A comprehensive approach for the development of new magnetite nanoparticles giving smart drilling fluids with superior properties for HP/HT applications

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Abstract
Commercial hematite (Fe2O3) and magnetite (Fe3O4) nanoparticles (NPs) had been used as additives to develop smart drilling fluids. Both types of NPs were found to enhance the properties of such fluids. This work focuses on using a custom-made (CM) magnetite (Fe3O4) NPs to improve the properties of bentonite-based fluids. The microstructure qualities and mode of interaction have indentified, which help in optimizing the rheological and fluid loss properties of drilling fluids.

Rheological properties of the tested fluids were measured using a rotational viscometer at different temperatures up to 60°C (140°F) and atmospheric pressure. Step-change shear rate measurements revealed the degree of thixotropy of the produced suspensions. Fluid loss characteristics were examined under 20.7 bar (300 psi) and 121°C (250°F). Both rheological and fluid loss measurements were also conducted using fluids that are thermally aged at 177°C (350°F) for 16 hrs. Filter cake surface morphology was evaluated using scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS). Bentonite composition was examined by X-ray diffraction (XRD) and X-ray fluorescence (XRF). A superconducting quantum interference device (SQUID) magnetometer was used to measure the magnetic properties of the CM Fe3O4 NPs, and their size was determined using transmission electron microscopy (TEM).

The CM Fe3O4 NPs, which were synthesized by co-precipitation method, have average diameter of 6-8 nm, as indicated by TEM. Magnetic measurements revealed their superparamagnetic behaviour with saturation magnetization of 60 emu/g. For all the tested samples, the Herschel-Bulkley (HB) model was determined to be the best fit model with good correlation coefficient (R² > 0.99). Yield stress, viscosity, and gel strength of the tested fluids showed significant improvement when adding the CM Fe3O4 NPs, which could be a result of the rigid network formed. A linear dependence of yield stress on temperature of the produced nanofluids (NF) was identified. Adding the CM Fe3O4 NPs at 0.5 wt% showed optimal rheological and filtration characteristics. Dynamic thermal aging adversely affects the properties of base fluid. However, the NF maintained its extraordinary rheological and filtration behavior. SEM-EDS analysis revealed the microstructure of the produced filter cake.

The better performance of the CM Fe3O4 NPs can be attributed to their extremely small size, which confer stability in suspensions and effective linking with the bentonite particles, thus allowing the formation of a rigid microstructure network. Such approach introduces the synergistic interaction of components to produce a water-based drilling fluid system with excellent fluid loss characteristics and optimal rheological properties for HP/HT applications.

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