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Enhancement of Water-Based Mud Properties using Polypropylene Fibers

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Abstract

This aim of study is to evaluate the effect of polypropylene fiber on the properties of water-based mud. In recent years, various additives have been examined to enhance the properties of drilling fluids. The effect of using polymeric synthetic fibers (polypropylene fiber) as a novel additive to drilling fluid for the purpose of improvement of the rheological and filtration properties has been studied. In the laboratory, several samples of water-based drilling fluid were prepared, different concentrations of polypropylene fibers with small percentages ranging between 0.050 wt% and 0.150 wt% of the total weight of the drilling fluid were tested by Fann 35 viscometer,140 Fann Mud Balance, and API LT-LP filtration. The results showed that adding 0.1 wt% of polypropylene fibers was the optimum concentration. It was found that the apparent viscosity and yield point increased by 16.6% and 16% respectively, when 0.1 wt% polypropylene fiber was added to the drilling fluid. Likewise, the fluid loss rate was reduced by 7.8% when using the same concentration of polypropylene fibers.

***Keywords**: Polypropylene fibers; Water based mud; Fiberglass; Rheology; Fluid loss.*

1. Introduction

In the oil and gas industry, drilling the well is the most complicated and expensive operation compared to other operations in oil well [1]. Drilling fluid is a main element during the drilling operation, it is not only limited to cooling and cleaning the drilling bit, but it also maintains the stability of the borehole, prevents collapsing, lifts the cutting to the surface from the bottom of the well etc [2]. Therefore, researchers try to improve the properties of the drilling fluid to maintain it under the extreme well conditions of high pressure and high temperature during the drilling process.

There are two main types of drilling fluids: water-based mud (common type) and oil-based mud. Water-based mud consists of water as liquid component and bentonite as solid component. Optimization of the properties of the drilling fluid is very important to determine the efficiency and integrity of drilling [3]. Different chemical additives are used in the water-based mud in order to improve the different properties of the drilling fluid such as viscosity, density, and fluid loss [4]. The change in the properties of drilling fluid is dependent on the type of additive to be used. For example, some additives can increase the viscosity of the drilling fluid while others can reduce it. However, these additives have several problems, such as their high price, rarity, and influence on the environment and human health during handling [4]. Due to these reasons researchers are always searching for the best additives to achieve the optimum properties of the drilling fluid which are cost effective and are not threat to human as well as environment.

Fiberglass (polypropylene fiber) is the materials which can be one of the newest additives to water-based mud. Polypropylene fibers are inexpensive and easy to grind into small particles. The polypropylene fibers are manufactured from propylene gas which is obtained from petroleum during extraction from the reservoir. Monomeric C_3H_6 is the source of the raw material of polypropylene [5]. Propylene is polymerized to generate a long chain polymer under high pressure and temperature [5]. The length of polypropylene fibres ranges between 6 mm to 12 mm [6]. Polypropylene fibers have been generally used in several industries and especially in construction projects. Usually, fibers have been mixed with cement to increase compressive strength and prevent cracking [7-11]. To date, there are no previous studies on the use of polypropylene fiber as an additive for drilling mud. Some of the studies mentioned that using polypropylene fibers can improve the performance of cement in oil well [12] and in constructions such as buildings and bridges [13]. Polypropylene fibers are a new chemical fiber that is produced in large quantities around the world, about four million tons annually [5]. Polypropylene fibers are cheap, widely available, high quality, and easy to handle. Polypropylene has a high molecular weight which makes it a best suit [5].

This paper presents an experimental study on polypropylene fiber as an additive to water-based mud using different concentration to determine the effect on various properties of mud such as rheology, density, fluid loss and cake thickness. Evaluation of polypropylene fiber in terms of cost efficiency and improvement of personal safety.

2. Experimental section

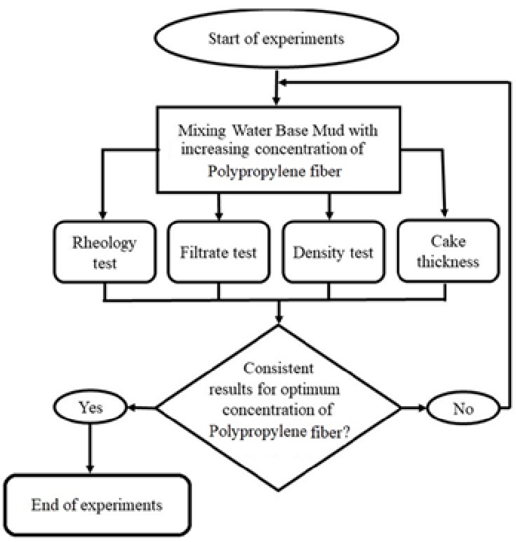

Figure 1. Experimental workflow chat

All experimental measurements for this article were carried out based on API-RP-13B-1, [14]. Workflow for the experimental process is shown in Fig. 1. The experimental measurements include rheological properties (plastic viscosity, apparent viscosity, yield point, gel strength for 10 seconds, 1min, and 10 minutes), density, the fluid loss for 30 minutes, and the thickness of the cake. The experiments were carried out with different concentration of polypropylene fiber.

