Settling of barite particles in oil-based drilling fluids

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Keywords: Weighting material, Oil-based drilling fluid, Rheometry, Gamma densitometry

Abstract

Controlling the downhole pressure is an important parameter for successful and safe operation of the drilling operation. The drilling fluid density is an important design parameter for preventing the fluid formation and gas entering the wellbore. Several types of weighting agents, barite in the present work, are added to maintain the desired density of the drilling fluid. The uneven density distribution of the barite, which can lead to a density variation as high as 0.5 kg/L (4 lbs/gal) (Tehrani et al. 2011), is caused by the settlement of barite or other weighting materials in the well bore. This paper presents the rheological properties of the drilling fluid measured using a rheometer and estimated rates of barite particle settlement in an oil-based drilling fluid using gamma-ray densitometry for the first time. Experiments were performed in a static cell (with no shear) and in a Taylor Couette cell (with low shear stress). Further, an attempt has also been made to relate the rate of barite particle settling to the rheological properties of the drilling fluid.

Introduction

Mechanical friction and the transport of cuttings are two significant parameters for successful drilling operation, which requires the adjustment of density and viscosity profiles to match the well conditions. Settling of barite particles, also referred to as barite sag, is persistent and a potentially serious problem that can occur during the oil wells drilled with weighting muds. This complex phenomenon is comprised of both static and dynamic settling of weighting agents to the low side of the wellbores, which can be related to the settling of particles in a fluidized bed. The formation of a high-density fixed bed and subsequent recirculation in the drilling fluid can lead to severe operational problems such as loss of control, lost circulation and stuck pipe, etc. (Zamora and Bell, 2004).

Several different phenomena such as static settling, dynamic settling and slumping can contribute to barite sag. The sag tendency is found to be more pronounced in inclined wells and known as Boycott effect (Bern et al. 1996). The sag potential is found to be affected by the operational and design parameters such as hole diameter, hole angle, well bore length, mud viscosity, weighting particle size and shape, drill pipe rotation, and so on. Among these parameters, controlling the rheological properties of the drilling fluid has a profound effect on minimizing the sag potential. Although the sag potential is a complex phenomenon, it appears to correlate with low shear rheology.

Several researchers such as Saasen et al. (1995), Bern et al. (1998) and Dye et al. (2003, 2006) tried to quantify the barite sag phenomenon in drilling fluids. Saasen et al. (1995) reported that sag may occur rapidly in a drilling fluid that has fragile gel forming structure. Dye et al. (2003, 2006) found that the dynamic sag occurs at shear rates less than $4 s^{-1}$, and it increases with an increase in the well inclination from 40° to 60°. Bern et al. (1998) proposed a model to predict the barite sag and the proposed model was able to fit a wide range of experimental data. Though there are several publications reported, no publication discusses the relation between barite sag and rheological properties of the drilling fluid. Hence in the present work, an attempt has been made to relate the static and dynamic sag potentials with the rheological properties of the oil-based drilling fluid.

Experimental Facility

An oil-based drilling fluid sample, obtained from MI Swaco, was subjected to a pre-shear of 6000 RPM for the duration of 10 mins. A high shear homogenizer (Silverson L-5 M A) was used to mix the drilling fluid. The well-mixed drilling fluid sample was used for both rheological and gamma densitometry measurements.

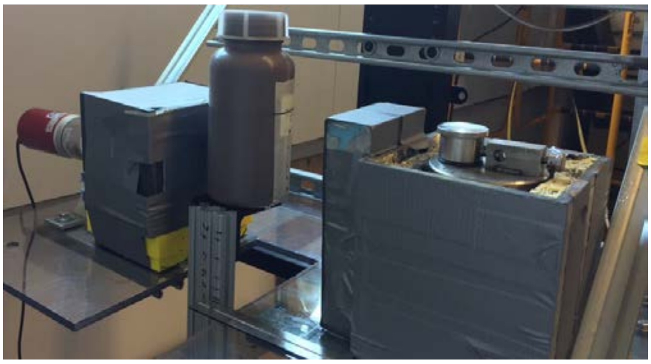

Figure 1: Photograph of the test facility, depicting gamma detector, gamma source and drilling fluid sample.

The rheological properties of the drilling fluid were characterized using the variable temperature rheometer (TA Instruments Model ARES G2) with cup-and-bob geometry. The diameters of the bob and cup were 28 mm and 30 mm, respectively, with a minimum sample volume of 25 ml.

