Development and Testing of Novel Drilling Fluids Using Fe2O3 and SiO2 Nanoparticles for Enhanced Drilling Operations

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Abstract
Access to deeper oil and gas reservoirs in hostile environments necessitates improvement of existing drilling fluids. This work focuses on the lab techniques for developing, assessing and analyzing innovative water-based drilling fluids containing iron oxide (Fe2O3) and silica nanoparticles (SiO2).

The fluid loss characteristics were examined both in an American Petroleum Institute (API) static filter press and in a High Temperature-High Pressure (HTHP) filter press under elevated pressures and temperatures (300 psi/250°F). A computed-tomography (CT) scan was used for deep analysis of the filter cake. Scanning Electron Microscopy (SEM) was used to analyze the morphology of the filter cake as well as to give deep insights for their microstructure, the interfacial phenomena and the interaction between bentonite particles and the nanoparticles. Inductively Coupled Plasma (ICP) mass spectrometry was used to determine the quality of the produced filtrate. Zeta potential measurements were used to assess the stability of the developed suspensions. The changes in the rheological properties of the nanofluids were measured at HT conditions using a standard Fann type viscometer.

Significant modifications have been observed with the addition of nanoparticles to the base fluid of water-bentonite suspension in rheological and filtration characteristics. The rheological analysis showed an increase of the yield stress and of the gel strength as the concentration of nanoparticles was increased. Both the API static and the HTHP filter press indicated a remarkable improvement in the fluid loss and filter cake characteristics for the samples containing iron oxide nanoparticles. For samples containing silica nanopowder, there was an adverse effect on the fluid loss characteristics with minor changes in the rheological profile.

The filtration efficiency was reduced with the increase of the concentration of Fe2O3 nanoparticles which was confirmed by CT scan measurements. Results revealed that 0.5% (w/w) is the optimal concentration for the Fe2O3 nanoparticles, above which they form a new layer in the filter cake that adversely affected the fluid loss and filter cake characteristics. SEM and ICP measurements confirmed this phenomenon and revealed the agglomeration effect and the smooth surface of the produced filter cakes. Zeta potential measurements at different concentrations and temperatures of the produced nanofluids showed that the iron oxide nanoparticles were stable in colloidal suspensions, whereas silica nanopowder was unstable under different temperatures.

The examined nanoparticles have the potential to significantly improve the characteristics of the filter cakes at both low temperature-low pressure (LTLP) and HTHP conditions. They also have the ability to maintain optimal rheological properties so that many drilling problems can be efficiently mitigated. Their low concentration in the drilling system, compared to other conventional drilling additives, provides a basis for more efficient drilling practices.

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