

INFLUENCE OF TEMPERATURE ON THE PROPERTIES OF WATER-BASED DRILLING FLUIDS USED IN THE PERFORATION OF OIL WELLS

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Abstract. *The aim of this work is to evaluate the influence of temperature on water-based drilling fluids for oil wells, on the rheological properties, filtration and lubricity. In this way, it was studied four fluid formulations containing the following additives: viscosifier, filtrate reducer, antifoam, pH controllers, expansive clay inhibitors, bactericide and lubricant. Fluids were prepared by adding additives to water with different concentrations under constant stirring. After 24 hours of rest, the fluids have been submitted to an aging for a period of 16 h at temperatures of 100 °F and 200 °F. Then it was conducted to measure the rheological behavior with a viscometer at 120 °F. After, it was also studied a fluid, called standard, whose additives and formulation are those used by the oil industry, as an element of comparison. In the situation of “offshore” perforation where deep and ultra deep wells, with complex geometries and with high temperatures and pressures are frequent, the challenge is the application of drilling fluids that meet these conditions. In the past, it was used diesel-based drilling fluids, which was abandoned due to serious environmental problems generated by their disposition. Today, synthetic fluids are commonly employed, they are less toxic, but present high cost as disadvantage. Optionally, water-based drilling fluids more elaborate, i.e., containing a variety of additives, with good performance and minor damage to the environment can be used. From the results achieved, it was concluded that the water-based fluids evaluated in this study are more thermal steady (until 200°F) than the standard fluids, because showed better lubricity coefficient values, as well as smaller losses of rheological properties after aging. Drilling fluids are the most important elements in the operation of oil well drilling, since they play several functions, such as: cool and lubricate the drill; clean bottom from the drilling debris; stabilize the subsurface pressures; allow a good sampling of the sectioned formations and reduce the friction between the drill rod and the walls of the borehole.*

Keywords: *drilling fluids, temperature, rheological properties.*

1. INTRODUCTION

The drilling fluids (Fig. 1) are essential elements during the perforation process and can be defined as circulation fluids used to help the drilling operation of oil well (Darley & Gray, 1988).



Figure 1. Drilling fluids known as “Drilling Mud”.
Source: SCHAFFEL, 2002.

The drilling fluids have important functions, such as, clean the well, that is, open the way to the drill cleaning the debris from the rock. The debris is transported to the surface in the annular space between the perforation column and the wall of the well (Veiga, 1998). The drilling fluids also help the cool and lubricate the drill, stabilize the subsurface pressures and reduce the friction between the perforation column and the well walls.

The way of the drilling fluids can be presented as illustrated in the Fig. 2. The fluids penetrate inside of the well together with the perforation column and is projected from the holes in the drill and returned to the surface with the debris generated in the perforation (Fig. 2).



Figure 2: The path of the drilling fluids.
 Source: SCHLUMBERGER, 2008.

The drilling fluids are traditionally classified according to the main constituent: gas based fluids, water based fluids and oil based fluids (Darley & Gray, 1988 and Lummus & Azar, 1986). Also there are synthetic fluids, which the continuous liquid phase is synthetic fluids.

According to Duarte (2004), the selection and the use of adequate perforation fluids have an important technical and economic role in the well perforation. Several additives, such as, lubricant, antifoam, viscosifier, filtrate reducer, expansive clay inhibitors, pH controller, sealant and bactericide, are used in the fluid compositions. Each additive has a specific function and the cost of the drilling fluids is directed related to the type and amount of the used additives. The drilling fluids are responsible by a significant percentage of the costs in the well perforation but an adequate perforation fluid can mean a great cost reduce and avoid some instability problems, usually found.

Today the perforation is capable to reach great complexity regions and is possible to make perforation in deep water, with water layer until 3000 m, where frequently are found high temperature and pressure. Also, the perforation onshore or offshore can be done in vertical or horizontal well. In these cases, it is frequent the use of fluids based on diesel oil. These fluids start to decrease their use due to the environmental problems caused by their discharge, and the synthetic fluids, which is less toxic has as disadvantage its high cost (Morton et al., 2005).

Due to these problems, arise the necessity to develop aqueous fluids with national additives that can be used in deep perforations and also environmental secure. Almost of the petrol companies use imported additives to improve the drilling fluids.

So, the aim of this work is to evaluate the aging of the aqueous drilling fluids to oil well, from the rheological properties, filtration and lubricity.

2. MATERIALS AND METHODS

Formulations

It was studied four formulations of water based fluids (Tab. 1). The studied additives where supplied by a national company.

Table 1. Studied Formulations.

