluids, the better the fluid loss control ability of the fluid.

Hence increase in the concentration of polypropylene glycol being used as lubricant additive in water – based drilling fluid, is advisable when considering its effect on the fluid loss control of the drill – in fluid being prepared.

Figure 8 shows a relationship between fluid loss or filtrate volume of the various drill – in fluid samples under review and time. This shows that the amount of fluid being lost from the drill – in fluid, generally reduces with respect to time in the course of drilling operation. This could be understood, as more filter cake is formed with time, plugging off the porous formation and thereby reducing the amount of filtrate seeping into the formation.

However, the rate at which the volume of fluid lost from the drill – in fluid with time varied for different fluid samples, as shown in figure 8.

3.4.2 FILTER CAKE THICKNESS

Filter or mud cake is a very thin layer of solid particles deposited from the drilling fluid onto the surface of the drilled formation. This is very important during drilling process because it helps to reduce fluid filtrate invasion, thereby contributing to the wellbore stability. In drilling operations, it is better to have a filter cake that is impermeable and thin. Thin mud cake is always desired because thick mud cake would lead to increase in torque, drag while tripping out of the hole or logging, and can cause differential sticking.

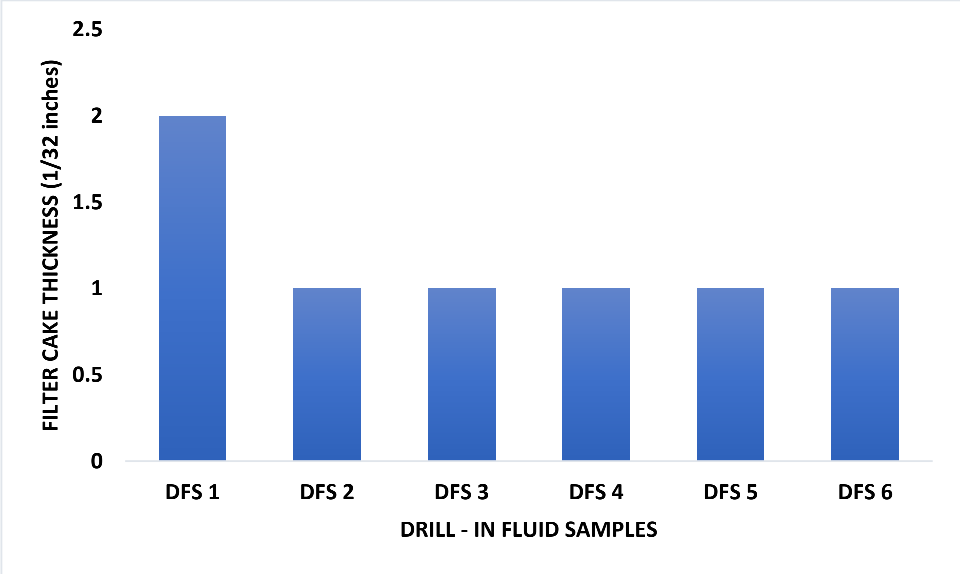

FIGURE 9 FILTER CAKE THICKNESS

The result shows that fluid sample 1 being the control sample (without any lubricant additive) had the highest filter cake thickness of 2/32 inch, while the rest had a thickness of 1/32 inch each. This could explain the reason for a higher filtrate volume/ fluid loss displayed by fluid sample 1, since a higher filter cake thickness will result in higher filtrate volume.

Again, the rest of the samples had a moderate filter cake thickness, indicating that using higher concentrations of polypropylene glycol as a lubricant additive in water – based drilling fluids will give a better result in terms of fluid loss and filter cake formation.

3.5 COEFICIENT OF FRICTION OF DRILL – IN FLUID SAMPLES

The coefficient of drill – in fluids is the property of the fluid which shows the lubricating properties of drilling fluids. It is a very important factor in well design. Certain well designs such as deviated wells, deep and ultra deep wells are usually associated with excess drag between the drill string and the casing, and casing wear especially during tripping in and out of the hole.

It is important to design a drilling fluid system that adequately lubricates the drill string without compromising other physical properties of the drilling fluid such as, density, rheology, and filtration.

A lower coefficient of friction indicates that a more effective lubricant has been used in preparing the drill – in fluid.

