Clinical Cancer Investigation Journal-ISSN: 2278-0513

Review of Physical Properties of Oil Well Drilling Mud

Abstract

Drilling mud which has long been used in Iran's drilling operations is a mixture of water and other materials to facilitate the drilling operations. This process has, over time, seen various materials of different physical and chemicals added to it. The present study reviews the physical properties of oil well drilling muds. For this, the PHB polymer mud is first made, and nanoparticles are then added to it to examine its properties. Findings suggest that polymer particles improve the rheological properties of drilling mud, increasing its shear stress, viscosity, and yield point.

Keywords: *lab test, drilling mud, oil well, Physical Properties of Oil*

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Introduction

Drilling operations are one of the most complicated and costliest operations in petroleum production. Thus, oil companies' capabilities in this industry are seen as a major advantage [1].

Drilling mud is composed of several different materials. Here, a type of clay known as Bentonite with expansion and volume-increase properties constitutes the main ingredient of the drilling mud. Other materials added to the mud include lime, starch, gum, etc., which are mixed with some water and make up the drilling mud [2]. Most drilling muds in the oil industry are water-based, i.e., a large part of which is made of water. Drilling mud system of its special mixture is one of the most important parts of drilling operation that greatly contributes to the operations. Drilling operations cannot be performed without a drilling mud system [3].

Costs of a drilling fluid system largely account for the costs of drilling a new well, and for this, the use of more useful and improved fluids forms a major section of researchers' studies. Drilling fluid must have good capability of cooling off the drilling bit, lubricating the drilling swivel pipes, cleaning the well, etc. Otherwise, such problems as fluid loss, formation damage, pipe adhesion, drag forces, and high stress will arise. These problems are specifically seen in wells with higher temperatures and pressure. Therefore, it is pivotal to achieve high-strength fluids under high temporal and pressure conditions. Viscosity and fluid density principles in drilling are key factors to control the fluid behavior and need to remain constant in operation. As known, viscosity is a drilling fluid that has its capability of going deep into the well reduced with the increase of temperature. However, a good drilling fluid must preserve its capability and properties to the extent possible under high temperature and pressure inside the well.

Methods

This study uses a water-based drilling mud. All materials needed to make the mud were purchased from the German company of Merck. The specifications of the made mud match those of the published literature. The DRISPAC polymer is one from the cellulose ether family, which has a powder appearance of light and odorless color. It is fully water-soluble, and its specific weight (relative to water) is…… Drilling Specialties Co made this polymer.

Lab design stages

Considering the properties needed for this fluid and its applicable conditions in difficult operational regions, various tests were carried out on the sample fabrication to select the most desirable additives of different values to achieve the technical goals. Then, the best formulation for the drilling fluid was proposed as follows:

1. Taking 350 ccs of water
2. Bentonite is added to water and mixed for one minute
3. Polymers regulating limpid drop are added and mixed at high speed for 20 minutes
4. PHPA polymers are added and mixed at high speed for 20 minutes
5. Viscosity-creating polymers are added and mixed at high speed for 20 minutes
6. Salts are added and mixed for 10 minutes
7. Glycol is added and mixed for 10 minutes
8. Sized calcium carbonates are added and mixed for 5 minutes
9. Potash is added and mixed for 5 minutes

Stages 1 to 9 plus their function and quantities of materials are given in Table 1-2. To experiment, samples of the mud are made, and their rheological properties are examined by adding different amounts (0.5, 1.5, and 1.5 g) of DRISPAC polymer.

Table 1: Proposed mud formulation

Order of addition	Type of material	Amount	Mixture time	Function in the fluid
1	Regional water	350 cc		

2	Sodium Bicarbonate	1g	1 minute	Removes ferrous ion
3	Synthetic XC polymer regulating limpid drop	6g	20 minutes	Regulates limpid drop
4	PHPA polymer	1g	20 minutes	Encapsulates shale surface
5	DRISPAC biopolymer	0	20 minutes	Creates viscosity
6	Potassium chloride	21g	10 minutes	Stabilizes shale
7	Sodium chloride	91g	10 minutes	Creates weight
8	Glycol	17.5cc	10 minutes	Creates stabilization
9	Bentonite	5g	5 minutes	Creates cake and regulates weight
10	Potash	0.2g	5 minutes	Regulates Ph

