Petroleum and Coal

Article Open Access

Effect of Salinity on Flow Properties of Drilling Fluids: An Experimental Approach

Emine Avcı

Department of Petroleum and Natural Gas Engineering, Faculty of Engineering and Natural Sciences, Iskenderun Technical University, 31200, Iskenderun-Hatay, Turkey

Received November 6, 2017; Accepted March 3, 2018

Abstract

This work presents an investigation of the effect seawater on laboratory prepared water-based mud recommended to be used in drilling formation. The properties measured are plastic viscosity, yield point, mud weight, fluid loss, gel strength, cake thickness and pH. As a result, it is found that the seawater significantly affects the rheological properties of drilling mud. It is indicated that seawater-based muds have considerably lower viscosity, yield point than those of fresh water-based muds. However, the fluid loss, the mud cake thickness and the mud weight of seawater-based muds are higher than those of fresh water-based muds.

Keywords: *Bentonite; Drilling mud; Salinity; Seawater; Rheology*.

1. Introduction

The extraction of fossil fuels from offshore fields largely increased in the last five decades [1-2]. Drilling fluid, also called drilling mud, is the most significant component in the drilling process. Drilling fluids perform several functions including controlling formation pressures, maintaining hole integrity and stability, cooling and lubricating the drill bit and the drill string, cleaning the bottom hole, and suspending cuttings in the annulus when circulation is stopped or carrying them to the surface during drilling [3-4]. Therefore, the success of the drilling operations largely depends on the performance of the drilling fluids. Drilling mud should have certain rheological properties in order to perform these functions. This indicate that the factors which affect the rheological properties of the drilling mud require investigation. Traditionally, muds have been classified into three categories according to the base fluid used in their preparation. These are: oil, air and water. About 5-10% of the wells drilled use oil muds and a much smaller percentage use air. Most air-drilled wells are relatively shallow in hard, competent formations [5]. Most of the world's drilling operations use water-based muds and they mainly consist of water and bentonite [6]. Many offshore wells are drilled using a seawater system because of ready availability [7]. There are many studies in the literature considering the effects of a great deal factors, such as temperature, pressure, contaminants and various additive on the rheological properties of the drilling mud during the drilling. The aim of this study to investigate the effect of seawater used in offshore drilling operations on the rheological properties of bentonite-based drilling mud at ambient temperature.

2. Material and method

Initially, four different mud samples were prepared using seawater obtained from Iskenderun Bay which is seen in Figure 1. Seawater was mixed with 20 g, 30 g, 40 g and 50 g bentonite concentrations using a five-spindle multi-mixer (model 9B) for 20 minutes and these samples were labeled as S1, S2, S3 and S4, respectively. After mixing, each bentonite dispersion was poured in a covered container and left for 16 h to provide that the bentonite achieve the exact hydration at ambient temperature. In order to compare, four bentonite mud samples were also prepared with deionized water with same bentonite concentrations following the same procedure, then these samples were also labeled as D1, D2, D3 and D4, respectively. Table 1 shows the concentrations of materials used and label names given in the prepared drilling muds. Prior to measurement, the samples were stirred for 5 min at high shear rate (11,000 rpm).

Figure 1. Map of the area obtained seawater

The rheological measurements were made on these samples prepared such as viscosity, yield point using OFI Testing Equipment, Inc. 8 Speed Viscometer (Model 800). The viscometer has 8 speeds (600 rpm, 300 rpm, 200 rpm, 100 rpm, 60 rpm, 30 rpm, 6 rpm and 3 rpm) as recommended by API to measure the rheological properties of drilling mud samples. Plastic viscosity (PV) and yield point (YP) were calculated from 300 and 600 rpm readings using following formulas from API Recommended practice of Standard procedure for field testing drilling fluids [8-9]:

$$\mathrm{PV}\ (\mu_p) = \theta_{600} - \theta_{300}\ \text{(cP)} \quad (1)$$

$$\mathrm{YP} = \theta_{300} - \mu_p\ (\text{lb}/100\text{ft}^2) \quad (2)$$

Filtration loss of the prepared samples were measured by using OFI Testing Equipment, Inc. Filter Press model (140-75) under a pressure of 6.894 bar (100 psi) for 30 min. Mud weights of the samples were measured by using the OFI Testing Equipment, Inc. mud balance model (900). Also pH and cake thickness values of drilling mud samples were measured using pH paper and vernier caliper, respectively. All of these studies carried out at room temperature.

