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EXPERIMENTAL INVESTIGATION OF NEW ADDITIVE TO OPTIMIZE THE PROPERTIES OF SYNTHETIC-BASED DRILLING FLUID

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ABSTRACT

This research focus on the formulation, development and testing a new additive in synthetic based drilling fluid include of amine-treated Quebracho agent . Traditionally invert emulsion drilling fluids have been formulated to achieve optimum performance of drilling operation because of the high level of wellbore stability and penetration rates by these drilling fluids. Amine-treated Quebracho agent is compatible with other chemical additives in Synthetic-Based Fluids. The laboratory research was run to evaluate the temperature effect on rheological and filtration properties of synthetic-based fluids under heated aging for 16hours at different temperatures up to 400 °F. Experimental results demonstrate that new synthetic sample including amine-treated Quebracho agent improves the thermal stability of polymers. This new agent have high biodegradability and a lower toxicity (environmentally friendly) so it was used as a synthetic based mud additive for oil well drilling fluids .The evaluation includes study of the rheological properties, filtration and thermal properties of the synthetic based–muds formulated with the new amine-treated Quebracho agent in comparison with the reference commercial synthetic based mud. The results showed that the rheological and filtration properties of synthetic fluid are enhanced. Thus, amine-treated Quebracho improved the thermal stability of polymers in synthetic based drilling fluids.

INTRODUCTION

Oil drilling has encountered increasingly challenging scenarios due to the difficulty of finding large oil reserves; moreover, the operational window associated with these scenarios has become increasingly narrow. Thus, to provide continuity of oil in Iran, it is necessary to critically analyze the processes involvedand search for ways to optimize them (Pereira *et al.*, 2012). During the drilling process, a fluid is used to remove the cuttings generated by the bit from the well. With the evolution of the drilling process, several types of drilling fluids emerged. The classification of a drilling fluid is most commonly made on the basis of its composition (Darley and Gray, 1988). Oil-based muds have many advantages over water-based muds. The most important advantages are listed by Boyd *et al.* (1987) as (1) superior thermal stability critical for drilling deep wells (2) lubricating properties which are helpful in offshore drilling of deviated wells (3) minimized drilling problems related to water-sensitive shales. Also, Bennett (1984) mentioned that mineral-oil based invert-emulsion fluids have greater tolerance to the contaminants such as carbonates, hydrogen sulfide, anhydrite, salt, or cement as compared to their water-based counterparts. Mineral-oil based muds also reduce differential pressure sticking problems due to their lubricating characteristics and formation of a thin and firm filter cake. These fluids are classified into water-based fluids (WBFs) and non-aqueous fluids (NAFs). NAFs are classified as synthetic or oil-based fluids. Synthetic drilling fluids are chemical formulations, while oil-based fluids are petroleum derivatives (Pereira *et al.*, 2013). More costly oil-based muds were used which were usually more stable than the water-based mud (when drilling a deep well at high temperatures) (Hall, 1999). Oil-based mud was more advantageous to use when drilling into subterranean formations which contain water swellable clays in as much as being damaged by water contact. Because of their comparatively lower cost and good availability, crude oil petroleum and diesel oil had been used in the formation of oil-

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based mud (Svon Tapavicza and Hall, 2002). All such petroleum-based oils used for drilling mud contain relatively large amounts of aromatics and at least a substantial concentration of n-olefins both of which may be harmful or toxic to animal and plant life. Synthetic-based fluids have reduced well completion times compared with WBMs. Similar to oil based mud, the Synthetic-based fluids have achieved significant cost savings over WBMs in problem wells because they improve performance (feet drilled per hour) and reduce downtime for common problems such as stuck drill pipe. It could also, improve the drilling efficiency without polluting the subsurface structures. When the cuttings are discharged, use of Synthetic-based fluids eliminates the use of expensive onshore disposal facilities. Similar to water based-mud, the Synthetic-based fluids exhibit low toxicity, but unlike water based mud, Synthetic-based fluids are recycled.