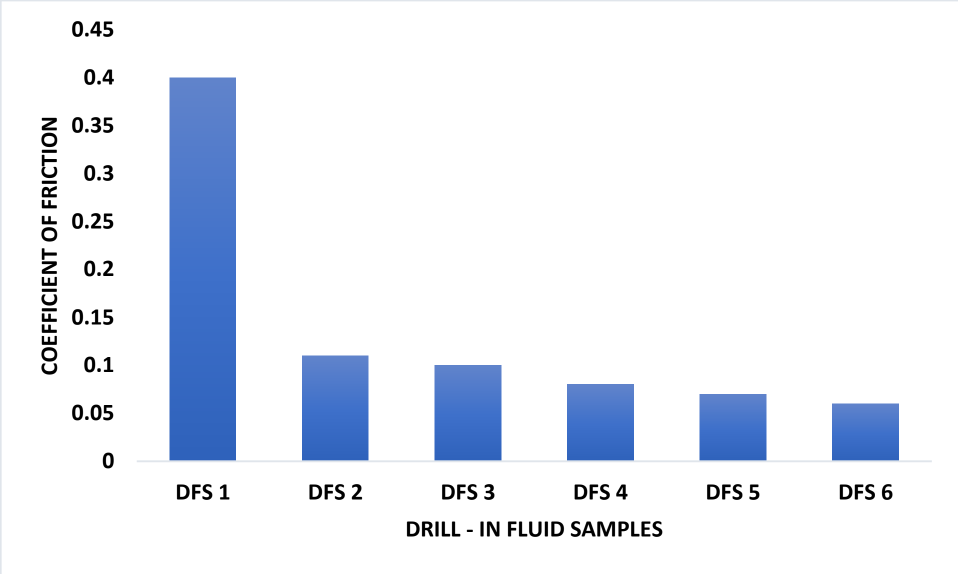

FIGURE 10 COEFICIENT OF FRICTION

The result in figure 10 above shows that fluid sample 1 being the control sample (without any lubricant additive), had the highest coefficient of friction with the value 0.4. this was followed by fluid sample 2 and 3 which had 0.11 and 0.1 respectively. Fluid sample 6 had the least coefficient of friction with the value 0.06.

Generally, it can be seen that the coefficient of friction reduced as the concentration of polypropylene glycol used in preparing the drill – in fluid samples increased from 1% to 5%. In this case, fluid sample 6 which had the value of 0.06, being the least value showed the best lubricity capacity amongst all the fluid samples. This shows that a fluid with a higher concentration of the lubricant additive polypropylene glycol would give a lower coefficient of friction, hence a better lubricity effect.

However, considering the impact of the high concentration of polypropylene glycol on the rheological and filtration properties of the drill – in fluids studied, it is necessary to apply caution in adopting a particular concentration of the polypropylene glycol in preparing the drill – in fluid needed to be used at the reservoir region of the well.

IV. CONCLUSION

The result of the study shows that slight changes or increase in the concentration of polypropylene glycol used in preparing the drill – in fluid samples had negligible or insignificant effect on the fluid density. Also, all samples had good fluid density which capable of maintaining wellbore stability and controlling formation pressures.

As shown in the figures, it is clearly visible that a viscosity and rheology hump was observed in drill-in fluids samples 5 and 6, with 4% and 5% poly propylene glycol respectively, as lubricants. This can have a negative impact in drilling efficiency due to a potential surge while tripping in or swab while tripping out, which could induce loss or even total loss of return. Fluid sample 4, with 3% showed moderate and acceptable range of rheological properties with minimal risk or surge or swab effect. It can result to swab effect – kick

The result also shows that using higher concentration would lead to lower filtrate volume/ fluid loss and good filter cake formation in the course of drilling operations.

Finally, the result shows that a fluid with a higher concentration of the lubricant additive polypropylene glycol would give a lower coefficient of friction, hence a better lubricity effect.

However, considering the impact of the high concentration of polypropylene glycol on the rheological properties of the drill – in fluids studied, it is necessary to apply caution in adopting a particular concentration of the polypropylene glycol in preparing the drill – in fluid needed to be used at the reservoir region of the well.

The choice of additive and its concentration should be guided by the specific drilling conditions and operational requirements.

V. RECOMENDATIONS

Hydraulic analysis, simulations of swab and surge effects should be done with the pilot tested sample to determine the acceptable range of % lubricant, while having the negative effects in mind. Further research is needed to explore the synergistic effects of combining more than one additive and their impact on fluid performance.

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