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Research Paper

Evaluation of the Effect of Metal Oxide Nanoparticles in Combination with Polyacrylamide on Improving the Filtration and Rheological Properties of Drilling Fluids

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Abstract: Drilling fluid properties and determination of its appropriate formulation are very important for the success of drilling operations. In this study, the effect of hydrophilic silicon oxide nanoparticles and iron oxide in combination with polyacrylamide on the rheological and filteration properties of water-based drilling mud was investigated. Silica and iron oxide have been used as nanomaterials due to their abundance and economical advantages. Material characterization was performed using X-ray diffraction analysis (XRD), scanning electron microscope (SEM), and Fourier Transform Infrared Spectroscopy (FTIR). Rheological properties including plastic viscosity and gel strength were measured at different concentrations of polymer and nanoparticles. Moreover, the effect of additives on the mud filtrate and mud cake quality was evaluated. The results showed that the presence of silicon oxide nanoparticles can improve the rheology of drilling mud up to 15% at a concentration of 1 wt %. The viscosity increased due to the separation and dispersion of clay plates. Furthermore, the results indicated that the addition of iron oxide nanoparticles did not have a significant effect on rheology. On the other hand, the addition of polymer caused a significant increase in viscosity and gel strength of drilling mud. The obtained results showed that due to the interaction of clay plates with silica nanoparticles, the gelatinous properties of drilling mud decrease at low concentrations of nanoparticles. The results of the filtration test showed that the addition of polymer and nanoparticles to the drilling mud causes a further decrease in the filtration rate at lower concentrations of the polymer. This effect is due to the clogging of mud cake pores by nanoparticles in the presence of polymer, so that with the simultaneous addition of nanoparticles and polymer, the mud filtrate was decreased from 128 cc to 14 cc.

Keywords: Drilling mud, Nanoparticles, Rheological properties, Filtration control.

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INTRODUCTION

The proper selection of drilling fluids plays an important role in determining and completing the efficiency of any drilling operation. With the increase in the number of ultra-deep wells that have been drilled, the behaviour of inexpensive water-based drilling fluids with less potential for pollution in high temperature conditions should be investigated more accurately [1]. The rheology of drilling mud is one of the most important parameters in controlling the pressure drop, cleaning the well, optimizing the drilling hydraulics, and cooling and lubricating the drill string. Drilling mud filtration are other important propertyiesthat control the penetration of the mud filtrate into the formations and are affected by the rheology of the drilling mud [2-5]. The formulation of drilling mud should be determined in such a way that the filtration properties are enhanced in order to reduce the formation damage. Also, the thickness of the mud cake formed on the wellbore wall should be kept at a minimum value in order to avoid the drill pipe stuck. In this research, the development of a polymeric fluid containing nanoparticles as a drilling mud was investigated. The presence of nanoparticles in the drilling mud causes a decrease in filtration loss by using the pore blocking mechanism and reducing the internal permeability of mud cake. In addition, as drilling mud is mainly composed of clay particles, the presence of nanoparticles with different surface charges causes changes in filtration properties. The clays in drilling mud are mainly aluminosilicates such as bentonite, which react with nanoparticles due to their surface charges. This may have negative or positive effects on the filtration properties, which can be achieved by controlling the surface properties of nanoparticles such as changing the surface charge or making the particles hydrophobic [6-8]. Hassani et al. investigated the modified drilling fluid properties by adding nanoparticles to the drilling mud. They showed that nanoparticles cause better rheological properties at higher pressure and temperature. The tested nanoparticles have higher thermal conductivity and also, due to the repulsive force between the clay particles in the drilling mud, they cause better rheology control. The results of their studies showed that the use of nanotechnology improves the performance of drilling fluids [9]. Abdo and Haneef modified drilling fluids using clay nanoparticles for drilling deep hydrocarbon wells [10]. Fazelabdolabadi et al. synthesized hybrid carbon nanotubes/multilayers to investigate the thermal conductivity of related nanomaterials. They reported the effects of nanoparticle concentration on increasing the effective thermal conductivity of nanofluids [11].

