

# The effect of nanoparticles addition on the properties of polymer weighted drilling fluid

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**Abstract.** The experimental studies of polymer drilling fluids weighted with B-5 and B-6 barite with the addition of silicon oxide nanoparticles wt. 2% are presented. The concentration of barite particles in muds ranged from 10 to 40 wt. %. The size of microparticles was 70  $\mu\text{m}$ . The size of nanoparticles was 5 nm. The effect of nanoparticles addition on rheological and tribological parameters of polymer drilling fluids weighted with barite depending on the concentration of microparticles was established.

## 1. Introduction

An active interest in suspensions with nanoparticles (nanofluids) appeared a quarter of a century ago and is continually growing. The effects observed with the nanoparticles addition to the mud are much more than those observed for microscopic particles equivalent in weight or volume, micron or larger in size. Unusual properties of nanoparticles make non-standard properties of nanofluids, in which they are a part. This led to a wide range of nanofluids applications [1]. Nanofluids were used in the technologies of development and operation of oil and gas fields much later. Numerous recent studies in this area show that nanoparticle addition can influence the most important properties of drilling fluids, such as viscosity, rheology and antifriction action [2].

The viscosity and rheology of drilling fluids are essential for their application, as they affect the pressure drop during well flushing, the cutting transport efficiency, borehole stability and many other factors in drilling. The energy costs of drilling fluid circulation are reduced with the decrease in viscosity, it becomes possible to realize a greater hydraulic power on the bit. On the other hand, the increase in viscosity raises the cutting transport efficiency and improves face cleaning. In this case, the viscosity change is always associated with a change in the mud density when using only the microscopic dispersed phase, which is undesirable, because of the need to support the hydrostatic pressure. Significant changes in viscosity are achieved at a very low nanoparticles concentration with the use of nanosuspensions, so the mud density remains almost unchanged.

Both theoretical and experimental studies show the main distinctive features of nanosuspensions in comparison with microparticle suspensions are an increase in rheological parameters with an increase in the concentration of the dispersed phase [3, 4] and the appearance of the dependence of rheological parameters on the nanoparticles size [5, 6]. This is most clearly manifested for nanoparticles with a size  $< 50\text{nm}$  [7].

Lubricity is another important characteristic of drilling fluids. The use of solutions with improved anti-friction properties leads to a significant reduction in energy costs during the construction of wells. One of the major complications of the drilling associated with friction is the sticking of the drill pipe, characterized by a complete or partial ceasing of drilling motion. This effect occurs due to the adhesion of the drill pipe to the filter cake, which is formed on the well walls as a result of drilling fluid filtration. Therefore, tests are carried out on the sticking or friction of the filter cake when creating new drilling fluids.

The use of drilling fluids on the basis of nanosuspension or the nanoparticles addition in the composition of the standard solutions is also a promising method of reducing friction coefficient of the drill pipe on the borehole wall. Studies show that the use of washing fluids with improved anti-friction properties has a positive effect on the work of rock cutting tools, so it affects the technical and economic performance of drilling [7, 8]. So, investigation [9] describe effects of nanoparticles  $\text{SiO}_2$  and  $\text{TiO}_2$  with an average size of 40-60 nm on the properties of the water based drilling fluid with the addition of 5% of the standard weights. The nanoparticles concentration was from 0.1 to 0.5%. The nanoparticles addition significantly improved the friction characteristics of the drilling fluid. The optimal concentration of nanoparticles – 0.25% was noted.

## **2. Experiment studies**

### *2.1 Materials*

Water suspension of polymer solutions was used as a basic model of drilling fluid weighted barite (brand B-5, B-6, manufactured by "Barit Ural" according to State Standard 4682-84, class B) size 70 microns. The barite concentration varied from 10 to 39%, which corresponded to a change in the density of drilling fluids from 1.06 g/cm<sup>3</sup> to 1.55 g/cm<sup>3</sup>. Gammaksan mass concentration of 0.5% was used as polymer additives. Also, some solutions was modified with starch 2 wt. %. Mass concentration of barite varied from 10 to 40%. The particles of silicon oxides were considered as nanoparticles. The particles concentration in solutions was 2 wt. %. The particle size was 5 nm.