All samples were examined under various temperatures and pressures, and shear rates, as their yield point (Y_p) and plastic viscosity (PV) as well as their strength were also examined. Bingham plastic is often used to demonstrate the rheological properties of the drilling mud. The math equation of this model is as follows:

(1)

$$S.S = S.S|_{SR=o} + P.V \times S.R$$

$$S.S|_{SR=o} = Y_P$$

(2)

When the Fann viscometer apparatus is used, SR conforms to rpm and SS to dial reading (degree of deviation) of the apparatus, yielding the following equation:

(3)

$$\theta = Y_P + PV \times \frac{\omega}{300}$$

The equation shows that the degree of deviation "θ" is a function of the rotation rate or ω**.** (PV and Y_p are parameters of the equation).

To achieve the values of the parameters, it is required to measure the values corresponding to θ for an arbitrary value of ω and then calculate the relevant coefficients via two equations and two unknowns.

(4)

$$\omega_1 = 600rpm \rightarrow \theta = \theta_{600}$$

$$\omega_2 = 300rpm \rightarrow \theta = \theta_{300}$$

$$\omega_{600} = Y_p + PV \times \frac{600}{300}$$

$$\omega_{300} = Y_P + PV \times \frac{300}{300}$$

Consistent with the definition, apparent viscosity is a non-Newtonian fluid in SR equivalent to 600 rpm. If the degree of deviation for 600rpm is θ_{600} With the values placed in the equation, then, the apparent viscosity is calculated from the following:

$$AV = U_e\Big|_{SR=600rpm} = 300\times\frac{dial\ reading}{\omega} = 300\times\frac{\theta_{600}}{600} = \frac{1}{2}\theta_{600}$$

(5)

To calculate the return seepage, the secondary-to-primary seepage ratio of the reservoir rock is calculated. The following formula shows the calculation of the return seepage consistent with the ΔP – Q diagram in previous stages following the injection of the drilling fluid.

(6)

$$\text{Return seepage content} = \frac{Q\text{-}\Delta P \text{ diagram slope after injecting the fluid}}{Q\text{-}\Delta P \text{ diagram slope before injecting the fluid}} \times 10$$

$$\text{Seepage reduction content} = 100 - \text{Return seepage content}$$

Examining the lubrication property of the sample mud

An appropriate drilling fluid must be lubricating enough to reduce friction between the drilling rig and the well and to reduce torque and frictional resistance forces. The proposed fluid makes use of special materials such as glycol and polymers to lubricate the mud sample. This property of the mud was measured by the E-P MUD TESTER apparatus in the lab.

Results

Base mud specifications

Here, the properties of the drilling mud are measured and reported. These properties included the rheological properties of the fluid and its density at different speeds of the viscometer. It should be pointed out that the polymer in this study is meant trading polymer (DRISPAC LOT1104). For the initial stages, the temperature is set at 150°F and pressure of 200 psi.

Table 2: Base mud specifications

RPM	**0.5g**	**1.0g**	**1.5g**
Electrical stability	950	956	957
Density(PCF)	75	79	84

Effective viscosity

Figure 1 illustrates the mud's effective viscosity of various sections of the rotating system at different speeds. As seen, with the increase of polymer concentration of the mud, its viscosity increases proportionally, and thus, this polymer can be regarded as a good additive to increase the effective viscosity of the mud.

