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FILTRATION AND RHEOLOGICAL PROPERTIES OF NATURAL RUBBER LATEX ADDED DRILLING FLUID

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Abstract

Drilling fluids play a very important role in rotary drilling activities. It is necessary to control their properties to optimize and to enhance efficiency of drilling operation. The objective of this study is to measure filtration and rheological properties of water-based mud using natural rubber latex (NRL) additive which is derived from the *Hevea brasiliensis* tree. This ecologically-friendly biopolymer water-based mud was tested by API RP 13B standard procedure for testing water-based drilling fluids. The effects of NRL concentration and temperature on filtration properties were investigated. The test results can be summarized as follows; (1) The presence of NRL containing mud had better static filtration properties compared to base bentonite mud, (2) The influence of elevated temperature showed negative effects on filtration properties by increasing fluid loss rate, (3) The rheological parameters of NRL containing mud increased with an increase of NRL concentration and temperature except plastic viscosity which slightly decreased with increasing temperature, and (4) The NRL could be used as drilling fluid additive for borehole having bottom hole temperature up to 80^{o}C without thermal degradation.

Keywords: **Natural rubber latex, *Hevea brasiliensis*, drilling mud, lost circulation additive, static filtration**

Introduction

In rotary drilling, there is a variety of functions and characteristics that are expected of drilling fluids. The drilling fluid is used in the process to (1) clean the rock fragments from beneath the bit and carry them to separate at the surface, (2) exert sufficient hydrostatic pressure against subsurface formations to prevent inflow fluids into the well, (3) keep the newly drilled borehole open until steel casing can be cemented in the hole, and (4) cool and lubricate the rotating drillstring and bit (Bourgoyne *et al*., 1986). In addition to serving these functions, the drilling fluid should not (1) have detrimental properties to use of planned formation evaluation techniques, (2) cause any adverse effects upon the formation penetrated, or (3) cause any corrosion of the drilling equipment and subsurface tubulars.

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The bentonite used in drilling fluid is monmorillonite clay (Chilingarian and Vorabutr, 1983). It is added to fresh water to (1) increase the hole cleaning properties, (2) reduce water seepage or filtration into permeable formation, (3) form a thin filter cake of low permeability, (4) promote holes stability in poorly cemented formation, and (5) avoid or overcome loss of circulation. The added bentonite is sometimes unable to provide satisfactorily those properties required for optimum performance in an oil well drilling. Hence, the polymers are added to achieve desired results.

Polymers are practically part of every water basedsystem in use today, and they can be classified according to their usage (Devereux, 1998). The major uses of polymers in drilling mud are flocculants, deflocculants (or thinners), viscosifiers, filtration control additives, and shale stabilization. It has been discovered that polymer latex added to the water-based drilling fluids can reduce the fluid loss rate that invades the borehole wall. The polymer latex is capable of providing a deformable latex film for sealing the formation (Stowe *et al*., 2004). Since filtration problems are usually related to flocculation of active clay particles, the deflocculant also aids filtration control. The common polymers used for filtration control are starch, sodium carboxymethyl cellulose, sodium polyacrylate and xanthan gum. They reduce water loss by increasing the effective water viscosity (Bourgoyne *et al*., 1986). There are various kinds of polymer that have been studied aboard but there are a few studies t in Thailand. Natural rubber latex is a good choice for this study because Thailand is one of the main rubber producers. Therefore, it is easy to provide a lot of this local inexpensive material. For the above mentioned purposes, natural rubber latex (NRL) was selected to study. The NRL is a biodegradable polymer. It can be designed for better environmentally friendly additive in drilling mud system that can be used to minimize the drilling fluid invasion into the permeable formation. Natural rubber latex used in this study is derived from the *Hevea brasiliensis* tree which is a common tree in Thailand. The NRL is a white, creamy and free flowing liquid. The rubber content is more than 98% of cis-1,4-polyisoprene. It exists as an amorphous and rubbery material. Natural rubber latex (NRL) typically contains 34% (by weight) of rubber, 2-3% proteins, 1.5-3.5% resins, 1.0-2.0% sugar, 0.5-1% ashes, 0.1-0.5% sterol glycosides, and 55 to 60% of water. It has a pH 6.5-7.0 and a density of 0.98 g per cubic-cm. Rubber particle size varies from 0.15 to 3 mm (Sridee, 2006).

Materials

The Sodium montmonrillonite (bentonite) clay was obtained from Mi-Swaco Company, Indonesia. The barite was obtained from Ajax Finechem Pty Ltd, Australia, and 60% rubber latex concentrate was produced by Thaihua rubber public company, Sakonnakorn, Thailand.

Mud Preparation

A base bentonite-water suspension was prepared using 30 g of bentonite per 500 ml of water and 60 g of barite were added to control its density. The mud components were mixed for 15 min using Hamilton Beach high-speed mixture. During mixing, the NRL was added slowly to agitated base fluid to prevent a lump fromoccurring within mud system. The testing

Table 1. Composition of mud

Mud components	Bentonite mud	Bentonite+ 1%NRL mud	Bentonite+ 3%NRL mud	Bentonite+ 5%NRL mud
Water (ml)	500	500	500	500
Bentonite (g)	30	30	30	30
Barite (g)	60	60	60	60
NRL (ml)	-	5	15	25

mud samples weighed 1.2 g per cubic-cm containing 6% bentonite weight by volume as a base composition. Various NRL concentrations were added to perform as fluid loss additive. These systems were prepared to compare the fluid loss control potential properties of the mud. The formulations of the mud are shown in Table 1.

