Çukurova Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 33(4), ss. 83-88, Aralık 2018
Çukurova University Journal of the Faculty of Engineering and Architecture, 33(4), pp. 83-88, December 2018

Effect of Micro-Sized Colemanite on the Rheological Properties of the Water Based Drilling Fluid

Abdullah ÖZKAN[*1], Behlül Merve KAPLAN[1], Vildan ÖZKAN[1], Sıtkı Ekrem TURAN[1]

[1]*Iskenderun Technical University, Faculty of Engineering and Natural Science, Department of Petroleum and Natural Gas Engineering, Hatay*

Geliş tarihi: 29.06.2018 Kabul tarihi: 25.12.2018

Abstract

Drilling mud have been the subject of constant study since they are the most costly item of oil exploration. Recently, the several additives have been added to improve the rheological properties of the drilling mud. In this study, a water based drilling mud that is (1, 2, 3, 4 and 5) (% w/v) of colemanite ($Ca_2B_6O_{11}.5H_2O$), which is a calcium borate group mineral in the particle size of 100 µm subscale, was prepared for this drilling mud. The rheological properties such as plastic viscosity (PV), apparent viscosity (AV), gel strength, water loss and cake thickness of the obtained drilling muds were analyzed in detail using Fann Viscometer and American Petroleum Institute (API) testing equipment. As a result of the study, it was found that the added colemanite had a positive effect on the rheological properties of the drilling mud. When the analysis results of the drilling muds obtained at different ratios of colemanite addition are compared with each other, it is found that 4% of colemanite-added drilling mud has the best properties (excluding gel strength). The water-based drilling mud prepared by adding colemanite has 30.4% cP of plastic viscosity; 63.6% cP of apparent viscosity; 140% of rupture point; gel strength (10-sec and 10-min) values compared to the water based drilling muds prepared without any addition was positively affected.

Key words: Drilling mud, Colemanite, Rheological properties, Loss of filtration

Mikro Boyutlu Kolemanitin Su Bazlı Sondaj Çamurunun Reolojik Özelliklerine Etkisi

Öz

Sondaj çamuru petrol aramalarının en büyük maliyet kalemini oluşturduğu için sürekli olarak üzerinde çalışılan konu olmuştur. Son zamanlarda, çeşitli katkı maddeleri eklenerek sondaj çamurunun reolojik özellikleri iyileştirilmeye yönelik çalışmalar devam etmektedir. Bu çalışmada, petrol aramalarında en çok kullanılan su bazlı sondaj çamuru hazırlanmış ve hazırlanan sondaj çamuruna 100 µm elek altı tane

[*]Sorumlu yazar (Corresponding author): Abdullah ÖZKAN, *abdullah.ozkan@iste.edu.tr*

boyutunda kalsiyum borat grubu minerali olan kolemanit ($Ca_2B_6O_{11}.5H_2O$) farklı konsantrasyonlarda (1, 2, 3, 4 ve 5) (%w/v) eklenmiştir. Elde edilen sondaj çamurlarının plastik viskozite (PV), görünür viskozite (AV), jel mukavemeti, su kaybı ve kek kalınlığı gibi reolojik özellikleri Fann Viskometre ve Amerikan Petrol Enstitüsü (API) sıvı kaybı test aletleri kullanılarak detaylı bir şekilde analiz edilmiştir. Çalışma sonucunda, eklenen kolemanitin sondaj çamurunun reolojik özelliklerine olumlu yönde etki ettiği görülmüştür. Farklı oranlarda kolemanit eklenmesi sonucu elde edilen sondaj çamurların analiz sonuçları birbiriyle mukayese edildiğinde ise; %4 oranında kolemanit eklenmiş sondaj çamurunun en iyi özelliklere (jel mukavemeti hariç) sahip olduğu görülmüştür. Kolemanit eklenerek hazırlanan su bazlı sondaj çamurunun, herhangi bir ekleme yapılmaksızın hazırlanan su bazlı sondaj çamuruna kıyasla, plastik viskozitesinin %30,4 cP; görünür vizkozitesinin %63,6 cP; kopma noktasının %140 arttığı; jel mukavemeti (10-saniye ve 10-dakika) değerlerinin de olumlu yönde etkilendiği tespit edilmiştir.