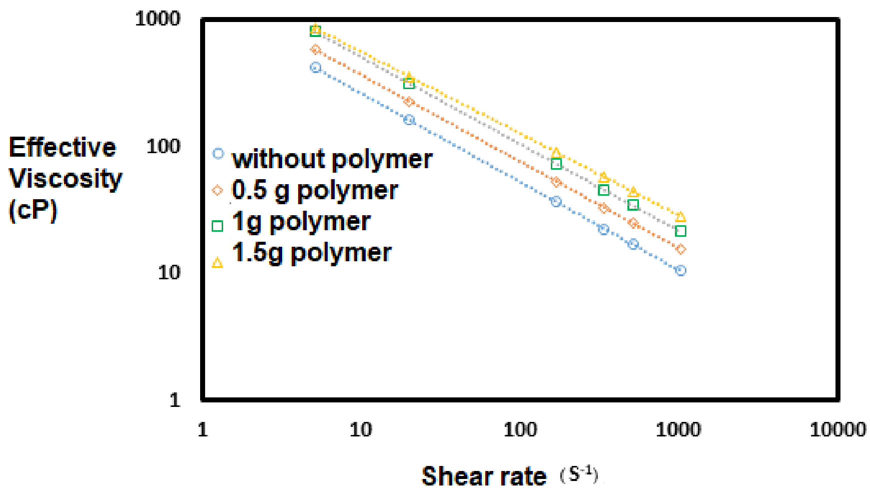

Figure 1: Effect of polymer on effective mud viscosity

Plastic viscosity and yield point

Figure 2 illustrates the effects of increasing the polymer on the plastic viscosity property and the yield point of the mud. As the figure shows, the use of this polymer in the mud as an additive causes its property to increase in a linear form ($100\ lb_f/ft^2$). Furthermore, the yield point of the mud has a greater sensitivity to polymer concentration compared to its plastic viscosity.

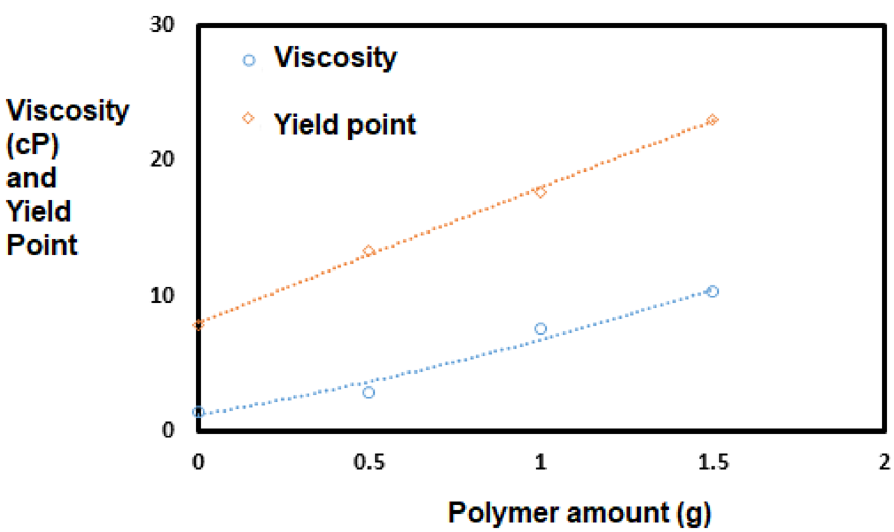

Figure 2: Effect of polymer concentration on plastic viscosity and yield point

Gel strength

Figure 3 illustrates the measurement results of the gel strength of the polymer mud. As seen, increasing the concentration of this polymer in the mud increases its strength properties. In this connection, the 10-minute gel strength is more sensitive to polymer concentration compared to the 10-second gel strength. In other words, the increase in the mud polymer concentration makes a greater difference in the two values, which indicates the gel property of the mud. As stated above, this behavior is positively evaluated from an operational point because the use of this polymer in the mud with weak gel properties not only improves the mud's suspension property by increasing the 10-minute gel strength but also prevents the relatively slight effects of the 10-second gel strength (primary gel strength) that may have negative effects on the mud recovery operation at the wellhead.