METHODS

In this study, the bentonite clay sample was prepared from a drilling platform in one of the fields in southern Iran. The XRD analysis was used to determine the number of different compounds in the bentonite sample and to identify the bentonite crystal structure. Silicon oxide (SiO_2), iron oxide (Fe_3O_4), and polyacrylamide were obtained from Sigma Aldrich. SEM imaging was implemented to determine the size and morphology of nanoparticles. In order to determine the structure and type of molecular bonds on the surface of nanostructures, FTIR analysis was used. At first, the base drilling fluid was prepared as a reference to compare the effect of different additives. To prepare the base fluid, a certain amount of bentonite was added to the water so that the fluid contains 10 wt% of bentonite. Then, the rheology and filtration properties of the based mud were measured. After that, polymer additives and nanoparticles were added in certain concentrations to the base fluid and the changes in its characteristics were investigated. Table 1 shows the formulation of different mud samples.

Fann viscometer was used to investigate the effects of nanoparticles and polymer on the rheology of different mud samples. API standard filtration device at 100 psi pressure and ambient temperature was also used to determine the filtration properties of drilling mud such as total mud filtrate loss and mud cake thickness.

FINDINGS AND ARGUMENT

Figure 1A shows the variations of shear stress in terms of shear rate for the mud sample containing silicon oxide nanoparticles. As shown, for low concentrations of nanoparticles (SM1 to SM3), the rheology is lower than the base fluid, while for higher concentrations, it is higher than the base fluid, which means the improvement of rheology properties at high concentrations of nanoparticles. Figure 1B shows the variations in the rheological properties of mud containing iron oxide nanoparticles. As can be seen, in different concentrations of iron oxide, the rheology does not change significantly compared to the base fluid. Finally,

Table 1. Formulation of different mud samples

Sample	Formulation
BF	Water+10%wt Bentonite+%0.4wt Salt
MS1	BF+0.2%wt nano silica
MS2	BF+0.4%wt nano silica
MS3	BF+0.6%wt nano silica
MS4	BF+0.8%wt nano silica
MS5	BF+1%wt nano silica
MS6	BF+0.5%wt nano iron oxide
MS7	BF+1%wt nano iron oxide
MS8	BF+1.5%wt nano iron oxide
MS9	BF+2%wt nano iron oxide
MS10	BF+0.1%wt PAM
MS11	BF+0.2%wt PAM
MS12	BF+0.3%wt PAM
MS13	BF+0.4%wt PAM
MS14	MS5+0.4%wt PAM
MS15	MS9+0.4%wt PAM

