The effect of nanoparticles additives on filtration properties of drilling muds with microparticles

E I Mikhienkova*[1], A V Minakov[1,2], V A Zhigarev[1], A V Matveev[1]

[1]Siberian Federal University, Svobodniy 79/10, Krasnoyarsk, 660041, Russia
[2]Institute of Thermophysics SB RAS, 1 Acad. Lavrentiev pr., Novosibirsk, 630090, Russia

E-mail: *mihienkova_evgeniya@mail.ru

Abstract. The results of experimental studies of the microsuspensions filtration with silicon oxide nanoparticles additions through a porous medium with different permeability are presented. The particles concentration in fluids ranged from 0.25 to 4 wt.%. The microparticles size was 1.2 μm. The nanoparticles size was 5 nm. The nanoparticles concentration was 2 wt.%. Dependences of the filtration losses of microsuspensions on the microparticles concentration and the permeability of a porous medium were established.

1. Introduction

Filtration of drilling mud into permeable rocks takes place in the technological processes of the well construction. The filtration process and associated pore colmatation, the mud cake formation and the time variation of pressure on the borehole walls have a significant impact on the complications and accidents in the borehole and on the change in reservoir properties. Filtration causes redistribution of pressure in the borehole vicinity, swelling and change of the strength properties of rocks, which leads to borehole instability, collapses, sloughs and the cavity formation as a consequence. If the filtration into the reservoir is significant, this is called drilling mud loss. Redistribution of pressure in the borehole vicinity and displacement of the reservoir fluid front from the borehole reduces the risk of well flow [1].

Drilling muds are suspensions consisting of a liquid phase and solid particles. The concept of filtration (fluid loss) is applicable to the liquid phase of a solution that invades a permeable reservoir as a result of differential pressure. During this process, the solid particles are filtered off, forming a filter cake. Permeability relates to the fluid ability to flow through a porous medium.

Drilling muds have to form a thin filter cake to isolate the permeable zones as quickly as possible. The solution can penetrate into the reservoir (depending on the solids size in solution) when drilling highly permeable rocks with large pores. It is necessary to use colmatants to packing of pores, that the solid phase of the solution can form an insulating layer. Various dispersed (1-100 μm) fillers of drilling muds are used, which can penetrate into the rock and clog it. However, the use of microparticles as fillers is not effective in rocks with low permeability, where the pore sizes do not exceed 0.1-1 μm. In this regard, there were studies in which suspensions of nanosized particles are used as filtering reducers [2-6].

Thus, it was shown in [3] that the addition of 2 mass% nanoparticles to the drilling mud provides a 22% reduction in filtration losses for Al_2O_3 nanoparticles and 38% for TiO_2 nanoparticles. A

publication [4] reports a tenfold reduction in mud filtration after adding 0.2 mass% TiO2 nanoparticles.
A significant reduction in the filtrate fluid volume was achieved when using ferric oxide nanoparticles (-43% for 0.5 wt.%) compared to that of the base fluid. However, adding silica nanoparticles led to an increase in the filtrate volume and mudcake thickness. Increasing the NP concentration resulted in an increase in the fluid loss and mudcake thickness. The mudcakes consisted of two layers, as indicated by the CT scan analysis. 0.5 wt% was found to be the optimal NP concentration, which provides less agglomeration and a reduction in the mudcake permeability by -76.4%.
This work [6] presents the use of nanofluids of CuO and ZnO prepared in various base fluids, such as xanthan gum, polyethylene glycol, and polyvinylpyrrolidone (PVP), which are commonly used in oilfield operations, for the development of nanofluid-enhanced drilling mud (NWBM). In this paper, formulations of various nanofluids with varying concentrations of nanoparticles, such as 0.1, 0.3, and 0.5 wt%, were investigated for their effect on fluid-loss properties of NWBM. In addition, these results also were compared with those obtained with microfluids of CuO and ZnO for the microfluid-enhanced drilling mud (MWBM) to understand the effect of particle size. It is observed that the fluid loss decreases with addition of the nanofluids and microfluids in water-based mud, with nanofluids showing an improved efficacy over microfluids. The studies, in general, bear testimony to the efficacy of nanofluids in the development of next-generation improved water-based drilling fluids suitable for efficient drilling.
Studies indicate the effectiveness of nanofluids in the development of improved water-based drilling muds, suitable for efficient drilling.
In our investigate for the first time a systematic experimental study of the influence of the microsuspensions concentration based on aluminum nitride with additions of silicon oxide nanoparticles through a porous medium with different permeability on the filtration properties of water-based muds were carryed out.