Thus, they are environmentally friendly, have high biodegradability and have lower toxicity. Various types of SBM systems can be classified according to use in petroleum industry such as Esters, Olefin, Ethers, Polyalphaolefins. Ester-based groups are selected to minimize fluid viscosity, maximize hydrolytic stability, and minimize toxicity. The rheological properties, the thermal stability and the filtration of the synthetic based mud were the most frequently used methods for selecting the best synthetic esterbased mud (Samira, 2009; Environmental protection Agency Part III, 1999). Generally, water-based drilling and invert emulsion drilling fluids are two mainly of drilling fluids using in petroluem drilling operations. The most commonly used additive to viscosify an oil based drilling fluid is organophilic clay. The use of organophilic clay in the drilling fluid, however, has some disadvantages. The utility of organophilic clay to viscosify the low aromatic, high paraffin oil muds which are considered safer to marine life than the traditional diesel oil-based fluids is limited. In the absence of heat and/or high shear mixing, excess organophilic clay is needed to provide viscosity to the mud prior to its equilibration in the drilling system. Also, the quaternary ammonium salts from which the clays are prepared are generally thought to be toxic to aquatic organisms (Ious Mud Formulations, 1998). Oil based mud systems have long been the fluids of choice for many operators. These systems have been consistently proven as technically superior to conventional water based muds in the areas of borehole stability, ionic inhibition, rate of penetration, cuttings condition and sticking avoidance. Principally, the beneficial technical attributes are derived from the continuous organic phase and with the benefits being inherent in the base fluid, these muds are often considered easier to maintain and more tolerant to contaminants such as drill solids. Properties of the wellbore oil based drilling fluid were selected to stable the wellbore, suspend solids, Hole cleaning, and minimize fluid loss. Similarly, the invert emulsion based fluid properties were chosen because it would suspend solid, hole cleaning, be a stable emulsion, and be of higher density than the wellbore fluid in over balanced drilling operation. Viscosity provided by the emulsified water phase has a serious limitation of thermal thinning at high temperatures. Hence, at these temperatures, the main source of viscosity should be other viscosifiers such as organophilic clays (Portnoy *et al.* 1986). Clays typically swell in water. For use with oil-based fluids, swelling clays are modified chemically so that they swell in oil instead of water to provide viscosity. These clays are called organophilic clays or organoclays and are typically treated with a quaternary amine. These clays, along with emulsion droplets, form a solid-like structure at rest and at very low shear rates (Herzhaft *et al.*, 2003; Portnoy *et al.,* 1986; American Petroleum Institute, 1998). In this study presents an experimental investigation on a novel additive in synthetic based drilling fluids. The effectiveness of this new additive on improving the thermal stability of new sample synthetic fluid filtration and rheological properties is evaluated. The comparison of these properties of synthetic base fluid contacting Amine-treated Quebracho after aging heated exhibit thermal stability of polymers especially when compared to synthetic based drilling fluid in same situations.

Material and experimental techniques

Test Methods

In order to evaluate and performance of new aditives, analysis are required on synthetic based mud samples. The experimental tests were performed on fluids in an attempt to establish a suitable formulation that would meet the properties specifications as outlined in API RP & RB 13B-2. Rheological properties were evaluated using Fann-35 viscometer at 400°F. during this test, the drilling fluid sample in the cells were mixed (Longeron *et al.,* 1998).

Drilling Fluid Materials

Invert emulsion drilling fluids have been widely used since 1980's due to their higher performance and wellbore stability during drilling operation. As drilling fluid is used for the drilling of multiple wells, it achieves low treatment and optimum properties, which strongly affects the drilling efficiency by viscosity maintenance, enhancing filtration properties. To investigate the temperature stability, two fluid formulations with mud weight of 7.6 lb/gal and O/W ratio of 80:20 was prepared. The drilling fluid formulations for 7.6ppg mud weight used in the experiments is given in Table 1. The muds are utilized according to the procedures recommended by API and other related mud service companies.One of the major problems of drilling fluids is their instability to thermal aging. In drilling operations, drilling fluids encounter geological formations with different temperature. So, theses fluid formulations were heat ageing under different temperatures from 300 to 400 ^{o}F, for 16 hours. After each experiment of heat aging, the rheological and filtration properties were measured at 120^{o}F. The HTHP fluid loss was run with high pressure cells at tempretures up to 300^{o}F with 500-psi differential pressure. The results for the 15 lb/gal mud are given in Figures 3 and 4. To overcome some of the challenges, such as environmental concerns, performance restrictions, economic disadvantages and drilling problems issues, a new amine-treated quebracho (ATQ) is used. This ATQ is completely soluble to dispersible in most based fluids. This agent is stable to temperatures excess of 400^{o}F and performs well in a variety of drilling fluid formulations. The product is utilized from readily available naturally occurring quebracho and naturally occurring fatty acid derived fatty amine.