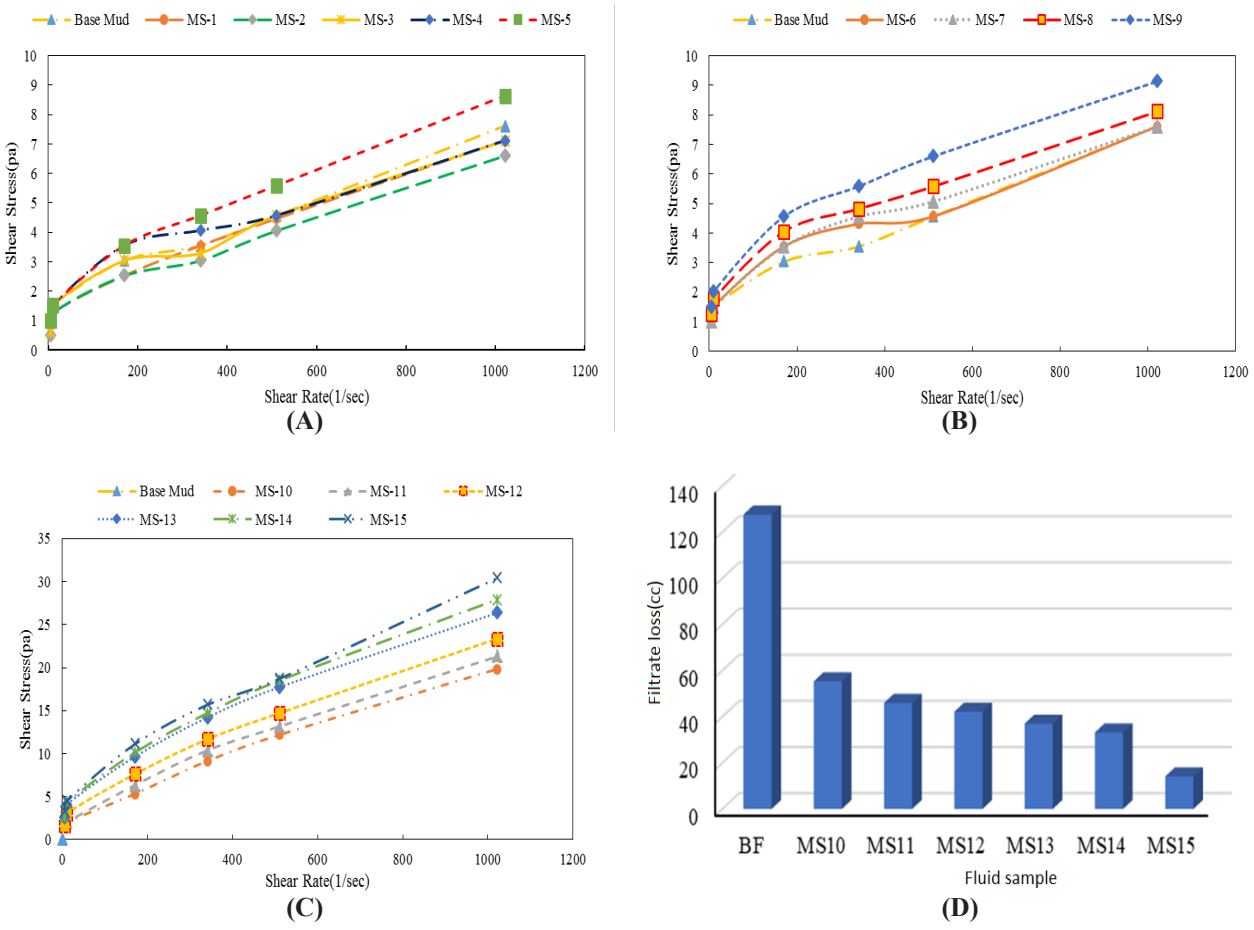

Figure 1. A: Rheological behavior of drilling mud containing silicon oxide nanoparticles at different concentrations, **B:** rheological behavior of drilling mud containing iron oxide nanoparticles at different concentrations, **C:** rheological behavior of drilling mud containing polymer and nanoparticles at different concentrations, **D:** total filtrate loss for different fluid samples with nanoparticles and polymer

the variation in the rheological properties of drilling mud containing polymer and different nanoparticles are shown in Figure 1C. As can be seen, the rheology of the samples containing polymer has increased considerably compared to the base fluid, and the addition of nanoparticles causes it to increase further. Figure 1D shows the variations in the filtration properties of mud samples containing nanoparticles with polymer compared to the base fluid under static conditions. As can be seen, the addition of polymer increases the viscosity and thus decreases the filtration behavior, which in combination with iron has shown the minimum amount of filtration.

CONCLUSIONS

In this study, the effect of hydrophilic silicon oxide and iron oxide nanoparticles in combination with polyacrylamide in the water-based drilling mud were investigated in order to control filtration and rheological properties. The results showed that the presence of silica nanoparticles can increase the rheological properties of drilling mud at a concentration higher than 1wt% where an increase in mud viscosity was observed up to 15%. The results showed that adding iron oxide nanoparticles to the water-based drilling fluid has a low effect on the rheological properties. Moreover, adding polymer to water-based drilling fluid caused a significant increase in its viscosity and gelatinization. Also, the obtained results showed that the gelatinous properties of drilling mud decrease in low concentrations of silica nanoparticles, which can be due to the interference of surface charges of clay plates with nanoparticles. The results of filtration showed that the use of silicon and iron oxide nanoparticles in combination with polymer has the ability to reduce the filtration rate more than the use of polymers itself where the mud filtrate loss decreased from 128 cc to 14 cc. The SEM images of the surface of the mud cake samples showed that the presence of polymer in combination with nanoparticles well blocks and covers the pores in the mud cake surface and reduces its permeability. Using the formulation presented in this research for water-based drilling muds can reduce formation damage and improve hole cleaning properties with minimum cost.

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