ADDITIVES	F1	F2	F3	F4
Water (mL)	350	350	350	350
Antifoam (drop)	6	6	6	6
Viscosifier (g)	1.0	1.0	1.0	1.0
Filtrate Reducer (g)	3.0	3.0	3.0	3.0
pH Controller (g)	1.0	1.0	1.0	1.0
Inhibitor I (g)	21.0	21.0	21.0	21.0
Inhibitor II (g)	12.0	12.0	12.0	12.0
Inhibitor III (g)	-	-	-	-
Bactericide (g)	0.7	0.7	0.7	0.7
Lubrificant (%)	1.0	1.5	2.0	1.0
Sealant (g)	15.0	15.0	15.0	20.0

Also it was studied a fluid, called Standard, which additives and formulations are supplied by PETROBRAS, as comparative fluid.

Drilling Fluids Preparation

The drilling fluids were prepared according to the field practice, and consist to put the additives, one by one, under constant stir. It was used a mechanical stirrer with high rotation from Hamilton Beach, model 936. The fluids were prepared with industrial water with a volume of 350mL. The additives were added according to the order presented in the Tab. 1. After the additions, the velocity of the stirrer was increased to 17000 rpm during 10 min. After, the fluid staying in rest for a period of 24 h.

Rheological studies

The rheological studies were done before and after the aging of the fluids, according to the N-2605 norm from Petrobras (1998), using a viscometer Fann model 35A.

To rheological studies of the fluids after aging, it was use a thermal cup from Fann at 120°F (\approx 49°C).

Aging of the fluids

The fluids were submitted to the aging in a rotate oven Fann Roller Oven, model 704 ES at temperatures from 100°F (\approx 38°C) and 200°F (\approx 93°C) for 16h.

Filtrate volume

After rheological measurements it was estimated the API filtrate volume (FV_{API}) to the fluids that were not submitted to the aging and the HPHT filtrate volume (FV_{HPHT}) to the fluids submitted to the aging.

The filtrate volume was measured by using a Fann press filter, with a pressure value of 7.0 kgf/cm² (100 psi) during 30 min. The results were expressed in mL.

The HPHT filtrate volume was measured by using a HPHT Fann filter press following the procedures:

Close to 1h before to start the measures a thermal jacket was switch on to reach the temperature of 200°F. The cell was filled with 200mL of the fluid and sealed. The exit valve was closed and the cell was introduced in the thermal jacket with a metallic thermometer in the superior part of the cell. In the exit valve it was put a measuring cylinder to collect the filtrate.

It was set up the pressure at 100 psi until the temperature reach 200°F. After this, the pressure was increased to 500 psi and the filtrate volume was measured in mL, after 30 min. and multiplies by a factor of 2.

Lubricity coefficient

To measure the lubricity coefficient it was used a lubricity tester manufacturer Ofite. It was used the methodology suggested by manufacturer, consist of to stir the fluid for 5 min at high rotation and soon after to transfer to a lubricity tester recipient and was kept for 5 min at 60 rpm and torque 0. Following, it was applied a torque of 150 in.lb and measure after 5 min. The lubricity coefficient (LC) is calculated with the Eq. (1) and the Eq. (2).

$$CF = 34 / \text{Reading}_{\text{water}} \quad (1)$$

$$LC = (\text{Reading}_{\text{fluid}} \times CF) / 100 \quad (2)$$

being:

CF = correction factor;

Reading_{water} = reading for deionized water;

Reading_{fluid} = reading for the fluid;

LC = lubricity coefficient.

3. RESULTS AND DISCUSSION

The results from rheological properties (apparent viscosity (AV) and plastic viscosity (PV)), filtration (API and HPHT filtrate volumes (FV_{API} and FV_{HPHT}) and lubricity (lubricity coefficient (LC)) of the fluids before and after aging at temperature of 100°F (≈ 38 °C) and 200°F (≈ 93 °C) are presented in the Tab. 2.

Table 2. Rheological, Filtration and Lubricity Properties of the Fluids F1, F2, F3, F4 and Standard Fluids Before and After Aging.