The analyzer Malvern Zetasizer Nano ZS was used to determine the nanoparticles size. The solution was prepared by adding a polymer, starch and barite to distilled water and stirring intensively after adding each component for 30 minutes using a high - speed stirrer (OFITE 152-18-Prince Castle) for 20000ob/min. Further, the necessary amount of pre-prepared nanosuspension was introduced into the clay suspension prepared in this way. A standard two-step method was used for the preparation of nanosuspension. The required amount of powder was added to the fluid, after the resulting suspension is thoroughly mechanically mixed. Suspensions are treated in the ultrasonic bath "Sapphire TC-10338" to destroy conglomerates of nanoparticles.

### *2.1 Experiments*

The rheology of the created suspensions was studied using a rotary viscometer OFITE 900 (Figure 1). Rotation speed range is 3-600 rpm. Accuracy of maintaining speed is 0.001 rpm. Shear rate range is 0.01-1700 s<sup>-1</sup>. The error of measurement of viscosity was 2%. All measurements were carried out at atmospheric pressure and temperature 298 K.

The friction coefficient measurements were carried out on the CFC-2 device with electric drive, model RS 1008 (Figure 2). The operating principle of this plant is simple. Cake obtained after filtration is placed on the horizontal semi-cylindrical surface. Next, the metal cylinder is placed on the cake. Thus, it simulates the sticking of the drill pipe to the well wall covered with a filter cake. Then the horizontal surface rises slowly and the cylinder slides off at a certain angle. This angle is fixed and the friction coefficient is measured.



Figure 1. Rotary viscometer OFITE 900.



Figure 2. CFC-2 device for measuring the friction coefficient of filter cake.

### 3. Result and Discussion

#### 3.1 Rheology measurements

The base solution was non-Newtonian. Its rheology was well described by the Bingham model:

$$\mu_f = \left( \tau_0 + k_v \dot{\gamma} \right) \dot{\gamma}^{-1},$$

here  $\tau_0$  - the yield point of a viscoplastic fluid, Pa,  $k_v$  - the plastic viscosity, Pa s,  $\dot{\gamma}$  - the shear rate,  $s^{-1}$ . The dependence of the rheological characteristics of polymer drilling fluids on the concentration of barite with the nanoparticles addition of a 2% mass concentration and without for two different base solutions is shown in figures 3-4. Here, the density of the drilling fluid was increased by the addition of barite particles.

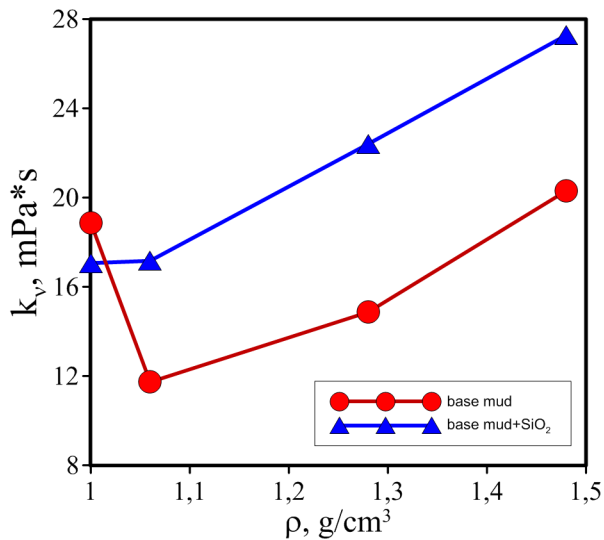


Figure 3. Plastic viscosity of the drilling fluid weighted with microparticles of barite grade B-6 as function of solution density.