2.1. Materials

The polypropylene fibers 12 mm were used and provided by EAMIC. Co. A sample of the polypropylene fibers is shown in Fig. 2. Fiber ratios of (0.05 wt%), (0.075 wt%), (0.1 wt%), (0.125 wt%), and (0.150 wt%) of the weight of water-based mud have been used. Physico-chemical of polypropylene fiber used in the experiments are shown in Table 1.

Table 1. Properties of polypropylene fiber

Appearance	White individual fiber
Fiber Length	12 - mm
Thickness	32 µm
Cross cection	Round
Tensile ctrength, (N/mm^2)	600 - 700
Young's modulus, (N/mm^2)	3000 - 3500
Elongation (%)	20 - 25
Specific density, ($grams/cm^3$)	0.91 grams
Water absorption (%)	Nil
Melting point (C)	160 - 170
Alkali resistance	Strong
Acid resistance	Strong
Biological resistance	Stable

Figure 2. Structure of polypropylene fiber

2.2. Preparation of water-based mud

In this study, fresh water-based mud system with bentonite, water, and polypropylene fiber with different concentration was used. 350 mL of fresh water was taken and poured into Hamilton beach mixer, then 6.4% of bentonite was added, which is equivalent to 22.5 grams, with continuous mixing for 20 minutes. Six samples were prepared, including the reference sample, meaning that 2100 ml of water and 135 grams of bentonite were used. The mixture was left for 24 hours before using it in experiments to ensure that the bentonite was hydrated in the water. In the next step, the polypropylene fibers were added to five samples of the drilling mud accordingly to the study concentrations ranging from 0.050 wt% to 0.150 wt% and the mixing was done after adding the polypropylene fibers for ten minutes before starting the experiments on each sample. All experiments were performed at room temperature.

3. Experimental procedures

3.1. Rheological properties determination

Fann 35 viscometer was used to perform Rheological test. This device is provided with six speeds (600, 300, 200, 100, 6, and 3) rpm. The test was conducted by pouring the sample into the device cup after making sure that the rotor was installed correctly. The readings were recorded at different rotation speeds, with rotating the sample at 600 rpm for ten seconds between the different readings to ensure the correctness of the reading. Through these readings, the apparent viscosity, the plastic viscosity, and yield point were determined by using the following equations:

Apparent viscosity (AV) in cP: $AV = \theta 600/2$ (1)

Plastic viscosity (PV) in cP: $PV = \theta 600 - \theta 300$ (2)

Yield point (YP) in lb/100ft^2: $YP = \theta 300 - PV$ (3)

where, θ600: dial reading at 600 rpm; θ300: dial reading at 300 rpm.

For measuring the gel strength, it was done by rotating the device at 600 rpm for ten seconds, then turning off the device for ten seconds, one minute and ten minutes respectively, and finally the device was turned on at 3 rpm and the maximum reading on the dial of the device was recorded in lbs/100ft^2.

3.2. Density determination

This test was performed by using a 140 Fann Mud Balance device. The device cup was filled with mud sample completely. Achieving the balance between the cup and the slider on the device arm by placing the bubble between the two horizontal lines on the reading arm of the device. Thereafter, the density of the mud sample was recorded from the arm ruler in lb/gal unit.

3.3. Fluid loss determination

The test was performed by using API LT-LP filtration device at room temperature, 100 psi pressure and measuring the fluid loss for 30 minutes. The device cell was filled with an appropriate amount of drilling mud sample. A pressure of 100 psi was applied to the cell and the filtrate was collected by a graduated cylinder for 30 minutes. The readings were taken at different times (1, 3, 5, 7.5, 10, 15, 20, 25, and 30 min). After the test was completed, the filter paper was taken out and the thickness of the cake was measured from three different places of the mud cake by graduated ruler in mm.