ATQ is relatively non-toxic to marine environment and HSE friendly. The performance of ATQ with respect to its stability of rheological properties and fluid-loss control is better than the usual additives. All chemical additives were added slowly using stirring and mixed well in the mixer For two mud formulations (Electronic mail correspondence with Fred Growcock, 2004; Patel and Salandanan, 1985). The descriptions of compositions in table 1 are as below:

Water often in the form of concentrated calcium chloride brine is emulsified in the SBF base material to increase viscosity. The brine promotes dehydration of shales in the formation being drilled. It is dispersed in the oil phase to form an inverted emulsion (a water-in-SBF emulsion). The solids in the SBF, including formation solids (cuttings), are SBF-wet. Emulsifiers which often are metal soaps of fatty acids are added to the SBF to aid in forming and maintaining the inverted emulsion. They are modified to be compatible with the physical/chemical properties of the organic base phase of the mud. Wetting agents are added to ensure the solids in the mud are SBF-wet. Wetting agents include polyamines, fatty acids, and oxidized tall oils. Lime is added to make calcium soaps that aid in emulsification of water in the SBF. Organophilic clays are added to aid in suspending drill cuttings in the mud. Barite, barium sulfate ($BaSO_4$), was the weighting material used to bring the density up to 17.0 ppg as needed for the wellbore fluid. Polymeric Agent was included to raise viscosity properties to improve cuttings and barite suspension properties. Amine-treated Quebracho is used to increase the thermal stability of polymers up to 400°F for improving rheology and filtration properties. Commercial Fluid loss control agent is designed to provide a suitable HTHP fluid-loss control at usual concentrations with a very low filtrate (Patel and Salandanan, 1985; Lahalih, 1989).

Rheological properties

Rheological properties measurement test was directly done at room temperature with Fann- 35 viscometer for each sample and model Fann 12BL of Multi filter press is run to achieve filtration properties consist of filter cake thickness and the volume of filtrate. Rheological parameters such as Pv, and Yp were calculated from the Bingham plastic model by using the following equations when extrapolated to a shear rate of zero the YP is obtained from the Bingham-Plastic rheological model. Plastic viscosity (PV) and yield point (YP) are two of the most recognized properties of drilling fluids. Although few drilling fluids match with this model, but the experience importance of PV and YP is tightly in drilling technology.

These rheological properties can be estimated reasonably by following equations:

PV = (600 rpm reading) – (300 rpm reading) …………….. (1)
YP = (300 rpm reading) – PV ………………………. (2)

Filtration test was run at static and dynamic conditions. static situation is ambient temperature and 100 psi pressure is applied with multi filter press (Model 12BL Fann) and filterate lost of thses fluid samples were presented as filtrate volume obtained in half of one hour. Static filtration tests are used to indicate filter cake quality and filtrate volume loss for drilling fluid samples under certain experiment conditions. The types and quantities of solids and their physical and chemical interactions are effective in filtration properties. Filtration properties under dynamic situations include down hole pressure and tempreture measuring by the Dynamic high pressure high temperature (HPHT) filter press as shown in Figure 5. A motor driven shaft fitted with propellers turns at varying speeds inside a standard 500 ml HPHT cell. RPM settings from 1 to 1,600 rpm impart laminar or turbulent flow to the fluid inside the cell, and by varying the shaft length, the shear stress may be increased or decreased. The power is driven to the stirring shaft by a timing belt that is easily accessible for quick adjustment and removal. Other features include a variable speed motor controlled through an SCR controller with RPM's indicated on a digital tachometer. The test procedure is exactly the same as that in the conventional static HPHT filtration test. The only difference is the fluid is circulating inside the cell, while filtrate is being collected.