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

Drilling Fluid samples	Material amount	Drilling Fluid samples	Material amount
S1	Bentonite: 20 g Seawater: 500 mL	S3	Bentonite: 40 g Seawater: 500 mL
D1	Bentonite: 20 g Deionized water: 500 mL	D3	Bentonite: 40 g Deionized water: 500 mL
S2	Bentonite: 30 g Seawater: 500 mL	S4	Bentonite: 50 g Seawater: 500 mL
D2	Bentonite: 30 g Deionized water: 500 mL	D4	Bentonite: 50 g Deionized water: 500 mL

3. Result and discussions

The comparative rheological properties of mud prepared using seawater and mud prepared using deionized water are shown in Figure 2 for S1 and D1 samples. This figure shows that the shear stress values of the S1 sample are considerably lower than the shear stress values of D1 sample at all shear rates (Figure. 2A). The fluid loss through the mud cake to the formation of S1 sample is over 70 percent more than that of D1 sample in 30 min period (Figure. 2B). From fig. 2C, it can be noticed that the mud weight and cake thickness of the S1 sample are higher than those of D1 sample, while the plastic viscosity, yield point and pH values of the S1 sample are lower than those of D1 sample (Figure. 2C).

Figure 3 shows comparative rheological properties for S2 and D2 samples. From Figure 3, it can be observed that the tendency of rheological properties of S2 and D2 samples is quite similar to that of S1 and D1 samples. This indicates that the shear stress values (Figure 3A), the plastic viscosity, the yield point, pH values of sample S2 (Figure 3C) are lower than those of D2 sample; on the other hand, the fluid loss (Figure 3B), density and cake thickness values (Figure 3C) of S2 sample are higher than those of D2 sample.

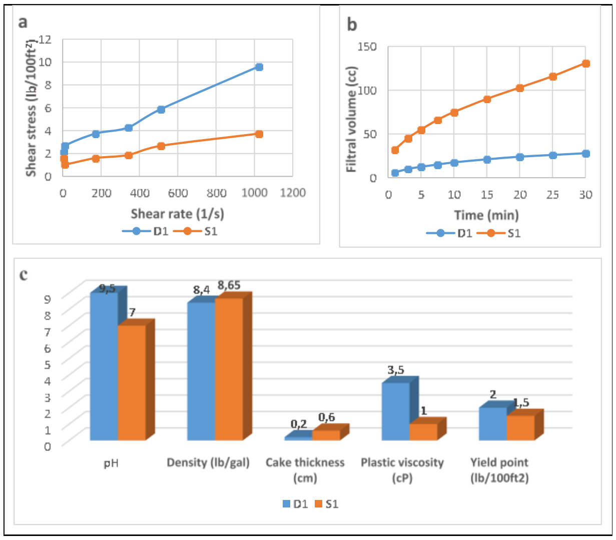

Figure 2. Comparison of rheological properties for S1 and D1 samples, a) Shear rate-shear stress relations b) Time-fluid loss relation, c) pH, density, cake thickness, plastic viscosity, yield point values

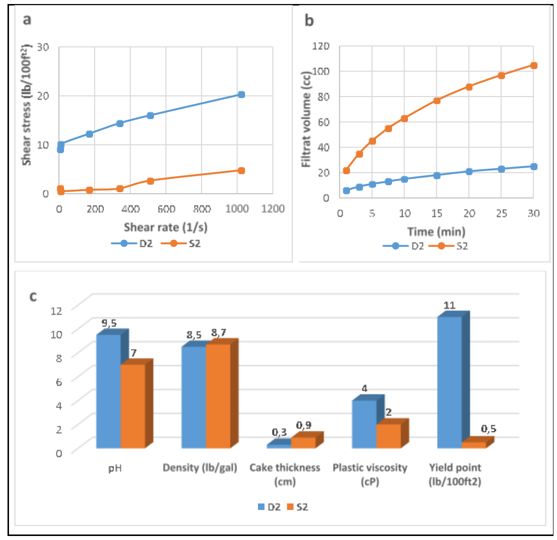

Figure 3. Comparison of rheological properties for S2 and D2 samples, a) Shear rate-shear stress relations b) Time-fluid loss relation, c) pH, density, cake thickness, plastic viscosity, yield point values

From Figure 4, it can be indicate that the tendency of rheological properties of S3 and D3 samples is similar to those of S1-D1 and S2-D2 samples as well. This indicate that the shear stress (Figure 4A), the plastic viscosity, the yield point, pH values (Figure 4C) of S3 sample are lower than those of D3 sample, while the fluid loss (Figure 4B), density and cake thickness (Figure 4C) of S3 are higher than those of D3 sample. However, it can be observed that there is an advenced difference particularly in yield point values.

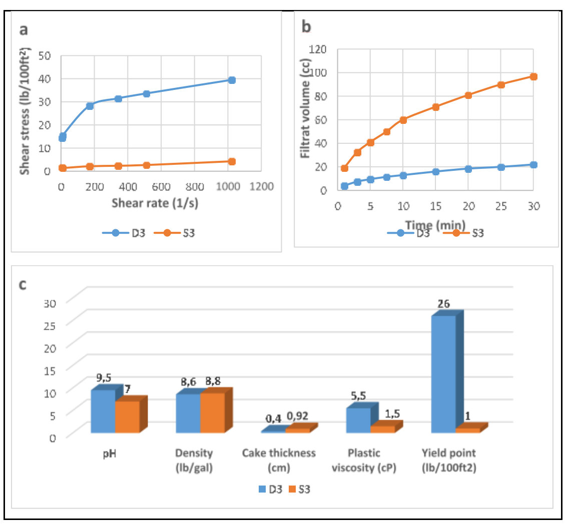

Figure 4. Comparison of rheological properties for S3 and D3 samples, a) Shear rate-shear stress relations b) Time-fluid loss relation, c) pH, density, cake thickness, plastic viscosity, yield point values

