Effect of Aging on Water Based Mud

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Abstract
Drilling mud is a vital component in rotary drilling operations. For a successful drilling operation to be achieved, drilling fluid used has to be continuously monitored and controlled. It is very easy to determine the properties of drilling mud at surface conditions but it does not represent bottom-hole conditions. Its properties change due to elevated temperature and aging time at the subsurface and these in effect, may cause series of down hole problems. A laboratory investigation of the effects of temperature and aging time on water based mud was made with aging cell and an oven, mud balance, API filter press and sand content kit. At days 1, 3, 5 and 7, filtrate volume, at 100 psi and room temperature, yielded 21, 20, 17 and 15 ml respectively. On the other hand, the viscosity of the aged mud sample increased from 27 sec/quart at 0 hour to 29, 30, 31 and 32 sec/quart for days 1, 3, 5 and 7 respectively. From the filtrate volume, a thin filter cake was deposited. It was observed as well that viscosity and filtrate loss decreased with the increase in aging and the effect diminished with the increase in aging time, but density and sand content increased with increase in aging time. Finally, it is drawn that temperature affect some of the properties of drilling mud at the subsurface such as density, sand content and most especially viscosity and filtration property. This led to a conclusion that aging affects the properties of drilling mud and its effect diminish with increase in time.

Keywords: *Drilling fluid, drilling mud, Aging time, temperature, water based mud, fluid loss.*

1. Introduction

A vital component in rotary drilling is the drilling fluid which is also known as drilling mud. Drilling fluid has been defined in different ways due to its different composition. Generally, it is said to be the fluid used in a drilling operation that is circulated or pumped from the surface, down the drill string, through the bit, and back to the surface (Committee, 2005). It can be seen as the equivalent to the blood in the human body, the mud pump is the heart, and the drilled out cuttings represent the slag product (Skalle, 2015). For a successful well to be drilled, deciding on the drilling fluid to be used is not only important, but considering the properties of the drilling fluid is vital as well. It follows that the selection of a suitable drilling fluid and the day-to-day control of its properties are of concern, not only to the mud engineer, but also of the drilling supervisor, the drilling foreman, and drilling, logging and production engineers (Darley and Gray, 1988). Also, it can be defined as a single phase fluid or emulsion containing colloidal or non-colloidal surface and that exhibit plastic or non-Newtonian behaviour which aids in a smooth drilling operation.

In the early days of rotary drilling, the primary function of drilling fluids was to bring the cutting from the bottom of the hole to the surface. Today, it is recognized that drilling fluid has at least eight important functions. The drilling fluid is related either directly or indirectly to most drilling problems. This is not to say that the drilling fluid is the cause or solution of all problems, but it is a tool that can often be used to alleviate some problematic situations (Max and Martin, 1996). If the drilling fluid does not adequately perform its basic functions, it could become necessary to abandon the well (Bourgoyne Jr., Millheim, Chenevert and Young Jr., 1991). Generally, a good drilling fluid is simple and contains a minimum number of additives. This allows easier maintenance and control of properties.

Aging as the name implies come in to use when handling bottom-hole conditions. This term actually helps to investigate the properties of a drilling fluid at bottom-hole conditions. The concept of aging is important in simulating the properties of drilling mud at bottom-hole conditions as the properties at the surface do not in any way give true picture of bottom-hole conditions (Awele, 2014). Aging is a process in which drilling fluids previously subjected to a period of shear are allowed to more fully develop their rheological and filtration properties (Makinde, Adejumo, Ako, and Efeovbokhan, 2011). Aging is done under conditions which vary from static to dynamic and from ambient to highly elevated temperatures.
The industry has faced a lot of problems due to poor conditioning of drilling muds. At bottom-hole conditions, properties of drilling mud change owing to elevated temperature, pressure and aging, and these may cause problems in drilling a successful well, especially deep wells. Without knowing the right and efficient aging of drilling mud, properties of the mud may diminish, affecting drilling operations. These problems may lead to non-productive time (NPT) thereby increasing the cost of operation and also may be lead to a kick or blow-out. A good example of the poor monitoring of the down hole condition of a drilling mud may lead to filtration loss and differential sticking.
This study is aimed at determine the effect of aging at various temperature on drilling mud properties (density, filtration property and funnel viscosity).

2.0 Methodology
This section includes detailed description of the apparatus, materials and experimental procedures used in this study. The experimental procedures are stated in Apendix A.