RESULTS AND DISCUSSION

The evaluation of new and base synthetic fluid was performed before and after 16 hours thermal aging at 400^o F, which summarized in Table 2. As shown in table-2, the rheological and filtration properties decreases by increasing temperature, but the decrease in the properties of base fluid is more than the decrease in the properties of new fluid. In Figure-6, filter cake under static condition is shown as thin and low permeable.

Table 1. Formulation Drilling Fluids

Component	Concentration	
	Base sample	New sample
Polymeric Agent	0.483 bpb	0.483 bpb
Water	0.126 bpb	0.126 bpb
Lime	3.6 ppb	3.6 ppb
$CaCl_2$	14.74 ppb	14.74 ppb
Organophilic Clay	4.0 ppb	4.0 ppb
Emulsifier	5 ppb	3 ppb
barite	As needed	As needed
Commercial Fluid loss control agent	1.5	1.5
Amine-treated Quebracho	-	5
Wetting agents	2	2

Table 2. Rheological test results of two synthetic based fluids

Parameters	Base fluid		New fluid	
	BHR	AHR	BHR	AHR
600 rpm	46	29	48	35
300 rpm	30	19	31	23
200 rpm	18	9	26	12
100 rpm	11	5	17	7
6 rpm	2	3	3	4
3 rpm	2	2	3	3
10 sec, lb/100sqft	2	4	3	2
10 min, lb/100sqft	3	7	5	6
PV ,cp	16	10	17	12
YP, lb/100sqft	14	9	14	11

BHR= Before Hot Rolling, AHR= After Hot Rolling

Effect of new additiveon rheological properties

At first, viscosity test was conducted by using viscometer, to obtain viscosity characteristic among two samples called base sample and sample with new additive. to present the effectiveness of new additive in synthetic based drillng fluid, were prepared standard mixing procedure for these synthetic drilling fluids is similar with standard oil based mud. Rheological properties were evaluated before and after aging at 120°F. After aging, the drilling fluids in the aging cells were mixed for 15 minutes before taking the rheological measurements again. This is because during static aging for 16 hours, oil breaks out at the surface and also there is a significant density variation between the top and bottom layers of mud in the aging cell due to sag. So for making the drilling fluid of uniform density, mixing is required. The HTHP filtration tests were conducted using high-pressure cells at 250oF with 500-psi differential pressure. As figure 1 observed that the rheological properties and figure 2 shows the HTHP fluid loss properties of the two fluid samples. The result of rheological parameters and HPHT filtrate test of two samples including new sample and base sample is shown in Figure 2 and 2. According to result, rheological parameters of new synthetic based fluid are higher than base synthetic fluid.

