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RESEARCH PAPER

Extending thermal stability of calcium carbonate pills using sepiolite drilling fluid

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Abstract: The aim is to investigate the plugging ability of sepiolite clay water base drilling fluids over a wide range of high permeable zones at high temperature and high pressure conditions. The special emphasis of this study is to extend the usage of loss preventer material (LPM) as a component of fresh water sepiolite base mud that has never been investigated for this purpose before. The rheology and loss tests at 27–204 °C and 2070 or 6895 kPa revealed that the sepiolite drilling mud shows good rheology and high solid suspension capability at all temperatures except 149 °C, and low loss circulation at high temperature and high pressure. The Permeability Plugging Apparatus (PPA) experiment, in which the 10–90 μm permeable ceramic plate was simulated as formation, showed that the sepiolite drilling mud without $CaCO_3$ can not plug the pores, while the sepiolite drilling mud with $CaCO_3$ can plug the pores quickly and keep the $CaCO_3$ particles suspended even at high temperature (up to 193 °C). The PPA experiment results were proved by the analysis using SEM and ideal packing theory.

Key words: sepiolite drilling mud; loss circulation; plugging performance; thermal stability; calcium carbonate particle; HTHP drilling

Introduction

Lost circulation, one of the most common drilling problems, would increase drilling costs and drilling risks, and cause other issues. Statistics show USD $2 to 4 billion each year is spent on plugging drilling fluid and materials around the world[1]. The circulation loss problem constitutes important portion of total NPT. According to US Department of Energy, on average 10% to 20% of the drilling cost in high temperature high pressure (HTHP) wells was spent on mud loss control[1]. For water base mud systems, high temperature causes clay particles to flocculate, and thus unacceptable high viscosity, water loss and excessive thick filter cake, and possibly more rapid mud loss. Moreover, high pressure differential between the mud hydrostatic and formation pore pressure make the loss circulation risk increase. Lost circulation can cause formation damage and production reduction, which could be serious in complex formation conditions. Lost control materials (LCMs) can effectively plug unconsolidated and fractured formations, and play an important role in stopping lost circulation. Moreover, stable and economic drilling fluid under high temperature and pressure is needed to extend the usage of LPMs. Commonly used Water-base drilling fluids have poorer stability at temperatures above 121 °C (250 °F); and synthetic-base muds are high in cost[2]. Sepiolite is a magnesium silicate clay mineral of fibrous texture. Altun et al found through experiment[3–6] that sepiolite drilling fluid could keep good rheology under high temperature. Adding calcium carbonate into bentonite drilling fluid as LCM is very common now, but there are few studies on adding it into sepiolite drilling fluid as LCM. In this study, the plugging ability of the sepiolite base drilling fluids with and without $CaCO_3$ pills have been tested in lab to find out if the sepiolite mud can enhance the thermal stability of $CaCO_3$, and thus prevent lost circulation effectively.

1. Experiment method and materials

1.1. Preparation of mud

The sepiolite clay used in this study is a raw clay sample (commercial product known as Turk Taciri Bej (TTB)) bought from AEM Company (AEM, 2015) near Sivrihisar-Eskisehir district of Turkey. The raw sepiolite clay sample was sieved to <200 mesh (<74 μm) after grinding with no physical or chemical treatment. X-ray Fluorescence Spectrometry (XRF) was used to perform elemental analysis of the sepiolite clay. The test conditions of measuring the sample purity and characterizing crystalline materials of sepiolite clay are defined in reference [3]. The formulas of sepiolite base drilling fluids are given in Table 1, in which there are some technical additives:

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Table 1. Formulas of sepiolite base mud systems

Materials	Quantity (kg/m^3)	
	Base mud	Base mud with $CaCO_3$
Sepiolite	57	57
Soda Ash	0.286	0.286
Polymer-1	11.43	11.43
Polymer-2	14.28	14.28
Calcium Carbonate	None	57

pH was controlled by the sodium carbonate (soda ash, Na_2CO_3, product of Karakaya); an anionic acrylic copolymer (polymer-1, product of Halliburton) was added as a thinner to ensure the thermal rheological stability; and a vinyl amide/vinyl sulfonate copolymer (polymer-2, product of Halliburton) was used as a filtration control agent.