2.1 Materials
The materials used for the formulation of mud sample include:

1. Fresh water: 350ml distilled water was used for the continuous phase for all the experiment where the different components are blended with it to form the drilling mud.
2. Wyoming bentonite: This was used as the clay mineral to develop viscosity. 10g of bentonite was used in 350ml of fresh water.
3. Barite: 2 grams of barite was added to the bentonite suspension to serve as a weighing material.
4. Potassium chloride: 5 grams of potassium chloride was added to the bentonite suspension to attain maximum gel strength of the drilling fluid and also for compatibility of salt formations.
5. Starch: 5 grams of starch was added for modification of viscosity.
6. Sodium carbonate: 5 grams of sodium carbonate was added to optimize p^H and alkalinity of mud and controlling mud additives

Phydrion dispenser was used to measure the formulated mud and the p^H of the measured was 9.5.

2.2 Apparatus

Experimental apparatus used in this study consisted of a Mud balance, Dead API Filter Press, sand content, Funnel Viscosity, an Aging Cell and an Oven.

3. Results

Details of the results obtained during the experiments are tabulated below. Values of density, filtrate volume at 1000psi, and funnel viscosity as a function of temperature are presented in figures with aging time as a parameter. Each curve of these figures represents the results for a different aging.

Table 1: Mud weight as a function of temperature for aging

Aging(days)	**0**	**1**	**3**	**5**	**7**
Temperature	37^0c	50^0c	100^0c	150^0c	200^0c
Density (ppg)	8.50	8.60	8.65	8.70	8.80
Specific gravity	1.02	1.03	1.35	1.40	1.50

As shown above (Table 1), temperature is elevated on each aging day. This have an effect on the density of mud as it increases due to aging effect.

Table 2: Filtration property as a function of temperature for aging time

Aging(days)	**0**	**1**	**3**	**5**	**7**
Temperature	37^0c	50^0c	100^0c	150^0c	200^0c
Filtrate volume (ml) at 100psi, room temperature.	22	21	20	17	15
Cake thickness (1/32")	1/32	1/32	1/32	1/32	1/32

Table 1: Sand content as a function of temperature for aging time

Aging(days)	**0**	**1**	**3**	**5**	**7**
Temperature	37^0c	50^0c	100^0c	150^0c	200^0c
Sand Content (%)	5	7	8	9	9

Table 4: Viscosity as a function of temperature for aging time

Aging(days)	**0**	**1**	**3**	**5**	**7**
Temperature	37^0c	50^0c	100^0c	150^0c	200^0c
Funnel Viscosity (sec/quart)	27	29	30	31	32

4 Discussion

4.1 Effects of Temperature

Factors such as reduction in the degree of hydration of the phases, reduction of the viscosity of the suspending medium, and increased dispersion of associated clay micelles are attributed by the effect of temperature on the properties of drilling mud. In a drilling fluid, all these processes take place simultaneously as temperature is varied, an interpretation of the observed results will only be possible in cases whereby some of the effects are predominant and as such be easily identified.

As shown in figures 1 – 3, density, funnel viscosity and sand content of mud increased gradually with the increase in temperature for all values of aging time. These changes in properties can be explained according to the investigation carried out by Annis (Annis, 1997), who observed that high temperature causes flocculation of bentonite clays. Increase in temperature causes the clay platelets to aggregate, ultimately leading to aggregation and flocculation and also dehydration of the clay platelets resulting to an increase in density of the drilling mud.