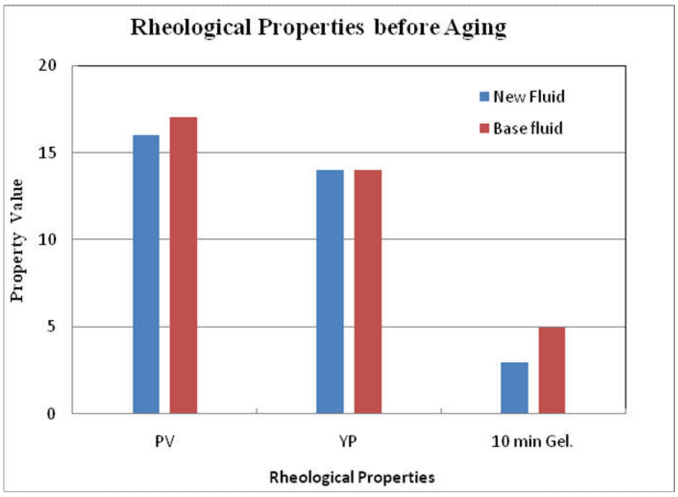

Figure 1. Rheological properties of different type of Synthetic Fluid

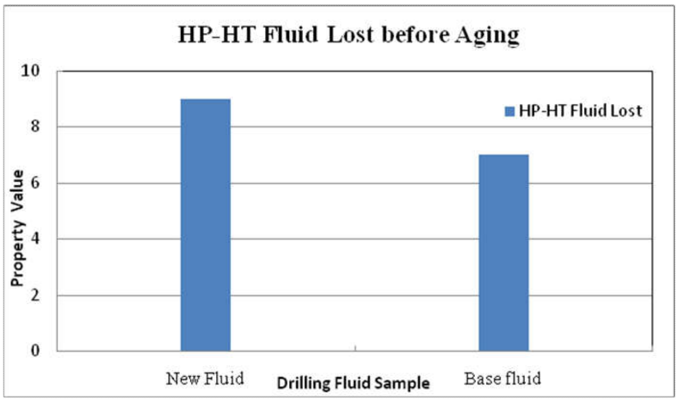

Figure 2. HTHP fluid loss test of different type of Synthetic Fluid

Effect of new additive on Temperature Stability:

Thermal stability of a drilling fluid is considered to be an important aspect of drilling fluid. Most formulations are in the range of 250 to 300^{o}F. In Figure 3, the rheological parameter including plastic viscosity and yield point of new synthetic based drilling fluid samples are shown at range of temperatures from 300 to 400 ^{o}F. As seen, the drop in these parameters of new fluid after hot rolling under different temperatures and 16 hours aging is less than 50% original values. According to Figure 4, the high pressure and high temperature filtrate is controlled to 350^{o}F in the presence of Amine-treated Quebracho aditive. Meanwhile, Thermal stability of the base fluid HP-HT filtrate property just is suitable at temperatures under 250°F.

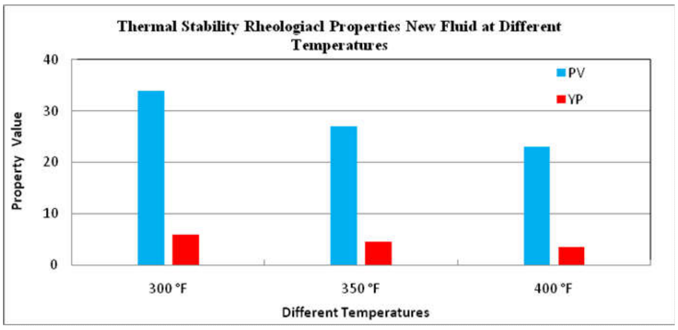

Figure 3. Rheological properties of new fluid aged at temperatures from 300 to 400 ^{o}F

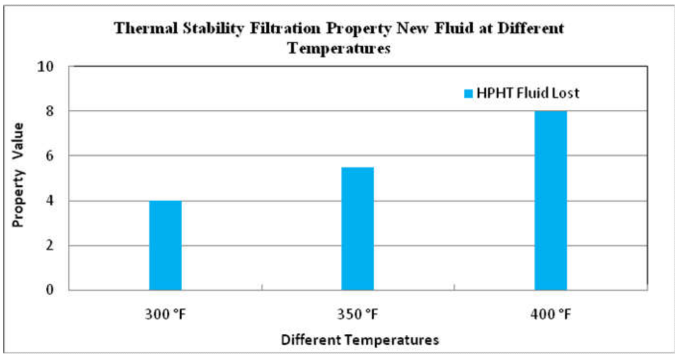

Figure 4. HT-HP fluid loss test at different temperatures with a 500-psi differential

Conclusions

The principal results of this study were to study the effectiveness of Amine-treated Quebracho (ATQ) on the stability polymers under high temperature up to 400^{O}F. The following conclusions were reached after an analysis of the results of this research.

- Temperature played a significant role in drop of synthetic base drilling fluid. Increasing the
- temperature of the synthetic base drilling fluid containing Amine-treated Quebracho shows that
- properties a slight decrease under high temperature in Hot rolling compared to synthetic base drilling fluid formulated without this Agent.
- In experiments, synthetic base drilling fluid with Amine-treated Quebracho showed to be more effective than base synthetic fluid. This Invert emulsion with new agent content demonstrated higher gel strength and plastic viscosity in comparison with other type of synthetic base fluid.
- We have found that during filtration tests in static and dynamic conditions, filtrate volume, mud cake thickness and filter cake weight formed with a new additive are suitable.

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