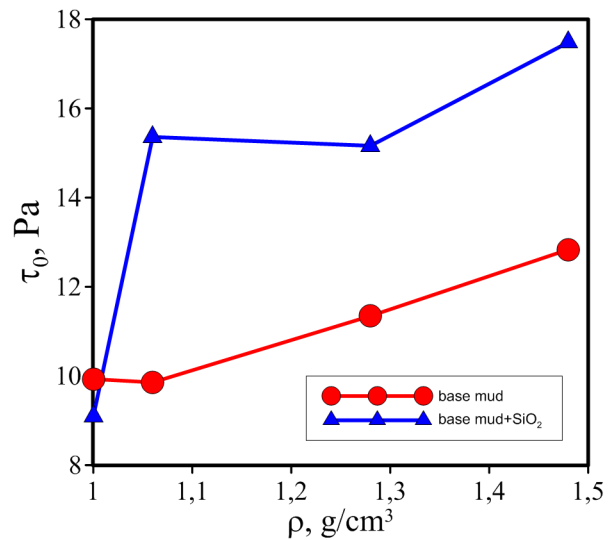
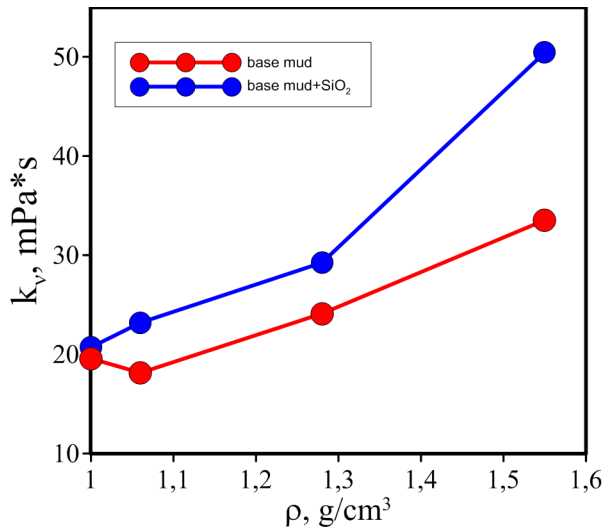


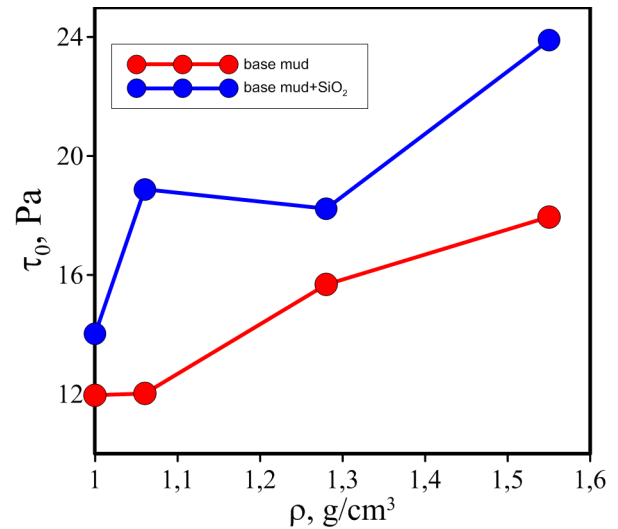
Figure 4. Yield point of the drilling fluid weighted with microparticles of barite grade B-6 as function of solution density.

As is obvious the addition of barite microparticles with a mass concentration of 40% increases the plastic viscosity by about 30%, the yield point at low concentrations of barite decreases and then restores to the level of a non-weighted solution with an increase in the concentration. Analysis of the

effect of nanoparticles on the rheology of polymer solutions with barite microfillers shows that the additive 2 wt.% of SiO<sub>2</sub> nanoparticles for any barite concentration increases the yield point and plastic viscosity of the solution by about 1.5 times. Similar influence of nanoparticles results were obtained for the drilling fluid with the microparticles of barite grade B-5 modified starch (Figure 5-6).