2. Experiment studies

2.1 Materials

Modeling solutions on a clay basis were considered as drilling muds in the experiments (Figure 1). An aqueous clay suspension (clay powder bentonite PBMA (Table 1), deposit of the Krasnoyarsk Territory) with the micropowder addition of aluminum nitride was used as a basic model of clay mud. The mass concentration of clay particles was 5%. The mass concentration of the micropowder of aluminum nitride ranged from 0 to 4%. The particle size of the micropowder was 1.2 μm. The solution was stirred for 30 minutes using a high-speed mixer (OFITE 152 18 - Prince Castle) after addition of each of the components. The suspension was stabilized for two days for the final swelling of the clay after preparation. A necessary amount of the previously prepared nanosuspension was added to the microsuspension. A standard two-step method was used to prepare nanosuspension. The required amount of nanopowder was added to the fluid, and the resulting suspension was subjected of a thoroughly mechanical stir [7]. Particles of silicon oxide were considered as nanoparticles. The nanoparticles concentration in drilling muds was 2 wt. %. The nanoparticles size was 5 nm.

2.2 HPHT filtration measurements

The filtration, or the cake-forming characteristics of the drilling mud, is determined by means of a filter press. The studies were carried out at high pressure and high temperature (HPHT). The analysis consists in determining the flow speed of fluid through a paper filter or a ceramic disc imitating a rock. The analysis is performed in predetermined conditions for a certain time, temperature and pressure. After the experiment, the thickness of the filter cake formed is analyzed. The filter press and analysis procedure have to comply with the requirements of the API Guidelines. The filterability measurement by the API method is performed at ambient temperature, at a pressure of 7 atm for paper filters and 100 atm for ceramic filters for 30 minutes. The filterability of the suspensions was measured on the OFITE filters (Figure 2).

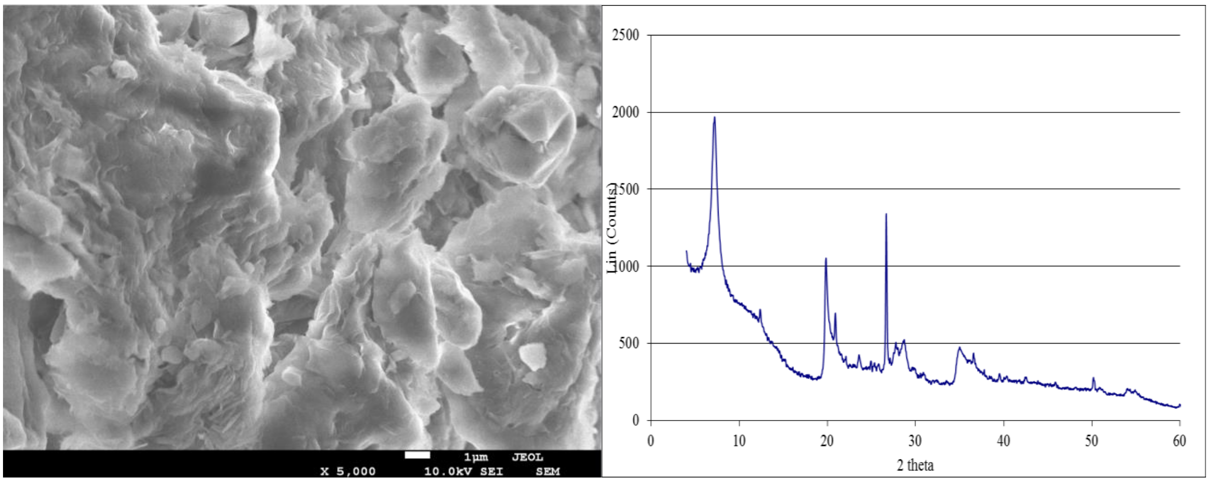


Figure 1. TEM image and X-ray diffraction pattern of clay particles.