4. Results and discussion

4.1. Mud rheology

Mud rheology is very important because it determines the ability of the drilling fluid to carry cutting from the bottom of the hole to the surface and the ability to clean the hole. From Fig. 3 shows different viscosity values of the drilling fluid depending on the percentage of polypropylene fiber. Fig. 3 also shows that the plastic viscosity increases slightly at 0.050 wt%, decreases at 0.075 wt% and reaches a maximum value at 0.1 wt%. plastic viscosity decreases with the increase in the concentration of polypropylene fibers. The apparent viscosity also increases slightly at 0.050 wt% and 0.075 wt%, then reaches its maximum value at 0.1 wt%. The value of yield point changes according to the percentage of polypropylene fiber added to the drilling fluid, and it reaches the maximum value at 0.1 wt% of the polypropylene fiber then can noticed decreasing in yield point values above 0.1wt% because increasing the percentage of polypropylene fibers above a certain concentration leads to accumulation in the mixture. Experiments had shown that the plastic viscosity ranges between 5 and 7 cP. The value of apparent viscosity ranges between 9.71 and 11.65 cP, using a very small concentration of polypropylene fibers leads to a noticeable change in the viscosity values. From the previous results, it can be concluded that adding up to 0.1 wt% of the polypropylene fibers improves the flowability of drilling fluid which means an increased cleaning efficiency of the borehole, which reduces several problems such as, high torque, overpull on trips, and pipe sticking.

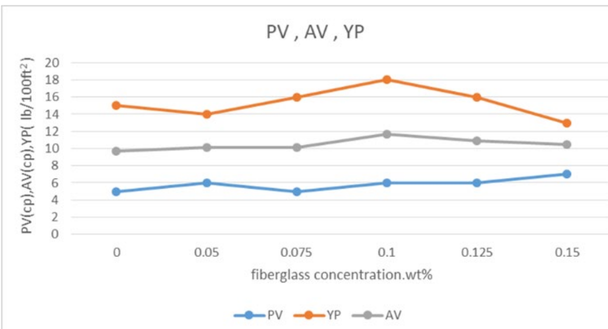

Figure 3. Mud rheology for mud samples

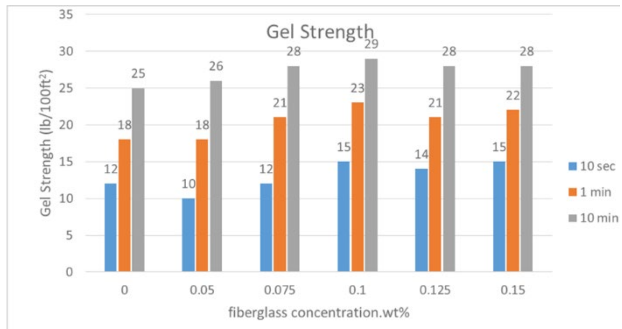

Figure 4. Gel strength of mud samples

The effect of the increased concentration of polypropylene fibers on gel strength is shown in the Fig. 4. The gel strength increases from 25 lb/100ft^2 to 29 lb/100ft^2 at 0.1 wt% of polypropylene fiber, which means that addition of polypropylene fibers in low concentration aids the carriage of the cuttings, the additive keeps the cuttings in suspension which is helpful when drilling is stopped for long period for maintenance thus reducing the sticking problems and the pressure needed to recycle the drilling fluid.

From Fig. 5, represents higher shear rates obtained for samples 0.1 wt%. Increase in polypropylene fiber concentration increase the needed shear stress necessary for mud circulation in the annulus. Fig. 5, shows the huge shear stress is provided by the lower concentration of polypropylene fiber. From the study of rheological properties, it was noted that the viscosity was greatly improved at 0.1 wt% of the polypropylene fiber, making this concentration the optimum that achieves the best viscosity value for water-based mud.