**Figure 5.** Plastic viscosity of the drilling fluid weighted with microparticles of barite grade B-5 and with addition of 5wt. % starch as function of solution density.



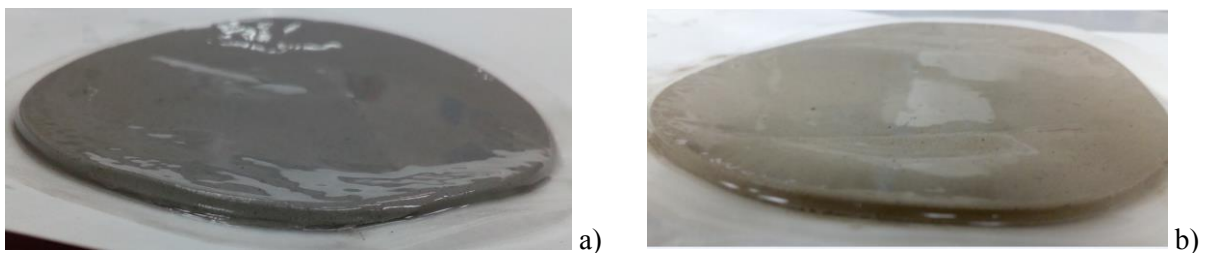
**Figure 6.** Yield point of the drilling fluid weighted with microparticles of barite grade B-5 and with addition of 5wt. % starch as function of solution density.

Thus, it was found that the addition of nanoparticles significantly affects the rheology of polymer drilling fluids, including solutions with a very high content of microparticles.

### 3.2 Friction measurements

In this paper, the effect of the nanoparticles addition on the friction coefficient of the filter cakes was studied.

Investigated the filter cake obtained after the filtration of drilling fluids on the paper according to the standard API (see Figure 7).

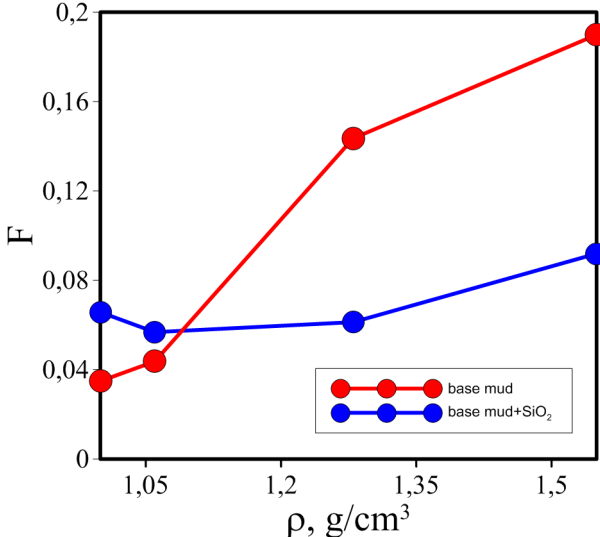


**Figure 7.** Filter cakes for polymer solution with 10 wt. % of barite microparticles without (a) and with (b) the addition of 2 wt. % of nanoparticles.

The test results of a water-based drilling fluid with a 0.5 wt. % addition gammaksan and 2% starch were obtained. Barite powder brand KB-5 used as a weighting agent. Silicon oxide nanoparticles with a mass concentration of 2% were used as an additive.

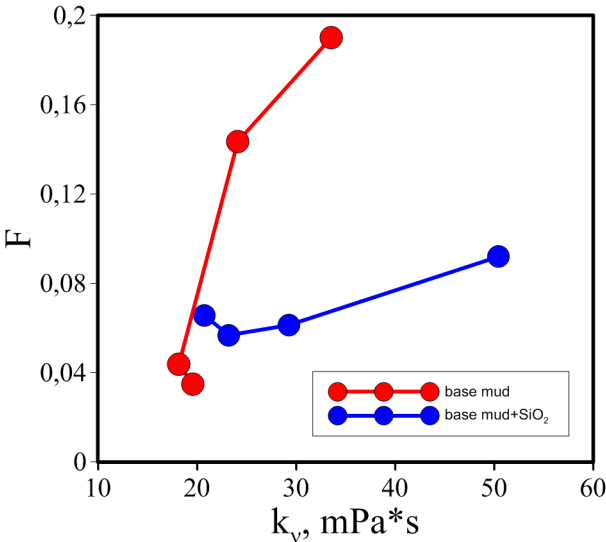
The dependence of the friction coefficient on the density of the drilling fluid, which increased with the addition of barite microparticles, is shown in Figure 8. As follow from graph, with an increase in the barite concentration, the friction coefficient between the steel cylinder and the cake increases by 4.5