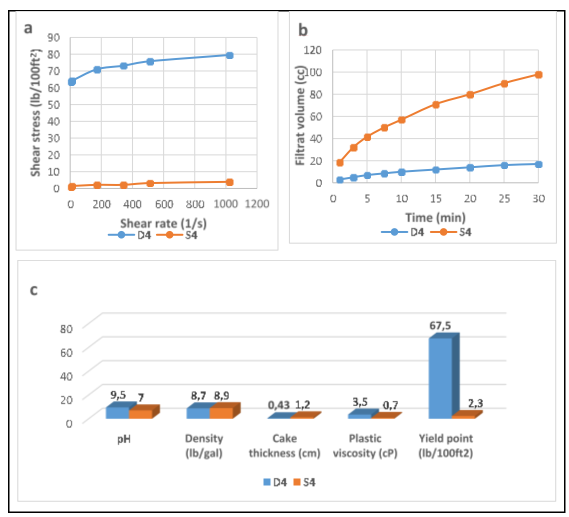

Figure 5. Comparison of rheological properties for S4 and D4 samples, a) Shear rate-shear stress relations b) Time-fluid loss relation, c) pH, density, cake thickness, plastic viscosity, yield point values

Figure 5 shows that the comparative rheological properties for S4 and D4 samples. It can be also noticed that the inclination of rheological properties of S4-D4 samples is similar to those of S1-D1, S2-D2 and S3-D3 samples. This indicate that the shear stress (Figure 5A), the plastic viscosity, the yield point, pH values (Figure 5C) of S4 sample are lower than those of D4 sample, while the fluid loss (Figure 5B), the density and the cake thickness (Figure 5C) of S4 sample are higher than those of D4 sample. However, it can be noticed that the the difference between the values of S4 and D4 samples is higher than the values of the other samples (S1-D1, S2-D2, S3-D3).

4. Conclusions

Drilling fluid should have stable reological properties during drilling operations. Based on this study, it is found that seawater dramatically affects the rheological properties of drilling mud. It is indicated that as bentonite concentration increased, both mud cake thickness and mud weights increased, whereas the fluid loss decreased and pH values remained steady for both types of mud and the differences of values related to seawater and fresh water-based increased. Also, it was observed that the viscosity, the yield point of seawater-based drilling mud were quite low compared to fresh water-based mud. Nevertheless, the fluid loss, the mud cake thickness and the mud weight were higher than those of fresh water-based mud. All of these are undesired consequence for drilling mud. Therefore, the use of seawater to prepare mud will immensely affect drilling performance and well cost.

References

[1] Ghisel RG (editor). Fifty years of off shore oil, gas development. Hart Publications 1997: Houston, TX.

[2] Terlizzi A, Bevilacqua S, Scuderi D, Fiorentino D, Guarnieri G, Giangrande A, Fraschetti S. Effects of offshore platforms on soft-bottom macro-benthic assemblages: a case study in a Mediterranean gas field. Marine Pollution Bulletin,2008; 56(7): 1303-1309.

[3] Rooki R, Ardejani FD, Moradzadeh A, Mirzae, H, Kelessidis V, Maglione R and Norouzi M. Optimal determination of rheological parameters for herschel-bulkley drilling fluids using genetic algorithms (GAs). Korea-Australia Rheology Journal, 2012; 24(3) 163-170.

[4] Sami NA. Effect of magnesium salt contamination on the behavior of drilling fluids. Egyptian Journal of Petroleum,2016; 25(4), 453-458.

[5] Caenn R, Chillingar GV. Drilling fluids: State of the art. Journal of petroleum science and engineering, 1996; 14(3-4): 221-230.

[6] Kafashi S, Rasaei M, Karimi G. (2017). Effects of sugarcane and polyanionic cellulose on rheological properties of drilling mud: An experimental approach. Egyptian journal of petroleum, 2017; 26(2): 371-374.

[7] Warren B, van der Horst PM, van't Zelfde TA. (2001). U.S. Patent No. 6,281,172. Washington, DC: U.S. Patent and Trademark Office.

[8] Recommended Practice, 1988. Standard procedure for field testing drilling fluids, 12th ed. vol. 13 B (RP13B). API, Washington, USA, pp. 7 –9.

[9] Mahto V, Sharma VP. Rheological study of a water based oil well drilling fluid. Journal of Petroleum Science and Engineering, 2004; 45(1): 123-128.

To whom correspondence should be addressed: Emine Avcı, Department of Petroleum and Natural Gas Engineering, Faculty of Engineering and Natural Sciences, Iskenderun Technical University, 31200, Iskenderun-Hatay, Turkey, emine.avci@iste.edu.tr