Testing

The static API filtration tests were run for all mud samples under 100 psi differential pressure of nitrogen by using API fluid loss apparatus (Fann Filter Press Series 821). The mud samples were filtered through 3.5 inch hardened filter paper. Rheological parameters were measured by Fann 35SA viscometer. Thermal treatments were run under temperature at 30, 45, 60 and 80°C, respectively. The temperature of mud samples were controlled by water bath. The mud samples were tested in triplicate and average values were determined. The testing procedures followed the API 13B standard procedure for oil field testing water-based drilling fluids (API Recommended Practice, 1985) after a period of components blending. The apparent viscosity, plastic viscosity and yield point were calculated from 300 and 600 rpm readings using following formulas:

Apparent viscosity $\mu_a = \phi_{600} / 2$ (cP)

Plastic viscosity $\mu_p = \phi_{600} - \phi_{300}$ (cP)

Yield point $\gamma_p = \phi_{600} - \mu_p$ (lb/100 ft^2)

where, ϕ_{600} = viscometer dial reading at 600 rpm

ϕ_{300} = viscometer dial reading at 300 rpm

The Gel strengths were measured by rotational speed at 3 rpm. The drilling mud was allowed to stand undisturbed for 10 sec and 10 min which are referred to initial gel strengths and 10 min gel strength. Gel strengths are reported in lb/100 ft^2.

Results and Discussion

Filtration Properties of NRL Containing Mud

The filtration properties of base bentonite mud measured at 30°C and other elevated temperatures are shown in Figure 1. The filtration properties of NRL containing mud measured at 30°C are also demonstrated in Figure 2. Both graphs show time-dependant filtration behavior of base bentonite mud and indicate that the fluid loss exponentially increased with time. Results also show a progressive decrease in filtration rate of mud with increasing time of filtration. The decrease in filtration resulted from continuous mudcake deposition and compaction until the layer of a constant thickness and stable mudcake had been formed completely. From Figure 1, omparison of curves indicates a significant increase in the static filtration of bentonite mud

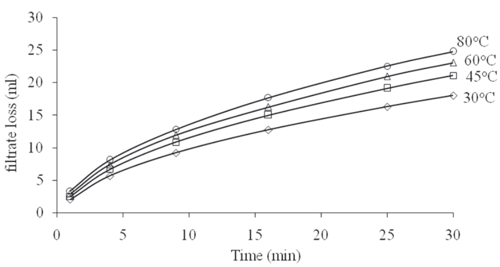

Figure 1. Static filtration versus time of bentonite mud

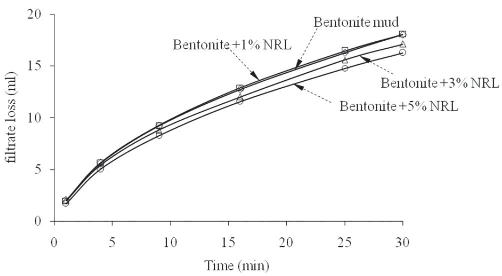

Figure 2. Static filtration of NRL containing mud versus time at 30°C

as the temperature increases. This is cause by adverse effect of temperature on filtration tests. It is result of decreasing in fluid phase viscosity and flocculating of colloidal particles. This could be the cause of mudcake permeability increasing.

Figure 2 shows the effect of NRL concentration on filtration properties at 30°C. The static filtration curves indicate that at 1% NRL concentration shows no improvement in filtration prevention behavior of bentonite mud. Comparison of 3 and 5% NRL concentration with base bentonite mud clearly showed reduction of fluid loss rate. The 3 and 5% NRL bentonite mud indicate about 5 and 10% improvement of 30 min filtration prevention properties, respectively. This is due to the effective bentonite mud swelling and NRL particles distributing. The more NRL concentration indicates more NRL particles dispersed in bentonite mud which facilitated quick and tight mudcake layer on the filter paper.

Analyses of filtration behavior of the mud after thermal treatment at 45, 60 and 80°C are demonstrated in Figure 3. The Figure represents 30 min static fluid loss values of 5% NRL containing mud and indicates that the presence of 5 % NRL in bentonite mud can reduce fluid loss about 10 to 15%. Moreover, there is no sign of thermal degradation of NRL in bentonite mud. Therefore, it can be concluded that the NRL additive could be used under this temperature range. Thus, most of mud possessesed a good thermal stability at tested

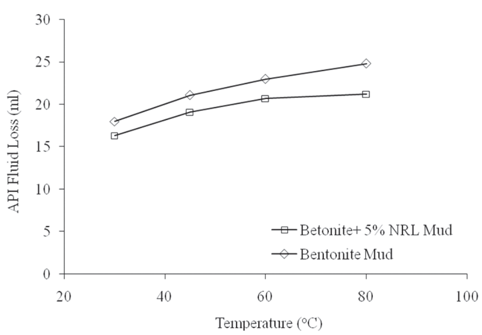

Figure 2. 30 min API fluid loss of mud system

temperatures. The thermal stability of the NRL mud indicated that the NRL additive could be used in subterranean well having downhole temperature up to 80°C. For example, in the Gulf of Thailand, geothermal gradients generally vary from 2.95 to 7.00°C per 100 m in area of hydrocarbon exploration (Lekuthai *et al*., 1995). Hence, the NRL containing mud could be used in the drilling well having depth in range of 700 and 1600 m depending on ambient temperature of well formation.