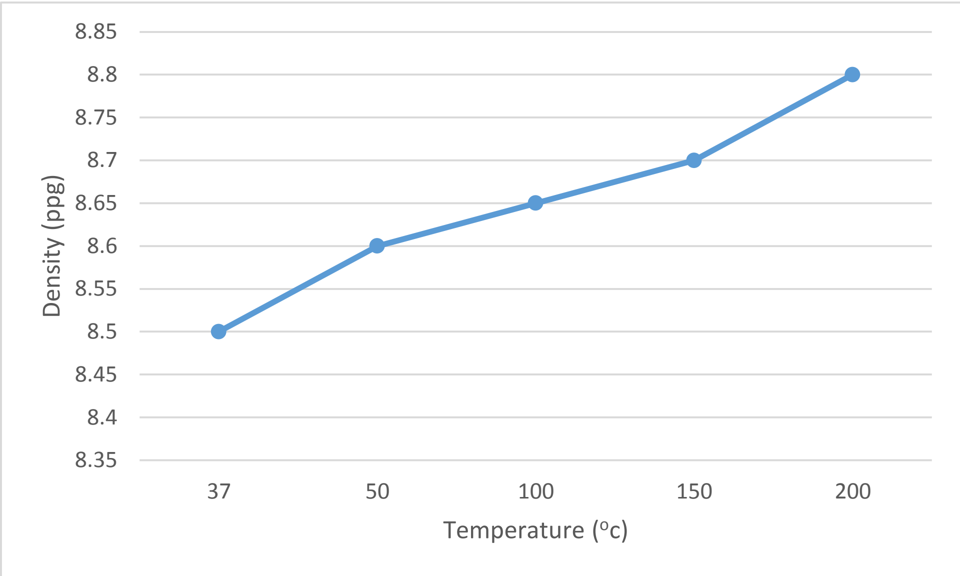


Figure 1: Density as a function of temperature for aging time

In the conducted experiment, it was observed that the funnel viscosity increased gradually due to increase in temperature. Viscosity of most mud was observed to have decreased on heating, while flocculation increased on heating. As flocculation and aggregation of the platelets increased, there is an overall reduction in solid volume, thus enabling the clay aggregates to move freely through the aqueous phase with consequent lowering of the internal friction. As the internal friction of the suspension decreases, the viscosity was observed to have diminished. It was observed that an increase in funnel viscosity was directly proportional to the decrease in viscosity of the mud (figure 2).

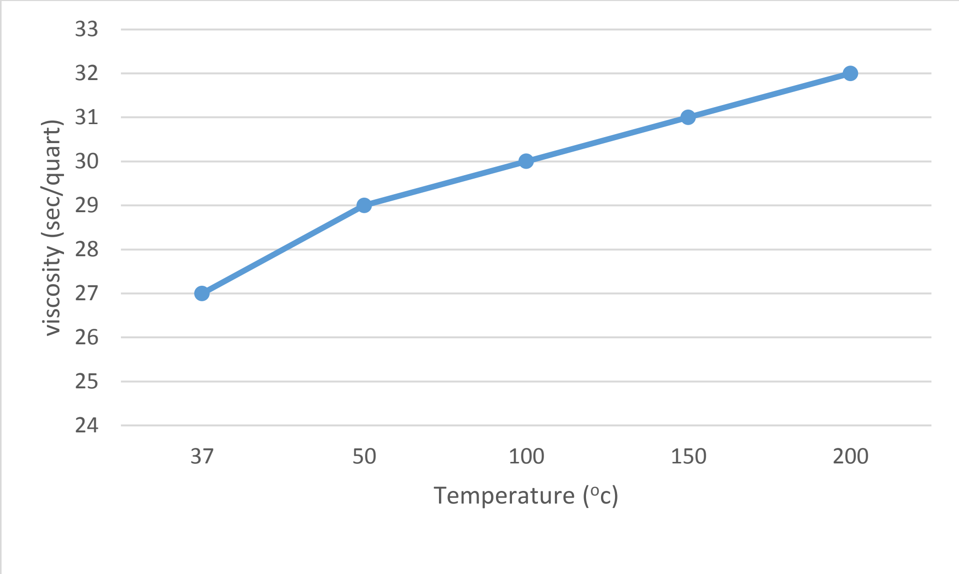


Figure 2: Funnel viscosity as a function of temperature for aging time

4.2 Effect of Sand content

Sand content is the percentage by volume of solids in the mud that are retained on a 200-mesh sieve. It is defined by the portion of drilling mud solids whose size is greater than 74 microns. Excessive sand may result in the deposition of a thick filter cake on the wall of the hole, or may settle in the hole about the tool when circulation is stopped which may cause excessive wear of bit and pipe, thus interfering with successful operation of drilling tools or setting casings. Due to the aggregation and flocculation caused by the increased temperature in the conducted experiment, sand content was observed to have gradually increased (figure 3).