Table 1. Elemental composition of the clay sample, site3-x1000, atomic. %

Clay, site3 –x1000, atomic %							
Spectrum	O	Na	Mg	Al	Si	Ca	Fe
Spectrum 1	69.74	1.30	1.76	6.53	19.01	0.41	1.24

Ceramic filter is a cylindrical disk of pressed sandstone with a diameter of 63.5 mm and a height of 6.4 mm. The pore size of the ceramic filters corresponded to a change in the permeability of the porous filter medium from 1.35 to 14.97 Darcy. The filters permeability before and after the experiments was determined using a probe permeameter PLAB 200. A OFITE HPHT 171-01 filter press (Figure 3) was used to model borehole conditions to study the microsuspensions filtration. Each experiment was repeated three times. The spread of data for the three measurements did not exceed 5%.

Numerous measurements were performed on standard paper filters. The filter press OFITE LTLP 140-50 was used for this experiments.

Figure 2. Ceramic disc imitating a rock.

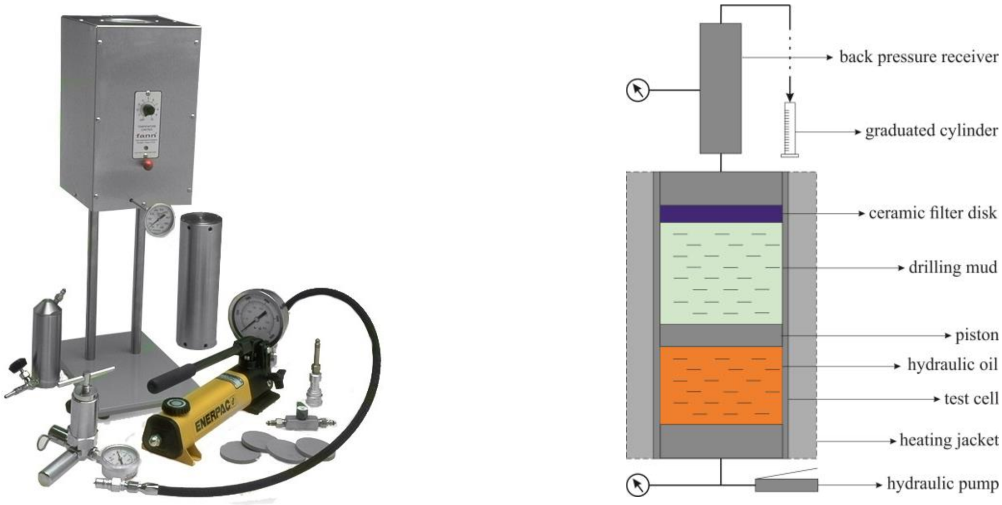


Figure 3. Filter press OFITE HPHT 171-01.

3. Result and Discussion

At first, the influence of the microparticles concentration on the drilling muids filterability was investigated. A series of measurements were on filters with a pore size of 3 and 20 μm. The concentration of AlN microparticles in muds varied from 0.5 to 4 wt.%. The results of the experiments are in Fig. 4, which shows the dependence of filtration losses of drilling mud 30 minutes after the start of filtration on the microparticles concentration. The dynamics of the change in the filtration losses versus time is shown in Figure 5. The filtration losses rise as the microparticles concentration increases. This is a well-known fact [8]. The drilling mud forms a cake of clay particles and microparticles on the filter surface. In this case, the microparticles are stacked between the clay cups making the filter cake more permeable and friable. The filter cakes formed by drilling mud with microparticles are shown in Figures 6a and 7a. The thickness of the cake rises as the microparticles concentration increases. The cake becomes more friable and permeable to the drilling mud. The filtration rate rises as the microparticles concentration increases. Comparison of diagrams 4a and 4b shows that the filtration losses really increase with rising filter pore size. Further, an effect of nanoparticles addition to drilling muds with microparticles was studied. 2 wt.% SiO2 nanoparticles with an average size of 5 nm were supplemented to each muds. Thus, drilling muds with the microparticles concentration from 0.5 to 4 wt.% and the nanoparticles concentration of 2 wt.% were obtained.

