IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 10, Issue 4 Ver. I (Jul. – Aug. 2018), 88-92
www.iosrjournals.org

Effect of Fly Ash on the Emulsion based Drilling Fluid and their Thermal Stability

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Abstract
The present work consists of the development of the novel eco-friendly emulsion mud using vegetable palm oil, surfactant and polymers. Palm oil (and its products) has good resistance to the heat and oxidation at prolonged elevated temperatures. The advantage of using palm oil in this study is the presence of naturally occurring emulsifiers such as phospholipids in trace amount, which may aid in the self emulsification of the palm oil. The polymers are added in the emulsion to improve the rheological and filtration properties and surfactant is used as stabilizer in order to prepare stable oil-in water emulsion. The poor filtration properties encountered in this emulsion system are controlled by fly ash. Being the industrial waste product it is cheaper, easily available and lacks any environmental issues.
Keywords: *palm oil, shale, emulsion, interfacial surface tension, zeta potential.*

I. Introduction

With increase in the demand for energy, the drilling activities are being increased by different oil and gas industries worldwide and it becomes essential to drill the highly sensitive formations such as shale gas formations, shaly sandstones, fractures reservoirs, etc. The highly advanced technologies such as multilateral drilling, horizontal drilling, open hole and slim hole drilling are being used to drill such complex formations. These formations possess many challenges raised due to swelling/dispersion of cuttings and formation. The main problems that we encounter during drilling of these complex formations are bit balling, high torque and drag, pipe sticking, additional reaming and formation damage [1].

The wellbore instability is the major concern with the application of conventional water based drilling fluid systems for the drilling of sensitive formations. This is due to the interaction of these fluids with the formation [2]. The wells drilled with aqueous drilling fluids suffer decrease in the permeability of the pay zones because of water blocking of the pore spaces with these fluids and swelling of anhydrous clays within the pore spaces. With the help of emulsions, drilling problems of sensitive formations can be controlled efficiently and effectively [3].

The emulsion system is a three component fluid system containing oleaginous fluid (such as paraffin's, olefins, diesel, and mineral oil), nonoleaginous fluid (brine) and a stabilizing agent (surfactant). It is formed effectively by mixing two incompatible liquids in presence of an emulsifier which in result lowers the interfacial surface tension of one liquid to enable that liquid to form a stable dispersion of fine droplets in other liquid. The stability of the emulsion depends on zeta potential of the emulsion droplets. Theoretically, a high negative zeta potential prevents aggregation of the emulsion droplets and increases stability through electrostatic repulsion. In case of polysaccharides, the stabilization arises from the mutual repulsion between the electrical double layer of particles and from the adsorption of macromolecules at the oil drops [4]. Also, the stability of the emulsion does not depend on the chemical stability of the emulsifier used but also upon the interaction of the emulsifier with the different additives loaded to the emulsion such as weighing agents, fluid loss additives, rheology modifiers and drilled cuttings [5].

II. Experimental Work

Experimental Procedure

Initially, potassium chloride salt was added to the water and mixed properly using Hamilton beach mixer. Further, water soluble polymers were added sequentially. After complete mixing of the polymers in the stirrer at high speed, palm oil and surfactant were added to the homogeneous solutions and allowed to mix unless stable emulsion was obtained. The zeta potentials of the oil droplets in the emulsions were determined by using a Zetameter 4.0, Zeta-Meter, USA as a function of xanthan gum concentration at 21 ^{o}C. It is essential for the study of the stability of the emulsion. The rheological and filtration properties of the samples were analysed using Fann V-G meter 35SA model was used to determine rheological properties such as apparent viscosity, plastic viscosity, yield point and also the initial and 10 min gel strength of the prepared emulsion. API (American Petroleum Institute) Filter press apparatus was used to measure the filtration properties of the emulsion. The same emulsion was again prepared and fly ash was loaded to it, which acted as a bridging agent in the developed formulations. The effect of fly ash particles on the rheological and filtration properties of emulsion mud was again analysed. Finally, the temperature stability of emulsion mud was studied by aging emulsion mud in a hot roller oven at 90 °C for 16 h and measuring its rheological and filtration properties after aging.