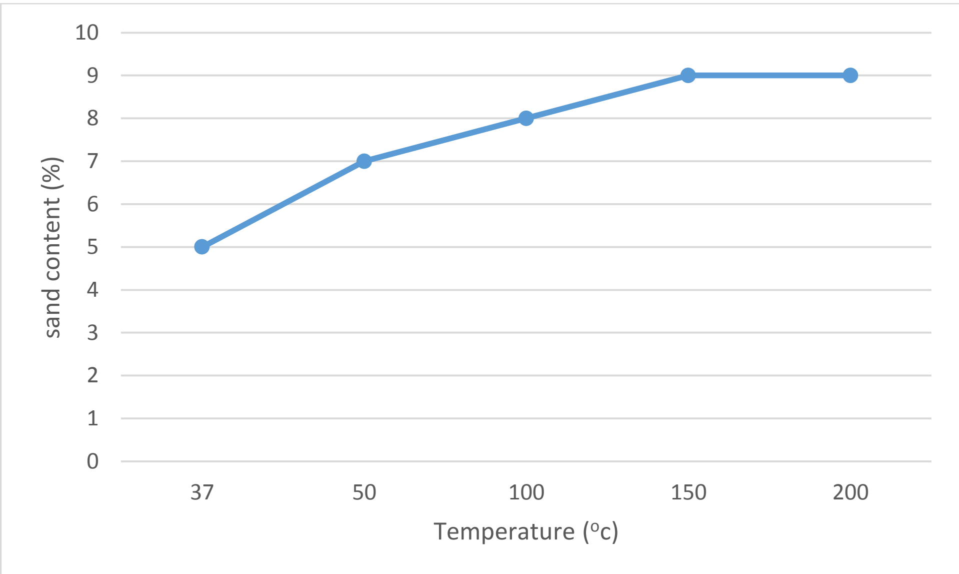
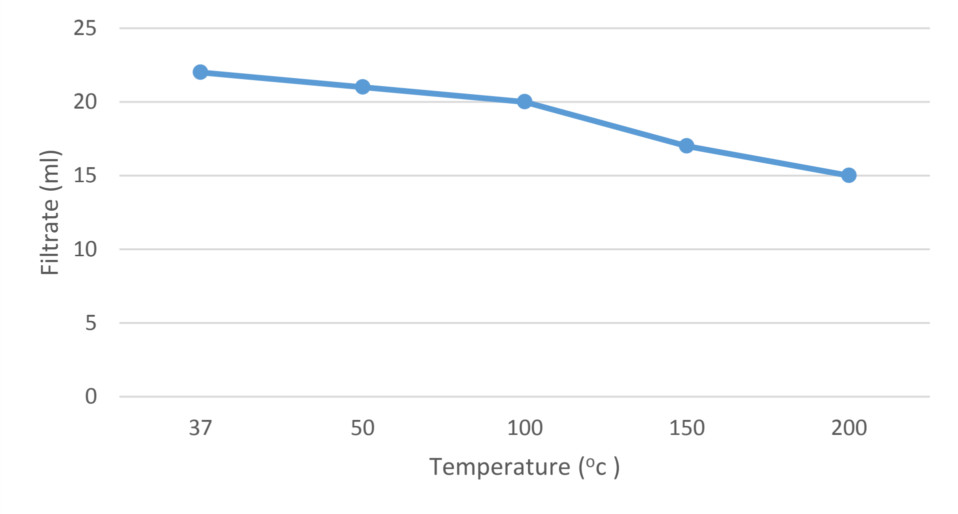


Figure 3: Sand content as a function of temperature for aging time

4.3 Effect of Fluid Loss Test

The API fluid loss test conducted on this drilling mud indicated that the bentonite is good in retaining its fluid content as temperature increased. Filtrate volume was observed to have decreased with increase in temperature (figure 4) and a thin filter cake deposited was observed.

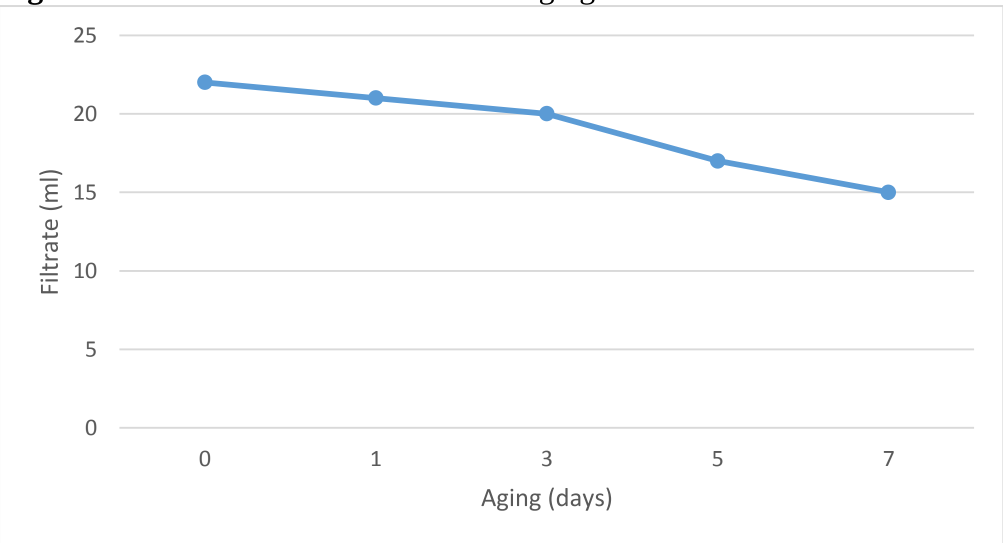
Figure 4: API fluid loss as a function of temperature for aging time



The effect of aging was also studied on the fluid loss test. A good mud must keep the loss of fluid to the formation as minimal as possible while preventing excessively thick filter cake. Thinner and less permeable are

thus the desired characteristics of a good filter cake. It was observed that the filtrate decreased with an increase in aging time (figure 5).

