Formation-Damage Assessment and Filter-Cake Characterization of Ca-Bentonite Fluids Enhanced with Nanoparticles

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Abstract

Invasion of mud filtrate while drilling is considered one of the most common sources of formation damage. Minimizing formation damage, using appropriate drilling-fluid additives that can generate good-quality filter cake, provides one of the key elements for the success of the drilling operation. This study focuses on assessing the effect of using different types of nanoparticles (NPs) with calcium- (Ca-) bentonite on the formation-damage and filter-cake properties under downhole conditions.

Four types of oxide NPs were added to a suspension of 7-wt% Ca-bentonite with deionized water: ferric oxide (Fe2O3), magnetic iron oxide (Fe3O4), zinc oxide (ZnO), and silica (SiO2) NPs. The NPs/Ca-bentonite suspensions were then used to conduct the filtration process at a differential pressure of 300 psi and a temperature of 250ÅF using a high-pressure/high-temperature (HP/HT) American Petroleum Institute (API) filter press. Indiana limestone disks of 1-in. thickness were examined as the filter medium to simulate the formation in the filtration experiments. A computed tomography (CT) scan technique was used to characterize the deposited filter cake and evaluate the formation damage that was caused by using different fluid samples.

The results of this study showed that the filtrate invasion is affected by the type of NPs, which is also affecting the disk porosity. Using 0.5-wt% Fe2O3 NPs with the 7-wt% Ca-bentonite fluid showed a greater potential to minimize the amount of damage. The average porosity of the disk was decreased by 1.0%. However, adding 0.5-wt% Fe3O4, SiO2, and ZnO NPs yielded a disk-porosity decrease of 4.7, 13.7, and 30%, respectively. The decrease in the disk porosity after filtration is directly proportional to the volume of the invaded filtrate. Compared with that of the base fluid, the best decrease in the filtrate invasion was achieved when adding 0.5 wt% Fe2O3 and Fe3O4 NPs by 42.5 and 23%, respectively. The results revealed that Fe2O3 and Fe3O4 NPs can build a better Ca-bentonite platelet structure and thus a good-quality filter cake. This is because of their positive surface charge and stability in suspensions, as demonstrated by zeta-potential measurements, which can minimize formation damage. Increasing the concentration of Fe3O4 NPs from 0.5% to 1.5 wt% showed an insignificant variation in the filtrate invasion, spurt loss, and filter cake permeability; however, an increase in the filter-cake thickness and amount of damage created was observed. The 1.5-wt% ZnO NPs showed better performance compared with the case having 0.5-wt% ZnO NPs, but in the meanwhile, it showed the lowest efficiency compared with the other types of NPs. This could be because of their surface charge and suspension instability.

Results of this work are useful in evaluating the drilling applications using Ca-bentonite-based fluids modified with NPs as an alternative to the commonly used Na-bentonite. In addition, it might help in understanding the NPs/Ca-bentonite interaction for providing more efficient drilling operations and less formation damage.

Society of Petroleum Engineering (SPE) 2020, July