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FULL LENGTH ARTICLE

Effect of magnesium salt contamination on the behavior of drilling fluids

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Abstract The drilling engineer must have a good estimate of how the stability of drilling fluid changes due to salt contamination encountered during drilling operation. Two mud samples with different concentrations of magnesium chloride salt ($MgCl_2$) were formulated in order to study its effect on the rheological properties of drilling fluid at ambient and elevated temperature conditions. This study shows that the drilling mud efficiency is affected with temperature as the result of thermal degradation until the mud fails; it is observed that the Gypsum mud tolerates higher temperature than Lignite mud. It was concluded that the rheological properties such as viscosity, yield point, and gel strength of drilling mud decrease as the concentration of magnesium salt increases. This indicates that with the magnesium salt contamination, there is an advanced decline in the performance of drilling mud and the salt affects the dispersion, hydration and flocculation behavior of the particles which make it incompetent for cutting suspender. Also, it was observed that when the concentration of salt increases in the drilling mud samples the fluid loss into the formation increases.

1. Introduction

Drilling muds are mixtures of synthetic and natural chemical compounds that serve several fundamental functions. The most common functions are to cool and lubricate the drill bit, clean the hole bottom from cuttings generated by the drill bit and carry cuttings to the surface, help in the collection and interpretation of information available from cores, drilling cuttings, and electrical logs, Control downhole formation pressures, and avoid damage of the producing formation [1]. Selection of the proper type of drilling fluid by the engineer is based on the desired rheological properties keeping in view the borehole conditions. Water based drilling fluids are more economical and environmentally friendly, although they are highly sensitive to formation characteristics, promote clay swelling and hydration which lead to an increase in well construction costs [2]. Water based drilling mud classically contain viscosifiers, fluid loss control agents, lubricants, weighting agents, corrosion inhibitors, emulsifiers, and pH control agents. Also, oil is present in small amounts, while water usually present in high amounts exceeds half the volume of the entire composition.

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Drilling muds should be designed with several desirable characteristics to enhance the efficiency of the drilling operation. The most common characteristics are the rheological properties (like plastic viscosity, yield value, gel strengths and filter cake), stability under various operating conditions and stability against contaminating fluids [3]. Rheological properties of drilling mud can be affected by many factors during drilling operation like temperature, pressure (which are a function of drilling depth) and contaminants [2]. During drilling operation the drilling mud picks up contaminants such as salts, drill solids, and cement. Drilling mud contamination with salt can come from a formation water influx, or during drilling salt beds. At elevated temperatures the drilling mud remedy is often necessary because the mud may be unable to tolerate the contaminants [4]. The degree of drilling fluid efficiency and its performance in drilling operation are affected by its rheological properties so it is interesting to study the drilling mud rheological parameters and properties at the downhole conditions [5].

Amani et al. [3] compared the rheological properties of the two drilling mud types and the study showed that drilling fluid with stable rheological properties are required during drilling at elevated pressures and temperatures. Ali et al. [6] investigated the effect of NaCl salt contamination on the rheological properties of bentonite drilling mud and concluded that both plastic viscosity and the electrical resistivity were reduced with an increase in salt content. Basirat et al. [7] concluded that contamination increases the filter loss about 30% and decreases the resistivity by 86% compared to the same sample with no contamination. Hassiba and Amani [8] investigated the effect of different electrolyses on the viscosity of water based mud at different conditions. The study led to the conclusion that NaCl contamination increases the shear stress/shear rate curves of water based mud; whereas KCl contamination decreases the shear stress/shear rate curves of water based mud. Nagre et al. [2] studied the effect of polyelectrolyte in salt-free and salt contaminated drilling fluid systems. The polyelectrolyte is an excellent fluid-loss reducer and could be used as a stabilizer for bentonite-based drilling muds by providing good temperature resistance and anti-aging performance.

Many researchers have studied the effects of temperature and pressure on the drilling fluid properties [9,10]. Also the effect of salt contamination on the drilling fluid performance has been studied by some researchers [6,7,11], but few of them researched on the effect of magnesium salt contaminants on the drilling fluid properties [12]. The present study focuses on the effect of magnesium salt contaminants at different concentrations on the efficiency of two drilling fluid samples. The study was carried out at ambient and elevated temperature in order to study the effect of thermal temperature on the behavior of drilling mud.

2. Material and methods

Two samples have been prepared with same material concentration used according to the Daily Drilling Fluids Report of the South Oil Company, Basra, Iraq. These muds are Lignite and Gypsum mud. The material was supplied from the Midland Oil Company, Baghdad, Iraq. Table 1 shows the concentrations of materials used in the formulated drilling muds and the physical properties of Gypsum and Lignite drilling muds are shown in Tables 2 and 3 respectively.

Table 1 Types and concentrations of materials used in the formulated drilling muds.

Mud sample	Types of materials used in the preparation of mud	Materials concentration g/l
Gypsum mud	Bentonite	60–65
	Caustic soda + C.L (chrome lignite)	1.5–4.5
	Gypsum	22
	CMC (L.V)	6
Lignite mud	Bentonite	60–65
	Caustic soda + C.L (chrome lignite)	1–3
	Barite	20
	CMC (L.V)	4–6

The principal additives used in formulating and maintaining gypsum mud are as follows: Bentonite range from 60 to 68 g/l, gypsum range from 11 to 22 g/l, addition of caustic soda to maintain the pH within the range 9.5–10.5, and starch range from 5.5 to 17 g/l [13].

Typical properties of Lignite water-based fluid systems are characterized by a pH range of 9–11.5, and API filtrate from 4 to 12 depending on the density of drilling fluids. Whereas Gypsum muds typically have a pH range of 9.5–10.5, and API filtrate from 6 to 12. A temperature of 350°F is usually considered to be the upper limit for well drilled gypsum fluids. The other rheological properties of Lignite and Gypsum fluid systems depend on the conditions and concentrations required in the formulated drilling muds [13,14].

The mud systems were formulated and to mix the materials of mud samples, the mud mixer was used to ensure homogeneous mixture. To determine the effect of magnesium salt on the mud rheological properties two concentrations of $MgCl_2$ salt (1.5 wt% and 5 wt%) were added systematically to the formulated mud systems. The mud properties were measured before and after salt addition at 86 °F, 100 °F, and 200 °F. The experiment was carried out in phases with the mud volume of 350 cm^3. The rheological measurements were made on fluids, such as viscosity, gel strength, yield point using OFI Testing Equipment, Inc. 8 Speed Viscometer (Model 800), USA. The equipment as shown in Fig. 1A is a coaxial cylindrical rotational Viscometer and can be used to determine single- or multi-point viscosities. It has 8 fixed speeds of (600, 300, 200, 100, 60, 30, 6, and 3) RPM that are switch selectable with the RPM knob.

The Plastic viscosity and Yield Point have been calculated as follows:

$$\text{Plastic viscosity } (\mu p) \text{ in (cp)} = 600 \text{ RPM reading} - 300 \text{ RPM reading} \quad (1)$$

$$\text{Yield point (Yp) in } (\text{lb}/100\ \text{ft}^2) = 300 \text{ RPM reading} - (\mu p) \quad (2)$$