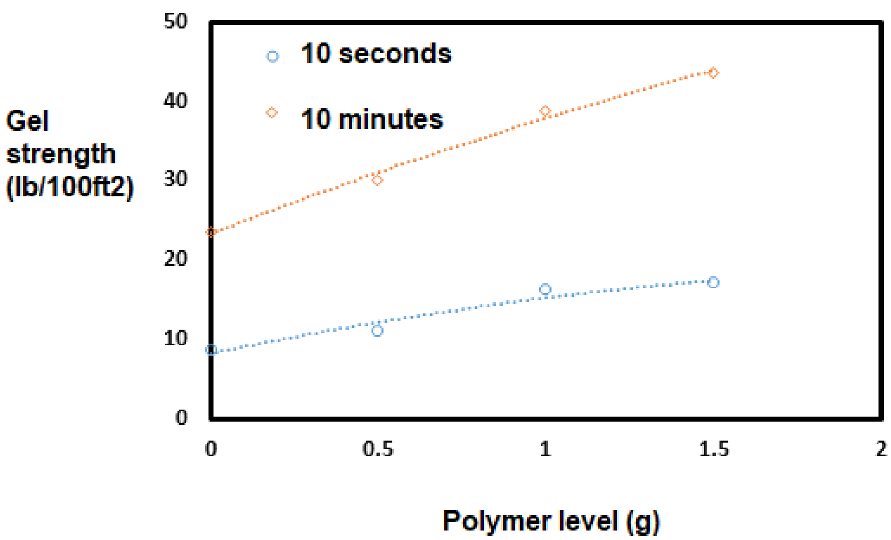

Figure 3 Effects of polymer concentration on mud gel strength

Pseudo-plastic behavior of the drilling mud

n and *k* values of the samples made are calculated and shown in figures 4 and 5.

As seen, at both low and relatively high rates, the addition of this polymer not only does not help strengthen the mud's pseudoplastic behavior but also weakens this behavior by increasing the effects it has on the n potential. As noted in Figure 4, the effects of this polymer at low rates are insignificant, as greater effects are noted at high rates. However, the pseudoplastic behavior of the mud is due to its reduced viscosity at sections of high rates, such as at jet bits. Figure 4 shows that this polymer does not have good efficiency in this regard. Also, the mud's uniformity index increases by increasing the polymer at relatively high rates; however, this effect is insignificant at low rates.

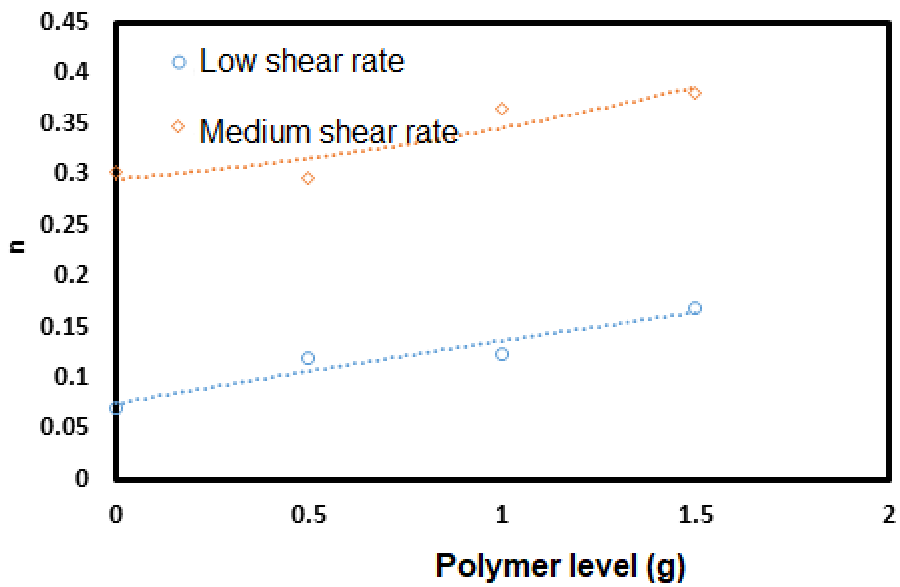

Figure 4: Effects of polymer on the pseudoplastic behavior of the mud at different shear rates