Figure 5: API fluid loss as a function of aging time



4.4 Effects of Aging

The effect of aging on the properties of sampled water base mud, as observed, are presented in figures 6 – 9. It was observed that density and sand content increases with increase in aging time and the aging effect diminishing as the aging time increases. This might be explained from the fact that the degree of dispersion and flocculation increased when the mud was aged statically. The sand content of the mud was increasing steadily with aging (days) until day 5. The day 5, the sand content ceased to increase at 9%. This was sustained from day 5 to day 7, that is a 2 day (48 hours) aging.

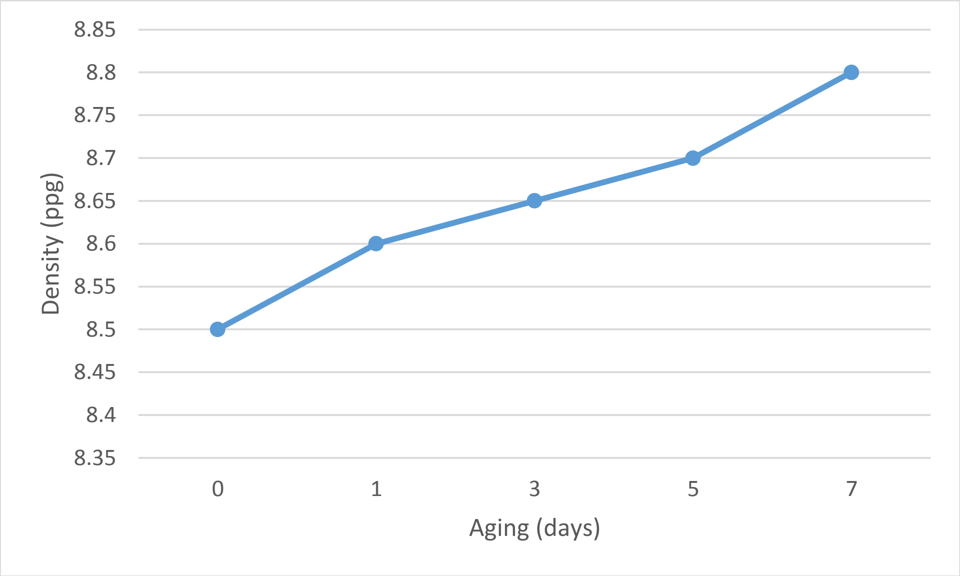


Figure 6: Density as a function of aging

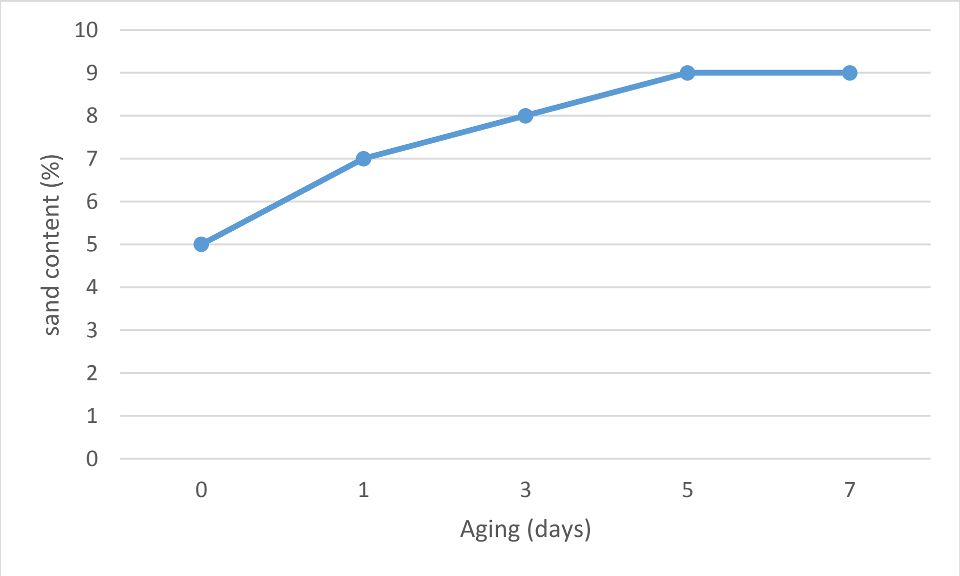


Figure 7: Sand content as a function of aging

4.4.1 Effect of Aging on Specific gravity: This might be explained from the fact that the degree of dispersion and flocculation increased when the mud was aged statically. In the conducted experiment, it was observed that the specific gravity was relatively constant from day 0 (0 hour) today 1 (24 hours after), but gradually increased afterwards as temperature increased (figure 8).