FLUID F1					
Temperature	AV (cP)	PV (cP)	FV _{API} (mL)	VF _{HPHT} (mL)	LC
T _{amb}	46.2	23.6	7.8	-	0.103
100 °F (≈ 38 °C)	34.8	24.0	8.8	16.2	0.119
200 °F (≈ 93 °C)	43.5	24.0	7.8	17.0	0.122
FLUID F2					
Temperature	AV (cP)	PV (cP)	FV _{API} (mL)	VF _{HPHT} (mL)	LC
T _{amb}	46.1	23.8	7.7	-	0.128
100 °F (≈ 38 °C)	33.7	22.3	7.4	12.6	0.099
200 °F (≈ 93 °C)	43.5	24.0	8.0	13.0	0.074
FLUID F3					
Temperature	AV (cP)	PV (cP)	FV _{API} (mL)	VF _{HPHT} (mL)	LC
T _{amb}	51.2	28.0	7.2	-	0.106
100 °F (≈ 38 °C)	35.3	22.5	7.6	12.8	0.098
200 °F (≈ 93 °C)	46.0	24.0	7.9	14.4	0.076
FLUID F4					
Temperature	AV (cP)	PV (cP)	FV _{API} (mL)	VF _{HPHT} (mL)	LC
T _{amb}	47.0	24.8	7.0	-	0.111
100 °F (≈ 38 °C)	38.0	24.0	7.7	12.4	0.115
200 °F (≈ 93 °C)	45.0	25.0	8.2	15.0	0.082
STANDARD FLUID					
Temperature	AV (cP)	PV (cP)	FV _{API} (mL)	VF _{HPHT} (mL)	LC
T _{amb}	44.5-60.0	23.5-35.0	6.0-7.2	-	0.090-0.120
100 °F (≈ 38 °C)	30.0-38.5	21.0-25.0	6.4-7.3	11.4-12.4	0.146-0.192
200 °F (≈ 93 °C)	30.0-38.0	16.0-24.0	6.8-8.0	14.0-16.0	0.110-0.120

being: T_{amb} – Room temperature (without aging); AV – apparent viscosity; PV - plastic viscosity; FV_{API} – API filtrate volume; FV_{HPHT} – HPHT filtrate volume and LC – lubricity coefficient.

From the results it was observed a reduction in the rheological properties (AV and PV) of the fluids after aging at 100 °F; this behavior can be due to the great mobility of the water molecules in the solvation layer on polymers (viscosifier and filtrate reducer), once the heating can promote a reorganization of the molecules structures of the polymers in a way to minimize the salvation energy, probably destroying hydrogen bonds and creating as small salvation layer of free water molecules, decrease the polymer-polymer interactions and consequently decrease the viscosity.

The filtrate reducer (caboxymethylcellulose or CMC) has great solubility potential and consequently, wettability that confer a good hydration, and can be explained by the presence of sodium in their molecule that in contact with water ionize and induce the solvation of the molecules (Melo, 2008). The presence of lateral chains and the ionic charater of xantan gum (viscosifier) also increase the hydration. It known that the polymeric hydration process is due to the complete dispersion of polymer in the aqueous system, this occur when the polymeric chains are solvated by water molecule due to the breakout of the hydrogen bonds, reducing the viscosity. This behavior was observed after aging in the temperature of 100 °F (≈ 38 °C).

With the increase of the aging temperature to 200 °F (≈ 93 °C), it was observed an increase in the AV values and to others properties it was not observed significant changing. This behavior is due to the aging that probably cause a recover of the previous value of viscosity. This can be justified by the formation of cross-linking between the polymers (viscosifier and filtrate reducer that are consisted by xantan gum and low viscosity carboxymethylcellulose, respectively), due to mainly by xantan gum that has a branched chain and can make possible the formation of cross-linking, which do not occur at low temperatures. Also, at high temperatures the polymers can present greater mobility and make their structure more open and free, producing great hydration and consequently great viscosity.

API and HPHT filtrate volumes (FV_{API} e FV_{HPHT}) do not present significant changing with the aging in the studied temperature.

A study of the additives characterization used in this work was done by Farias (2009) and concluded that all additives are resistant to temperature close to 357 °F (≈ 180 °C). In this work the maximum aging temperature was 200 °F (≈ 66 °C).

By analyzing the results obtained for standard fluids, it was observed a significant reduction in the AV values with the aging at 100 °F (≈ 38 °C), and after aging at 200 °F (≈ 93 °C) it was observed a small reduction. By comparison the results obtained to standard fluids without aging (at room temperature) and after aging at 200 °F (≈ 93 °C), it was observed that the reduction of the AV values was more stressed than to those found to developed fluids. This behavior is good and indicates that the developed fluids present better thermal stability, once a reduction of the apparent viscosity can characterize degradation, with loss of rheological properties. So, the standard fluids present great losses of rheological properties with the aging at studied temperatures, consequently, the developed fluids are more stable at studied aging temperatures.

It was also observed that the developed fluids present better values of lubricity coefficient with aging when compared with the standard fluids.

4. CONCLUSIONS

From the results presented in this work it can be conclude that the water based drilling fluids studied have bigger thermally stable (until 200 °F (≈ 93 °C)) than the standard fluids, because they presented better values of lubricity coefficient and small loss of rheological properties after aging.

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