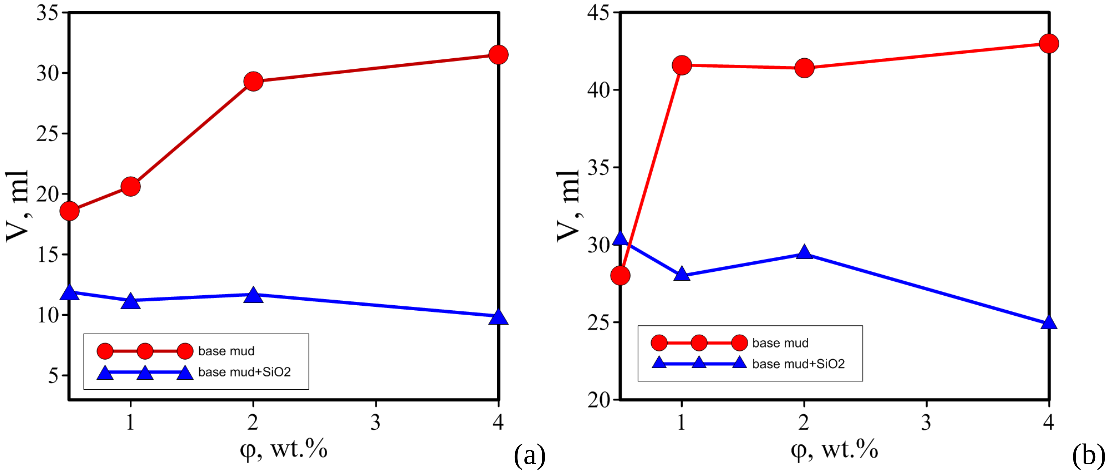
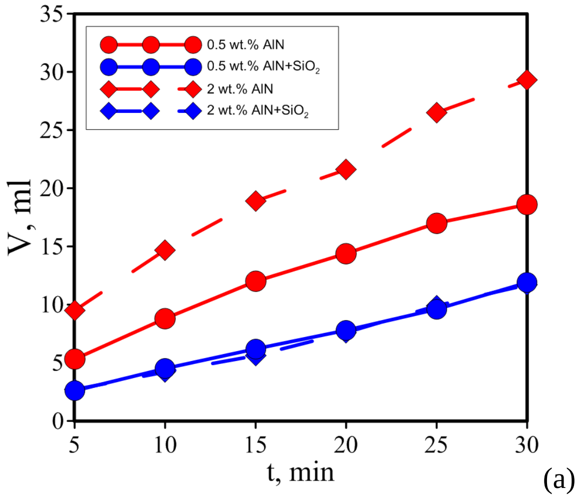


Figure 4. The filtration losses of microsuspensions with the nanoparticles addition as function of the AlN microparticles concentration and the pore size of ceramic filters. (a) – 3 μm, (b) – 20 μm.



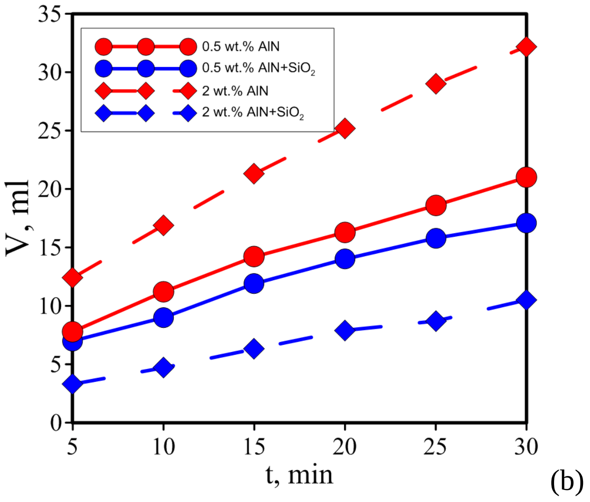


Figure 5. The filtration losses of microsuspensions with AlN addition as function of the time and pore size of ceramic filters. (a) – 3 μm, (b) – 20 μm.