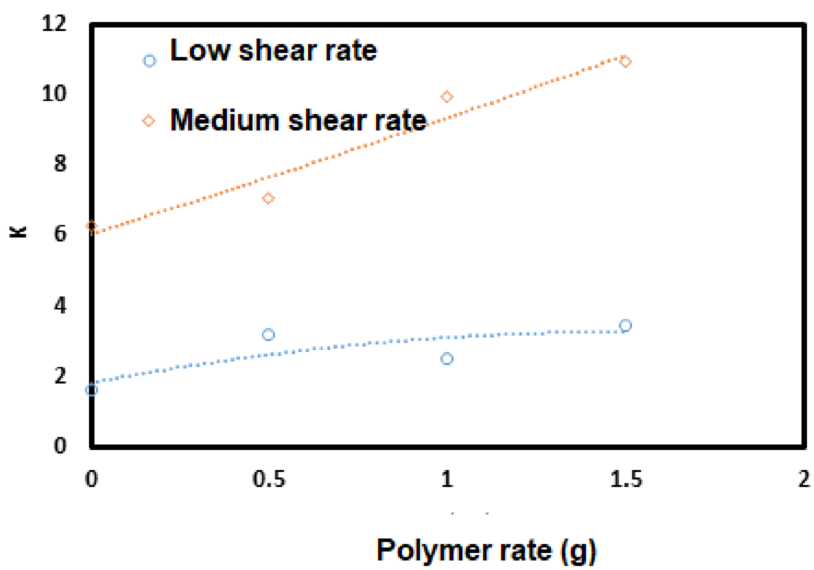

Figure 5: Effect of polymer on the uniformity index of the mud at different shear rates

Effects of increasing temperature on the polymer mud performance

Figure 6 illustrates the effects of temperature on the 1.5g polymer mud, which shows that as temperature increases, the connections between the polymer and clay particles are broken, which help scatter the molecules, thus reducing the viscosity or shear stress.

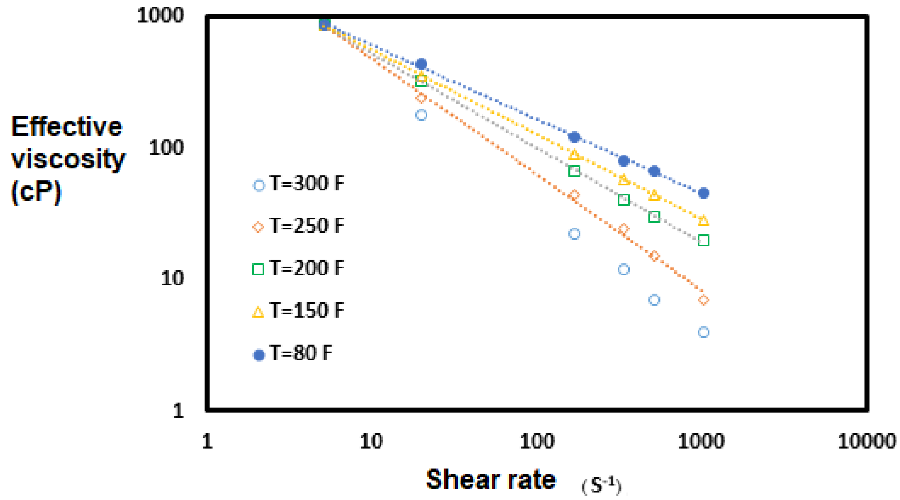

Figure 6: Effects of temperature on the rheological behavior of polymer mud

Conclusion

Drilling fluids (also known as drilling muds) are the main instruments for successful drilling operations. Costs of a drilling fluid system largely account for the costs of drilling a new well, and for this, the use of more useful and improved fluids forms a major section of researchers' studies. Drilling fluid must have good capability of cooling off the drilling bit, lubricating the drilling swivel pipes, cleaning the well, etc. Otherwise, such problems as fluid loss, formation damage, pipe adhesion, drag forces, and high stress will arise. Limitations and the inefficacy of Bentonite drilling muds are nowadays being replaced by other fluids. Thus, polymer muds are being tested and used, which not only create viscosity in the system but also control and regulate limpid drops under various stable contaminations. This study reviews the effects of ZnO/CMC nanoparticles on the efficacy of polymer mud. For this, the water-based glycol polymer gel is first made, and its properties are examined. Findings suggest that the addition of polymer particles improves the rheological properties of the drilling mud and thus increases its shear stress, viscosity, and yield point.

Conflict of interest: None

Financial support : None

Ethical statement: None

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