times. The nanoparticles addition allows to reduce the value of the friction coefficient of the filter cake twice, which should also significantly reduce the sticking of the drilling tool.

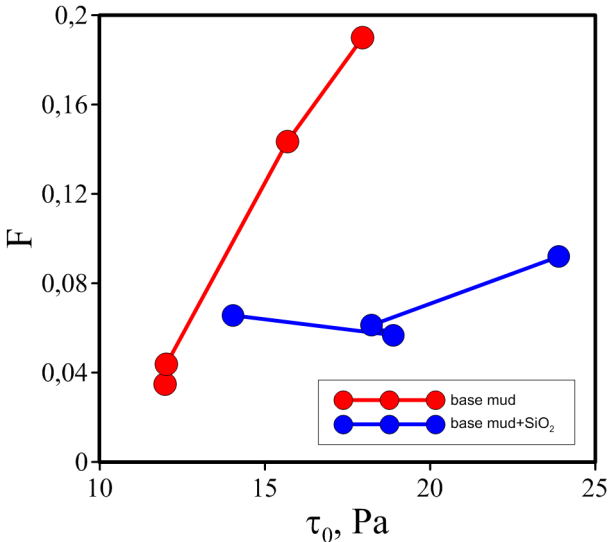


**Figure 8.** The friction coefficient of the filter cakes of polymer drilling fluids weighted with barite as function of the solution density.

The dependence of the friction coefficient of the filter cake on the viscosity and rheology of the drilling fluid was also studied (Figures 9-10). As can be seen the friction coefficient increases with rising yield point and plastic viscosity of the solution. But at the same time, though the solution with nanoparticles has significantly higher yield point and plastic viscosity, the friction coefficient under other different conditions is much lower than the solution with microparticles.



**Figure 9.** The friction coefficient of filtration cakes of drilling fluids with nanoparticles addition, weighted with barite microparticles, as function of the plastic viscosity of the solution.



**Figure 10.** The friction coefficient of filtration cakes of drilling fluids with nanoparticles addition, weighted with barite microparticles, as function of the yield point of the solution.

Thus, it was found the mechanism of reducing the friction of filtration cakes with the nanoparticles addition is not directly related to the solution viscosity. A probable mechanism of this reduction, in our opinion, is the so-called "ball bearing" mechanism, in which nanoparticles act as a kind of lubricant,

facilitating the sliding or rolling of barite microparticles between solid surfaces. Confirmation of this hypothesis can be the fact that a necessary condition for reducing the friction coefficient of the cake with the nanoparticles addition is the availability of enough microparticles in the drilling fluid.

#### 4. Conclusion

Thus, in this paper a systematic study of the effect of nanoparticle additives on the rheological and tribological properties of polymer drilling fluids weighted with barite grade B with an average size of 70 were carried out depending on the solution density. It was shown that addition 2 wt.% of SiO<sub>2</sub> nanoparticles in a weighted drilling fluid for any concentration of barite increases the yield point and plastic viscosity of the solution by about 1.5 times. This effect depends on the microparticles concentration. It is also demonstrated that despite the fact that the solution with nanoparticles has a yield point and plastic viscosity is significantly higher, the friction coefficient under other different conditions is much lower than the solution with microparticles. This opens up a wide prospect of using nanoparticles to control the characteristics of weighted drilling fluids.

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