Figures 4-5 show that the nanoparticles addition leads to a significant reduction in filtration losses for all microparticles concentrations. At the same time, the filtration losses decrease more strongly with increasing concentration of microparticles. It had been found that the reduction in filtration losses with nanoparticles addition to the mud is enhanced as the pore size decreases. The nanoparticles addition works particularly effective for poorly permeable cores with pore sizes of 3 μm. Here, a threefold decrease in the filtration rate was obtained in comparison with the base mud. This is very important for practical application. It is important to note that the nanoparticles addition affects the structure and thickness of the cake formed on the filter surface. Photos of cake on a paper filter with nanoparticles addition to the mud are shown in Figures 6b and 7b. Obviously a friable mass, consisting of clay particles and AlN microparticles, remains on the the filter surface for a mud without the nanoparticles addition. This cake is about 1-2 cm thick. The nanoparticles addition results in the formation of a dense and uniform cake 2-3 mm thick. The adhesion of the cake to the filter is high.

In our opinion the physical mechanism for reducing the filtration loss with nanoparticles addition to the drilling mud is related to a change in the permeability of the filter cake. An easily permeable filter cake from the microscopic particles of the standard filtering depressant and clay particles is formed on the filter surface without nanoparticles. The nanoparticles addition leads to the pores filling in the filter cake and makes it more dense and poorly permeable.

(a)

(b)

Figure 6. Photos of filter cake for a base mud with an AlN of 0.5 wt.% to (a) and after (b) the addition of SiO_2 2 wt.%.

(a) (b)

Figure 7. Photos of filter cake for a base mud with an AlN of 4 wt.% to (a) and after (b) the addition of SiO_2 2 wt.%.

4. Conclusion

Thus in this study, a systematic investigate of the effect of the nanoparticles addition on the filtration losses of water-based drilling muds were carried out. It was shown that the nanoparticles addition to the drilling mud significantly reduces filtration losses. In this case, this effect depends on the microparticles concentration and is most significant for rocks with low permeability. This is a good outlook of using nanoparticles to control the filtration characteristics of drilling muds.

5. References

[1] Stepanov N V 1989 *Modeling and forecasting of complications when drilling boreholes* (Moscow: Nedra) P 252

[2] Evdokimov I N 2016 *"Nano-fluids" and "smart fluids" in the technologies of development of oil and gas fields* (Moskow: M Nedra) P 247

[3] Ismail A R, Seong T C, Buang N A and Sulaiman W R W 2014 Improve Performance of Water-based Drilling Fluids Using Nanoparticles *5th Sriw. Int. Sem. on Ener. and Envir. Sci. and Tech.* 43-47

[4] Shakib J T, Kanani V, Pourafshary P 2016 Nano-clays as additives for controlling filtration properties of water–bentonite suspensions *J. Petr. Science and Eng.* **138** 257-64

[5] Mahmoud O, Nasr-El-Din H A, Vrysas Z and Kelessidis V C. Nanoparticle-Based Drilling Fluids for Minimizing Formation Damage in HP/HT Applications 2017 *J. SPE* 178949-MS

[6] Ponmani S, Nagarajan R and Sangwai J S 2016 Effect of Nanofluids of CuO and ZnO in Polyethylene Glycol and Polyvinylpyrrolidone on the Thermal, Electrical, and Filtration-Loss Properties of Water-Based Drilling Fluids *J. SPE* **21** 178919-PA

[7] Rudyak V Ya, Minakov A Vand Pryazhnikov M I 2016 *J. Appl. Phys. Let.* **42** 9-16

[8] Peng S J 1990 *Filtration properties of water based drilling fluid* (Ph.D. Thes. Subm. to Heriot-Watt Univ.) P 325

The reported study was funded by Russian Science Foundation to the research project №17-79-20218.