The following formulas were used to obtain the rheological parameters as per API recommended practice of standard procedure for field testing of drilling fluids [9]:
Apparent viscosity (μ_a) = $Ø_{600}/2$ (cP)
Plastic viscosity (μ_p) = $Ø_{600} – Ø_{300}$ (cP)
Yield point (y_p) = ($Ø_{300} – \mu_p$) (lb/100 ft^2)

III. Results And Discussions

In the present study, xanthan gum was used to control of rheological properties of the emulsion muds for a number of important reasons including emulsion stabilization, temperature stability up to 120 °C and its pseudo plastic rheological properties [10, 11]. Further, the optimum concentration of xanthan was optimized by measuring zeta potential of the mud system as Zeta potential measurements ensures the stability of the developed emulsions. That optimized oil in water emulsion was selected as drilling fluid and rheological properties and filtration properties of that mud system was chosen as emulsion mud for oil and gas well drilling.

Emulsion Stability

The higher negative zeta potential determination for various combinations (−66 to −42 mV) illustrated that combinations have more electronegativity and stability [12]. Zeta potential of the emulsion droplets as the function of xanthan gum concentration has been measured (Figure 1).

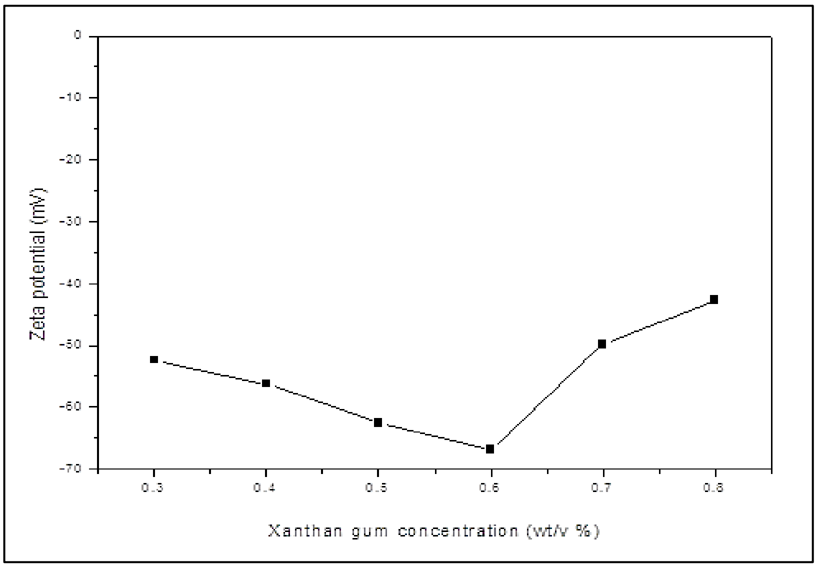

Fig.1. *Variation of Zeta Potential as a Function of the Concentration of Xanthan Gum.*

It has been observed that with the increase in xanthan gum concentration the zeta potential value (absolute value) has increased initially, but when the concentration of the biopolymer is increased beyond 0.6 (wt/v%) the trend of graph has changed. The probable reason for the decrease in zeta potential (absolute value) is the flocculation of the smaller droplets. Xanthan gum is a high molecular weight, long chain polymer and it is capable of wrapping or bridging various droplets to form a larger droplet structure or flocs [13]. This problem can further be mitigated by increasing the amount of surfactant so that it may remove adsorbed polymer from the surfaces resulting in partitioning of the particles from polymer rich to polymer deficit phase [14].

Rheological Properties of the Prepared Emulsions

The composition of developed emulsion mud is shown in Table 1.

Table 1: *Composition of Developed Emulsion Based Drilling Fluid.*

Constituents	Composition	Unit
Water	90	% (vol/vol)
Oil	10	%(vol/vol)
Potassium chloride	5	%(wt/vol)
Sodium lauryl sulphate	0.3	%(wt/vol)
Xanthan gum	0.6	%(wt/vol)
Polyanionic cellulose	0.5	%(wt/vol)
Carboxy methyl cellulose	0.5	%(wt/vol)

The appearance of a yield stress for xanthan gum solutions may originate from the fact that a large number of hydrogen bonds in the helix structure result in a stable configuration that can exhibit a resistance to flow. Only when a sufficient magnitude of shear stress (larger than a yield stress) is applied, this structure becomes broken down. Subsequently, orientation of the polymer chains takes place, resulting in shear-thinning flow behaviour at higher shear rates.

The shear thinning property of the system can be observed with the high yield point and plastic viscosity ratio of the developed formulations as shown in the Table 2.