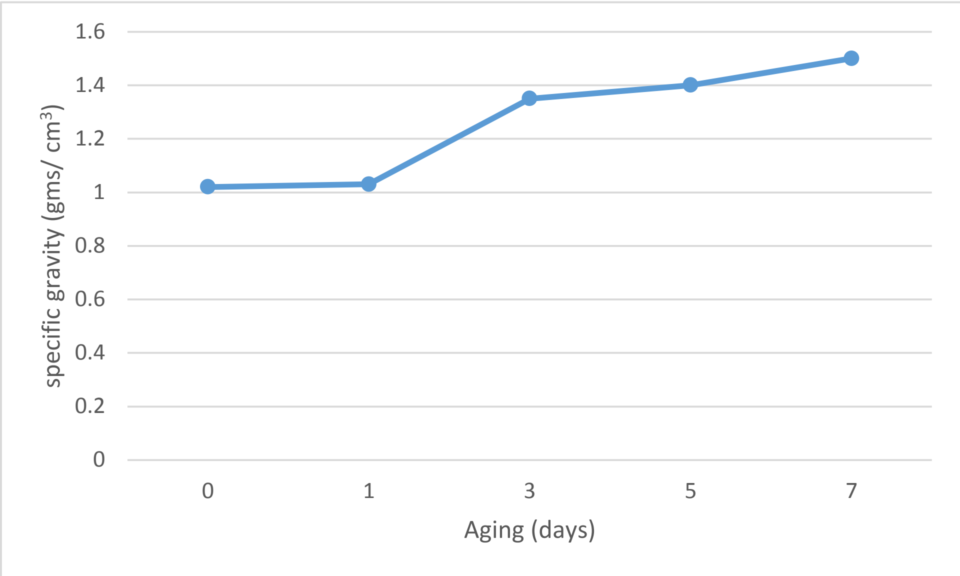


Figure 8: Specific gravity as a function of aging

4.4.2 Effect of Aging on viscosity

As shown in figure 9, the viscosity of the mud decreased gradually having an increase in the funnel viscosity due to increase in aging time while the aging effect diminishes. The explanation of for the decrease may be gotten from the composition of the formulated mud. Potassium chloride (KCl) was added to maximise gel strength and also for compatibility against salt formations. Moreover, salt from its chemical properties is known to have a high water holding capacity which increases with exposure time (aging). It can be deduced that there is an increase in moisture content as a result of the absorption of water molecules from the surrounding by the salt molecule as aging time increased which therefore results in decrease in viscosity. Also the addition of starch in the formulation of mud is another factor to be considered. As drilling mud ages, the starch components becomes degraded leading to the weakening of its viscosity modification effect more so as temperature is increased.

It is a known fact that temperature and aging have effects on the properties of drilling mud. It was also observed form the study that density and sand content increased with increase in temperature and aging time while viscosity and API filter loss decreased with increase in temperature and aging time. A lot of drilling problems can be avoided if the optimum values of these properties are maintained.

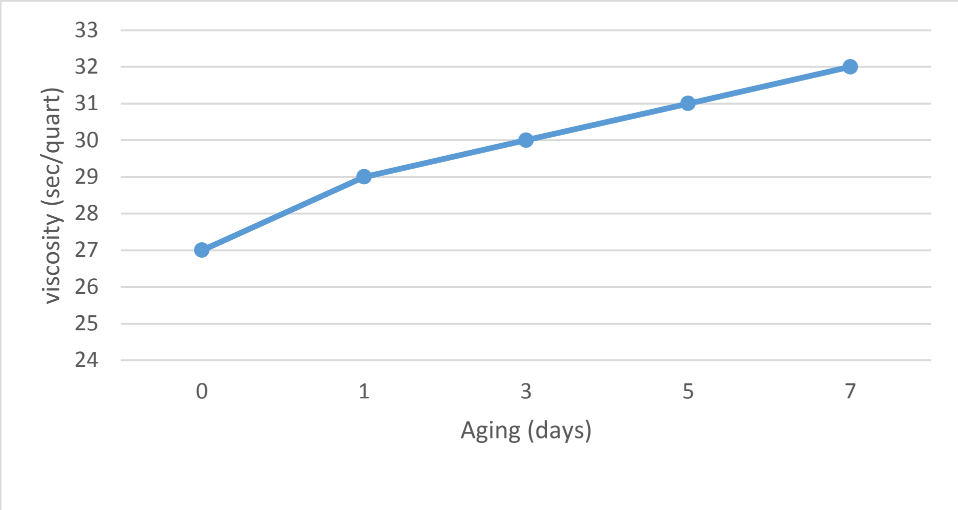


Figure 9: Viscosity as a function of aging

5. Conclusion

Based on the laboratory investigation, the analysis and discussion of the results made the following conclusions;