Couette type viscometer (Fann Model 35SA/SR-12) was used to measure rheological properties such as apparent viscosity, plastic viscosity (PV), yield point (YP), and gel strength (GS). HTHP filter press (Fann 500 ml HTHP filter press) was used to test the static filtration properties of the samples at elevated temperatures. The pore plugging apparatus (PPA) made by Fann Instruments (No. 206846), was employed to investigate plugging ability and fluid loss of the sepiolite mud through porous media under upward pressure, because PPA can simulate the gravity effect on impermeable mud cake buildup under wellbore conditions. In the PPA, fluid loss can be measured with ceramic discs 6.35 cm (2.5 inches) in diameter and 0.635 cm (0.25 inch) thick. The prepared mud samples were tested with ceramic discs with pore diameters of 10, 20, 35, 60, and 90 micron (corresponding to 2, 5, 10, 20, 100 Darcy of air permeability) at differential pressures of 2070 kPa and 6895 kPa (300 and 1000 psi) and temperatures from 27 °C to 204 °C (400°F). $CaCO_3$ pills in the technical grade were added to the base mud as LPM. Particle size distribution of $CaCO_3$ was measured using ethanol as dispersant (Fig. 1). The test results show the $CaCO_3$ particles are wide in size distribution, and thus can provide effective pore sealing.

Standard procedures (API RP 13B-1, 2004) were followed throughout the experimental study[7]. First, fresh water-base un-weighted sepiolite (TTB clay) base drilling fluid was prepared according to the formulas given in Table 1. Then the sample was aged for 16 hours under heating condition. The mud sample was heated to 27 °C and 49 °C by heat jacket respectively, and then its rheological and HTHP filtration properties were measured. After that, plugging performance of the base mud sample without $CaCO_3$ was measured using PPA apparatus. Second, 57 kg/m^3 (20 lbm/bbl) $CaCO_3$ was added to the base mud system as LCM. Similarly, after hydrothermal treatment in an aging cell, the rheological properties of this mixture were measured. Finally, the plugging performance of this mixture was tested by PPA experiment.

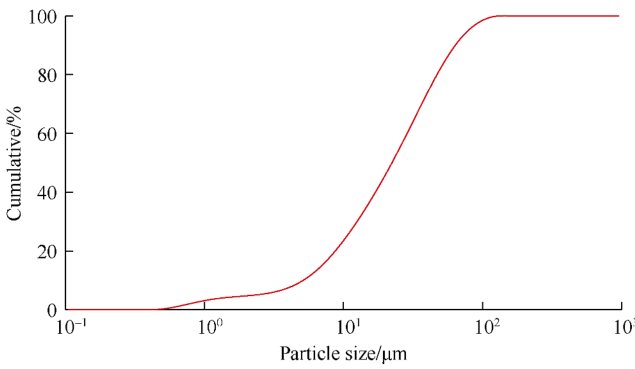

Fig. 1. Particle size distribution of $CaCO_3$.

1.2. Evaluation of PPA test results

Based on the results of PPA experiments, spurt loss, total fluid loss, and static filtration rate were calculated to qualitatively analyze the plugging performance of the mud samples.

The calculation equation of spurt loss[8] is:

$$V_0 = 2\left[V_{7.5} - \left(V_{30} - V_{7.5}\right)\right] \tag{1}$$

The total fluid loss is calculated by the following equation[8]:

$$V_{\text{total}} = 2V_{30} \tag{2}$$

Static filtration rate is the ratio of fluid loss to the square root of elapsed time, its calculation equation[8] is:

$$v = \frac{2\left(V_{30} - V_{7.5}\right)}{2.739} \tag{3}$$

Plugging index I_p indicating plugging efficiency of drilling fluid was introduced to evaluate the plugging performance at different temperatures, and it is calculated by Eq. 4:

$$I_p = \frac{V'_{30}(27) - V''_{30}(t)}{V'_{30}(27)} \tag{4}$$

The data collected after 5 minutes into the experiment was used in the calculation, evaluation and plotting to minimize the error.

1.3. Scanning electron microscopy (SEM) analysis

Plugging effectiveness of the fresh water sepiolite base mud was evaluated also using scanning electronic microscopy (SEM). The surface morphology of the new and used ceramic discs was observed by using a Quanta FEG 250 Microscope equipped with EDAX ZAF quantifier. After a light coating with gold, samples were observed with an FEI Quanta FEG-250 field emission environmental SEM (FE-ESEM) at magnifications ranging from 3500 to 3200,000 to determine the range of pore sizes present in each porous disc. Five representative areas (approximately 1 cm^2) in each pore discs were tagged for observation in order to acquire more accurate pore sizes. In order to find out plugging ability of the prepared mud samples with and without $CaCO_3$, the pore discs were characterized using image analysis software, ImageJ, to calculate the pore area before and after plugging test. First, the SEM images in JPEG format were converted to binary images, then, the binary images were analyzed with the ImageJ software to get a statistic table including the number of pores, percentage pore area, and analysis of the size of individual pores. In the computation of average pore diameter with