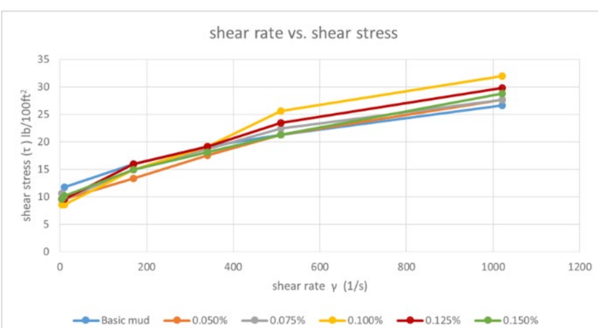

Figure 5. Shear stress vs shear rate for mud samples

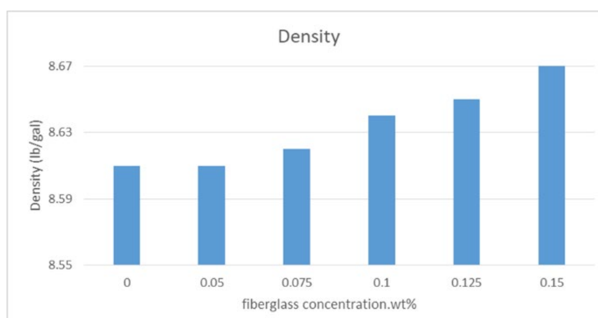

Figure 6. Mud Density of the samples

4.2. Mud density

The mud density is one of the important characteristics that help to control the well during the drilling operations. Fig. 6, indicates that the reference drilling fluid has a density of 8.6 ppg resulted from the addition of 22.5 gr of bentonite to 350 mL of fresh water, with the increase in the concentration of polypropylene fibres in the drilling fluid, the density value increases. The polypropylene fibers have a weight increase effect on the density of drilling fluid. A slight density increase can be achieved only by adding fibers into the mixture resulting less need for barite.

4.3. Fluid loss and cake thickness

The fluid loss test was performed on all studied samples using API LT-LP filtration device at room temperature. From the Fig. 7 it can be noticed that the volume of fluid loss in the reference drilling fluid was 19.2 ml and with the increase in the concentration of the polypropylene fiber in the drilling fluid, the volume of the fluid loss decreases to 19 ml at 0.050 wt%, to 18.2 at 0.075 wt% and the minimum value for the fluid loss volume was 17.7 mL at 0.1 wt%. When the concentration of polypropylene fibers was raised above 0.1 wt percent, the fluid loss volume increased again to 17.9 mL at 0.125 wt% and 19.1 at 0.150 wt%.it is clear that the optimum concentration is 0.1 wt% of the polypropylene fiber, which gives a minimum volume of fluid loss and consequently reduces the problems of contamination of formations by drilling fluid. The reason of that could be the polypropylene fibers at 0.1 wt% concentration reduce the permeability of the filter cake, and above this concentration, the fibers accumulation may lead to an increase in permeability of filter cake again.

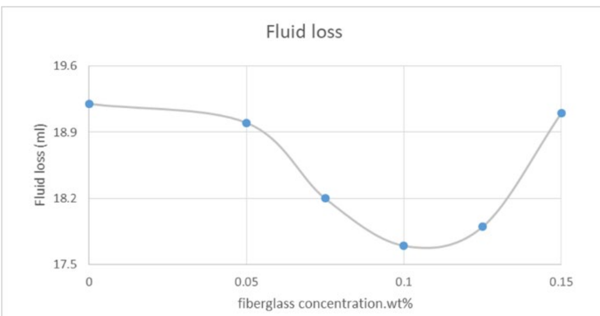

Figure 7. Fluid loss for mud samples

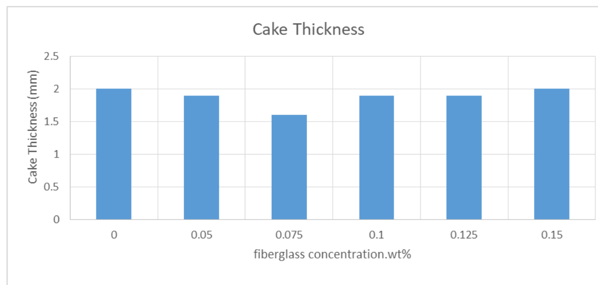

Figure 8. Cake thickness for mud samples

Fig. 8 shows that the cake thickness decreases from 2 mm to 1.6 mm with the increase in the concentration of polypropylene fibers in the drilling fluid. The thickness of cake increased with the increase in the concentration of the propylene fiber above 0.075 wt%.

5. Conclusions

In the present study, the effect of polypropylene fiber on water-based mud samples was evaluated based on the experimental tests in drilling lab. The drilling fluid samples properties were examined according to rheology, density, fluid loss and cake thickness tests. Adding polypropylene fiber to drilling fluid with 0.1 wt% concentration increase and enhance rheology of the water-based mud and is cost efficient. So, the optimum concentration that showed the greatest enhancement was at 0.1 wt% of polypropylene fiber. Addition of polypropylene fiber reduces fluid loss around 8% at 0.1 wt%. Addition of polypropylene fiber to drilling fluids enhanced the properties of the drilling fluid and hence resulted in better drilling performance with reduced drilling problems. The enhancement of rheology led to increased efficiency of cleaning the borehole, reduced several problems such as, high torque, overpull on trips, and pipe sticking.

For further improvement, several points can be taken into consideration. Firstly, the water-based mud composition could be changed by adding CMC and XG. In addition, the effect of polypropylene fiber at different temperature can be applied on mud samples at drilling lab, usage of different sizes of fibers can lead to different results. Finally, a more extensive study of the chemical interaction between the polypropylene fiber and the drilling fluids can help to improve the different properties of the drilling fluids result.

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