A Cesium 137 isotope was used as a gamma source and NaI scintillation detector was used to measure the transmitted gamma radiation. 2-inch thick lead collimators on both the detector and source sides were used to create a 3 mm pencil beam (Fig. 1). The gamma beam scans were performed at four different axial locations from the bottom of the test sample. Changes in the fluid density were measured using Beer Lambert's law:

$$I = I_0 e^{-\mu L} \tag{1}$$

where I is the intensity of a gamma beam transmitted through a drilling fluid sample in a container, I_0 is the gamma beam intensity transmitted through the same container filled with water, and L is the path length of the gamma beam through the container. The parameter μ is the attenuation coefficient which is proportional to the drilling fluid density.

Results and Discussion

Figure 2 shows the variation of drilling fluid's viscosity with the shear rate (0.01-1000 S^{-1}) and temperature (10 -70 ºC). A shear thinning effect with the existence of yield stresses is observed at all temperatures, as indicated by the decreasing slope of the stress profile with an increase in shear rate. The temperature dependency is also clearly visible as the viscosity decreases exponentially with increasing temperature.

Figure 3 shows changes in the fluid density at different axial locations of the drilling fluid sample. It is clear from the figure that the fluid density decreases at an axial location of 6 cm (near the top of the container) with time. The decrease in fluid density is observed due to the gravitational settling of high-density barite particles. On the other hand, the fluid density increased with time at lower axial locations (1, 3 and 5 cm from the bottom). Interestingly, the increment in the fluid density is approximately the same at all three axial locations, and it can be attributed to the gel forming nature of the drilling fluid. The rate of change in the density can be correlated to the sedimentation rate, and it will be discussed in the full paper. Additionally, the multiphase flow characteristics of the drilling fluid in well bores will be examined in terms of the rheological and barite sag properties.

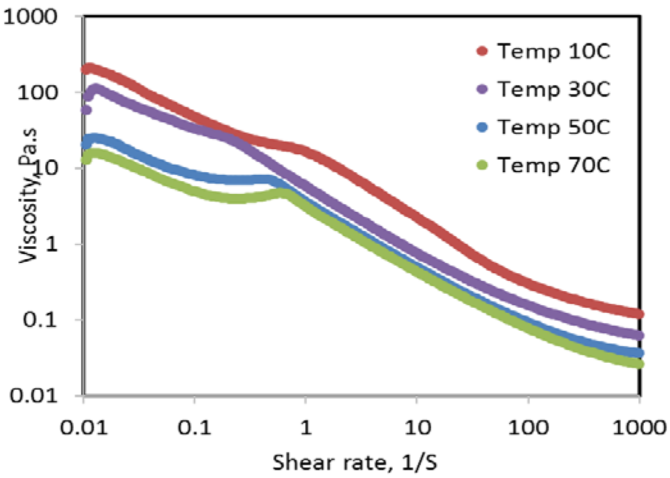

Figure 2: Viscosity of the drilling fluid varying with shear rate and temperature.

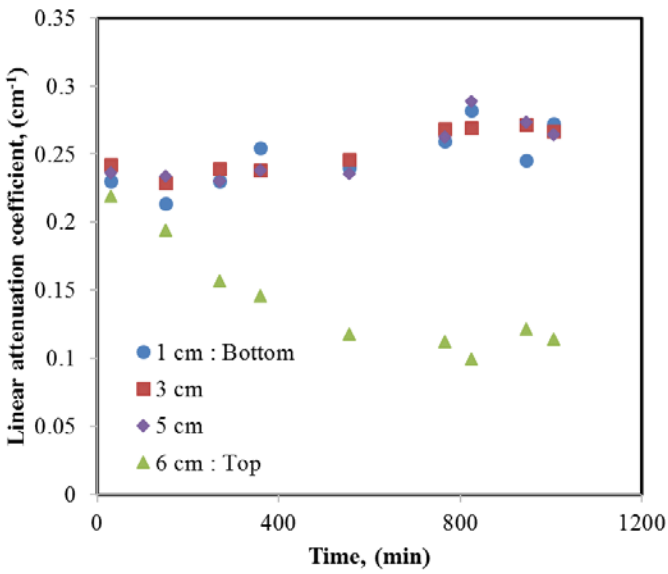

Figure 3: Change in linear attenuation with respect to time. Legend: Distance from the bottom of the test sample.

Conclusions

Preliminary rheological measurements of the oil-based drilling fluid have been performed. Experiments at different shear rate and temperature ramps revealed a shear thinning behavior. A temperature dependence was also observed in the viscosity data. A barite sag phenomenon in oil-based drilling fluid was experimentally investigated under static conditions using gamma densitometry. A gradual reduction in the density of the drilling fluid sample was observed at the top of the test cell indicating barite particle sedimentation with time.

Acknowledgments

This work was conducted under the Partnerships for International Research and Education (PIRE) project supported by the US National Science Foundation under Award Number 1743794.

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