1. Density of the drilling mud increases with increasing temperature and with increase in aging.
2. The funnel viscosity increases with increase in temperature and increase in aging.
3. As aging increases, its viscosity become diminished and also color of the mud changes from brown to pale green.
4. Sand content of the drilling mud gradually increased with increasing temperature and increase in aging but later became constant.
5. API filter loss had a decrease in filtrate with an increase in temperature and aging. Also thin layer filter cake was deposited.

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Appendix A

A.1 Aging

The concept of aging is important in simulating the properties of drilling mud at bottom-hole conditions from the surface conditions as the properties at the surface do not in any way give true picture of bottom-hole conditions (Awele, 2014).

A.1.1 Aging Cell and Oven

Aging cell as shown in figure is designed for use in aging tests which help predict the performance of a drilling fluid under static, high temperature conditions. It is a stainless steel suitable container for drilling fluids. It comprises of three major parts which are; outer cap, inner cap and the cell body.
The oven is used to heat the aging cell containing the formulated mud to a desired temperature for a period of time or days.

A.1.2 Procedure

1. After the mud was formulated, it was poured in to the 500ml aging cell.
2. The inner cap was put in place at the top of the cell and the outer cap was placed on top of the inner cap then properly covered and tighten in place by means of the centre screw nut.
3. Placed in the oven is the cell and its content at a desired temperature (100^{o}C) and allowed to age for a desired period of time (0 day, 1 days, 3 days and 7days, 9days till 19days)
4. After the desired aging time has elapsed, the cell is removed from the oven and the caps untighten and removed. The sample was tested.

This process is called static aging as opposed to dynamic aging where the mud sample is placed in high-pressurized aging cell and rolled in an oven (Baroid Roller Oven) for specific period. Non-pressurized aging cell is used for static aging of both WBMS, OBMS AND SBM. The cell should be filled with no more than 350ml mud to avoid a build-up of high pressure. Following aging, the cell is allowed to cool to room temperature, either by fan or water bath.

A.2 Mud Balance

A mud balance is an equipment used in the determination of mud density. It provides a simple method for the accurate determination of mud density. An outstanding advantage of this balance is the fact that temperature does not materially affect the accuracy of readings. The durable construction of the mud balance makes it ideal for both laboratory and field use. Despite its sensitivity, it contains no easily breakable parts. Principally, it consists of a base and graduated arm with cup, lid, knife-edge, rider, build-in-spirit level and counter weight on the opposite end. Scale reads in pounds per gallon (6-24 lb/gal); specific gravity (0.72-2.88 gms/ cm^3); pounds per cubic foot (45-180 lb.cu ft). The H-4790 Mud balance meets all requirement of the API standard procedures for testing water based mud.

A.2.1 Calibration

1. The cup was filled with fresh water, the lid was replaced and wiped dry.
2. The balance arm was replaced on the base with knife-edge resting on the fulcrum
3. The level vial was centred when the rider was set on 8.33

A.2.2 Procedure

1. The cup was filled with mud sample to be tested and the cup tapped briskly until the mud bubbles trapped in the mud broke off.
2. The lid was replaced and rotated until it was firmly seated. This was to ensure some mud squeezes out through the vent holes. The exterior of the balance was wiped clean.
3. The balance was placed on the base with knife edge resting on the fulcrum.
4. Rider was moved until instrument was balanced as determined by spirit level. The mud weight was observed and recorded.

A.3 Dead Weight Filter Press

This measures the volume of liquid forced through the mud cake into the formation drilled in a 30-minute period under given pressure and temperature using a standard size cell. The Dead Weight Filter Press Assembly, as shown, consists of a water reservoir, piston and cylinder, dead weight, delivery pressure gauge, two check valves and a bleed-off valve-all mounted in a compact frame designed to stand upright and mounted directly on top of a workbench.