Table 2 shows the thickness of mudcake deposited by NRL containing mud. The Table shows a thicker mudcake as the NRL concentration and temperature increase. The qualities of mudcakes deposited by the NRL containing mud were also investigated. The toughness and slickness of NRL containing mud is more than those of base bentonite mud that indicates the presence of mudcake stability and lubricity. Moreover, filtration test results indicated that the presence of NRL containing mud had a favorable mudcake quality under the tested temperature range. A good quality mudcake is an effective means of preventing inflow, minimized formation damage by screening out fines migration to invaded formation. It is also easily removed when reservoir fluid is produced (Amanullar and Yu, 2005).

Rheological Properties of NRL Containing Mud

The rheological properties of base bentonite mud and NRL containing mud samples are summarized in Table 3. For all tested temperatures, the results indicated that the presence of NRL containing mud increases the apparent viscosity, yield point, gel strength and plastic viscosity. This is due to the greater colloidal fraction of bentonite and NRL in mud samples, thus increasing surface area of particles and friction between colloidal particles that is a result of increasing flow resistance.

Considering effect of thermal treatment temperature, it is clearly seen that for all of NRL compositions, the apparent viscosity, yield point and gel strength increase with increasing temperature except the plastic viscosity which slightly decreases with increasing temperature.

The consequence of increasing temperature increase interaction energy of mud system (Luckham and Rossi 1999). This induces more inter-particle attractive force between solid particles so the clay particles come into contact with another and agglomerate.

Conclusions and Recommendations

The presence of NRL containing mud indicates a better fluid loss control properties and increases rheological properties of bentonite mud. Therefore, combinations of NRL with bentonite clay could reduce lost circulation and produce favorable rheological properties. These properties are required for optimum performance of drilling well having borehole temperature up to 80°C. The NRL is not expensive and it is ecologically-friendly biopolymer which is easily affordable in Thailand. Thus, it is quite suitable to be used in drilling fluid system.

For further studies, different bentonite mud concentrations should be tested in experiment to represent other conditions of fluid composition. It should be directed to study the thermal behavior of NRL containing bentonite mud under high pressure and temperature which represents a real borehole circulation condition by using dynamic filtration test. The formation damage is concerned and should be measured because there is presence of NRL mudcake erodibility.

Table 2. Mudcake thickness deposited by mud system

Tested Temperature	Mud composition	Mudcake thickness (mm)
30°C	Bentonite	2.40
	Bentonite+ 1%NRL	2.58
	Bentonite+ 3%NRL	2.82
	Bentonite+ 5%NRL	2.89
45°C	Bentonite	3.12
	Bentonite+ 5%NRL	4.07
60°C	Bentonite	3.43
	Bentonite+ 5%NRL	4.23
80°C	Bentonite	3.45
	Bentonite+ 5%NRL	4.92

Table 3. Rheological parameters of mud samples

Tested temperature	Bentonite mud composition	μ_a (cP)	μ_p (cP)	γ_p (lb_f/100 ft^2)	Gelin (lb_f/100 ft^2)	Gel10 (lb_f/100 ft^2)
30°C	-	10.8	4.7	12.3	11.3	13.7
	1%NRL	11.7	5.0	13.3	11.3	13.7
	3%NRL	12.5	5.0	15.0	13.2	15.7
	5%NRL	13.8	5.3	17.0	14.7	15.7
45°C	-	12.5	5.0	15.0	14.8	18.7
	1%NRL	14.5	5.3	17.3	16.3	19.3
	3%NRL	15.5	5.3	20.3	18.0	21.2
	5%NRL	16.2	5.3	21.7	19.0	19.3
60°C	-	15.2	4.7	21.0	20.7	20.2
	1%NRL	16.6	5.2	22.2	21.0	21.3
	3%NRL	18.0	5.3	23.3	22.7	22.2
	5%NRL	18.5	5.3	25.7	23.3	22.3
80°C	-	18.3	4.2	28.3	24.7	24.2
	1%NRL	19.5	5.0	29.0	26.0	24.5
	3%NRL	20.5	5.0	31.0	31.5	27.7
	5%NRL	23.2	5.0	36.3	31.7	31.3

Nomenclature

μ_a	=	Apparent viscosity
μ_p	=	Plastic viscosity
γ_p	=	Yield point
rpm	=	Rotational speed
Gel_{in}	=	Initial gel strength
Gel_{10}	=	10 min gel strength

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