Table 2: *Rheological and Filtration Properties of the Developed Emulsion based Drilling Fluid.*

Properties	Units	Values
Apparent viscosity	Centipoises	32.5
Plastic viscosity	Centipoises	20
Yield point	lb/100 ft^2	25
Initial gel strength	lb/100 ft^2	12
10 minutes gel strength	lb/100 ft^2	21
API, fluid loss	cc/30 min	46
Cake thickness	1/32 of an inch	1.20

As drilling fluid system exhibits different properties prevailing to variable shear rate conditions inside the borehole [15, 16].Thus, the shear thinning property must be present in the emulsion mud.The plastic viscosity of the developed system with varying concentrations is maintained and kept low as it affects the rate of penetration (ROP).The apparent viscosity of the developed system is optimum as this property is essential for borehole cleaning by circulating the cuttings up to the derrick floor prevailing to different shear rate conditions. Drilling mud must have good suspending ability in order to provide better suspension of drilled cuttings inside the borehole when drilling is paused for some surface operations.

This property can be analysed by measuring gel strength of the emulsions. The gel strength of the emulsion is quite suitable for the drilling.

Filtration Properties of the Emulsions

The sensitive formations have high magnitude of interaction with the drilling fluid present inside the wellbore.The filtrate invasion having different types of ions may accelerate the diffusion process which in result disturbs the stress regime of any particular formation. The formation damage becomes a severe issue when it affects the productivity of the pay zones. Poor filtration properties are the concerned issue in case of the emulsions as shown in Table 2.

This severe problem can be solved by selecting proper fluid loss additives and an inert bridging agent [17].The poor filtration properties have been observed in the absence of a bridging agent as shown in the Table 2. The reason for this is the inability of the system to form filter cake quickly. To mitigate this problem, fly ash, an inert bridging agent is used to control the filtration properties of the developed emulsions. Fly ash which acts as a bridging agent in the developed system has negligible impact on the rheological properties [16].

Effect of Fly Ash on the Emulsions and their Thermal Stability

With the increase in the concentration of the fly ash the filtration properties are controlled significantly. The cake thickness and filtration volume of the different emulsions are decreased further with the addition of 2% fly ash, which is quite evident from the results shown in Table 3.

Table 3: *Effect of Fly Ash (2%) on the Rheological and Filtration Properties of Emulsion Based Drilling Fluid.*

Properties	Units	Values
Apparent viscosity	Centipoises	32.5
Plastic viscosity	Centipoises	20
Yield point	lb/100 ft^2	25
Initial gel strength	lb/100 ft^2	12
10 minutes gel strength	lb/100 ft^2	21
API, fluid loss	cc/30 min.	5.5
Cake thickness	1/32 of an inch	0.44

The cake formation in the presence of fly ash is very quick when a hydrostatic head is applied inside the wellbore hence; filtration properties are controlled further with the addition of fly ash to the emulsions.

Table 4: *Rheological and Filtration Properties of the Emulsions with 2% Fly Ash after Aging for 16 h at 90 °C.*

Properties	Units	Values
Apparent viscosity	Centipoises	37
Plastic viscosity	Centipoises	20
Yield point	lb/100 ft^2	34
Initial gel strength	lb/100 ft^2	14
10 minutes gel strength	lb/100 ft^2	23
API, fluid loss	cc/30 min.	5.5
Cake thickness	1/32 of an inch	0.38

Many mud constituents degrade slowly with the increase in temperature. Hence, the thermal stability of the emulsions is checked in the roller oven at different temperatures [11]. The rheological and filtration properties of the system with 2% fly ash after aging for 16 h at 90 °C are reported in Table 4. It is found that these properties are not affected significantly up to 90 °C, which shows its potential for the drilling of sensitive formations at 90 °C.

IV. Conclusions

The following conclusions can be drawn from the present study:

1. The zeta potential measurements had validated good stability of the developed oil-in water emulsions.
2. The high yield stress plastic viscosity ration had shown shear thinning behaviour of the emulsions which is an essential property of the drilling fluid.
3. The rheological parameters of the emulsions were in the optimum range and may be suitable for optimum drilling fluid performance.
4. The filtration properties of the emulsions were controlled with fly ash which had acted as an inert bridging agent in the various emulsion muds.
5. The palm oil-in water emulsion may overcome the nontoxic effects associated with the conventional oil based drilling fluids used for drilling oil/gas wells.

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