The low pressure filter press assemblies consist of the following items:

- Filter cell mounted in a frame
- Pressure assembly and regulator
- Filter paper, the filtering medium
- 25 ml graduated cylinder, the filtrate receiver

The filter press cell body, top cap, and base cap are constructed of 303 stainless steel. The filtering medium is filter paper that has been especially hardened for filtrate testing. Pressure sources deliver the required pressure, 100 ± 5 psi (690 ± 35 kPa) and can be any of the following:

- Compressed nitrogen or air in cylinders,
- Carbon dioxide gas cartridges,
- High pressure air or water systems,
- Dead-weight hydraulic pressure assembly

A.3.1 Procedure

1. The following dry parts were assembled in this order, base cup, rubber gasket, and screen, a sheet of filter paper, rubber gasket and cells.
2. The base was rotated clockwise and the cell secured.
3. The cell was filled with the sample to be tested within approximately $\frac{1}{4}$ inch of the top.
4. The filter press assembly was set in place within the frame and the top cap was checked to ensure the rubber gasket was in place.
5. Already connected to the pressure source was the top cap, placed onto the filter cell, and the cell was secured in place with the T-screw.
6. The graduated cylinder was placed directly below the filtrate tube on the support.
7. Pressure was applied to the cell by the weight raised to the top of its stroke and allowed to settle. In about two-thirds of the stroke, the delivery pressure gauge indicated 100 psi.
8. As the weight was released at 100psi, the timer was set.
9. At every 5 minute, the filtrate level of the cylinder with respect to time was measured.
10. After 30 minutes, the pressure source valve and back off the regulator were closed. The safety-bleeder valve was then opened to release the pressure on the entire system.
11. The volume of filtrate collected in the graduated cylinder was measured and recorded. The volume was recorded in millilitres as the API 30-minute filtrate loss of the drilling fluid.
12. The T-screw was loosened, removed the cell top, and then removed the cell from the frame.
13. The drilling fluid was discarded.
14. Disassembled the filter cell and carefully the filter cake on the filter paper was removed from the base cap.
15. The thickness of filter cake was measured and recorded to the nearest 1/32 in.

A.4 Sand Content Kit

The sand content kit is a simple, accurate and inexpensive sieve analysis apparatus for determining the sand content of drilling muds.

Sieve analysis is the preferred method for sand content determination because of the reliability of the test and simplicity of equipment. The volume of sand, including that of void spaces between grains, is usually measured and expressed as a percentage by volume of the drilling fluid.

The sand content kit consists of a special 200-mesh sieve 2½ inches in diameter, fastened inside a collar upon which a small funnel is fitted on either end. This is used with a 10ml glass measuring tube, graduated to read from 0 to 20% the percentage sand by volume. The collar and funnel are made of polyethylene and the screen is made of brass. A 500ml wash bottle and carrying case are included.

A.4.1 Procedure

1. The measuring tube was filled to the indicated mark with mud. The wash bottle was used to add water to the upper mark. Mouth of the tube was closed and shake vigorously.
2. The mixture was poured onto the clean sieve. Liquid passing through the sieve was discarded.
3. Added more water from the wash bottle to the tube, shake, and again poured onto the sieve. It was repeated until all the drilling fluid had been washed out of the tube.
4. The sieve was flushed with water from the wash bottle to free the sand remaining on the sieve of any remaining mud.
5. The funnel was fitted upside down over the top of the sieve. Slowly, the assembly was inverted and the tip of the funnel inserted into the mouth of the measuring tube glass.
6. The sand into the tube was washed by spraying a fine spray of water from the water bottle through the sieve (tapped the side of the sieve with a spatula handle to facilitate the process). The sand was allowed to settle.
7. The volume percent of the sand was read from the scale on the graduated tube and recorded.

A.5 Funnel Viscosity

The marsh funnel viscometer is a rugged, easy to operate instrument that is used for making rapid, on the spot measurement of drilling mud viscosity. Marsh funnel readings are only general measurements, but the frequent reporting of the marsh funnel viscosity will alert the mud engineer to sudden changes in the mud viscosity that could require corrective action. The marsh funnel viscosity is a ratio of the speed of the mud as it passes through the outlet tube (the shear rate) to the amount of force- the weight of the mud itself, which is causing the mud to flow (the shear stress). Marsh funnel viscosity is reported as the number of seconds required for one quart (946cc) of mud to flow out of a full marsh.

A.5.1 Procedure

1. The funnel was held in an upright position with the index finger over the outlet.
2. Formulated mud was poured through the screen on the top of the funnel until mud level just reached the underside of the screen.
3. Immediately the finger was removed from outlet tube and the number of seconds for a quart of the sample to run out was measured.

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