Anahtar Kelimeler: Sondaj çamuru, Kolemanit, Reolojik özellikler, Filtrasyon kaybı

1. INTRODUCTION

Drilling mud or drilling fluid is one of the main components to remove rock fragment from the wellbore, to implement necessary hydrostatic pressure, to cool and lubricate the all systems and to ensure the stability of the hole and preventing crossflow of fluids between borehole and formation in a drilling operation [1]. Drilling mud is classified into three main title; as water-based, oil-based and air-based, while water-based mud are widely used in the industry [2]. Generally, the water-based drilling fluid has been used and consists of mainly water, bentonite, viscosity increaser, fluid loss reducer, lubricants, etc [3]. It is known that a convenient drilling fluid makes drilling operations easier and economical. For this purpose, any studies have been reported to improve the related properties of drilling fluids by using some additives, usually polymers, ore and nano-materials, at different compositions and size [4-6]. At same time, some industrial minerals that nano and micro-sized particles were applied as a mud additive to improve rheological properties of the drilling fluid [7-9]. Nano and micro fluids can be prepared by adding nano-micro sized particles in low volumetric fractions to a fluid [10]. Borate mineral ores such as Colemanite, as well as refined borates and boron products, are important additives found in many formulations used in petroleum, natural gas and shale gas well operations in order to maximize yields and improve performance. Depending on the situation and type of application-such as drilling muds, well stimulation or fracking—borate and boron products are selected alongside other chemical components in order to modify a formulation's viscosity, pH, thermal stability, lubricity and/or flow rate. Among the more popular borate products for use in oil and gas exploration, drilling and well completion, mineral ores Colemanite and Ulexite are the subject of numerous patents in the energy industry [11,12]. Considering that Turkey has about 65-70% of world boron reserves [11] and in which the mineral colemanite can easily be provided; water-based drilling mud was prepared and colemanite ($Ca_2B_6O_{11}.5H_2O$) (1-5) (%w/v), which is a calcium borate group mineral of particle size of 100 μm subscale was added to drilling mud [9]. The rheological properties such as plastic viscosity (PV), apparent viscosity (AV), gel strength, water loss and cake thickness of the obtained drilling muds were analyzed in detail using Fann Viscometer and American Petroleum Institute (API) testing equipment [13].

2. MATERIALS AND METHOD

2.1. Sample Preparation

Water based drilling fluids is the most common drilling mud which are used in oil industry. Water is the continuous phase, providing the initial rheological properties of the drilling fluid. In this study, in order to prepare the water based drilling fluid, bentonite and barite were purchased from Turkish Petroleum Corporation (TPAO). Colemanite ($Ca_2B_6O_{11}.5H_2O$), which is a calcium borate group mineral of particle size of 100 μm is provided from Turkey Bore Institute. Then, water based drilling fluid (WBDF) system was prepared by using fresh water, bentonite (5% wt) and barite as a densifier. The pH of the fluid was adjusted by sodium hydroxide (NaOH). After preparation of the mud, the system was mixed for 30 minutes in total. This drilling fluid was used as an arbitration specimen. Secondly, same drilling fluid was prepared and the different amount of colemanite (1, 2, 3, 4 and 5 wt%) was added in it. The mixture was kept mixing for 3 minutes and then aged for 16 hours. Conventional WBDF and colemanite added WBDF formulation are given in Table 1.

Table 1. Formulation of conventional and colemanite added WBDF

Materials	WBDF	Colemanite added WBDF				
		% 1	% 2	% 3	% 4	% 5
Colemanite (g)	-	4.35	8.70	13.05	17.4	21.75
Fresh water (g)	400	400	400	400	400	400
Bentonite (g)	22.8	22.8	22.8	22.8	22.8	22.8
Barite (g)	11.4	11.4	11.4	11.4	11.4	11.4
NaOH (g)	1	1	1	1	1	1

2.2. Analysis of the Physical Properties

The elemental composition of the colemanite was determined using XRF. The physical properties of the drilling mud were determined based on API-13 B1standard [13], including all filtration and rheological properties. Fann Viscometer was used to measure dial readings of the solutions. Rheological properties such as plastic viscosity, apparent viscosity, yield point, 10 second and 10 min gel strength were correlated according to the empirical formulas below;

$\mu p = \theta\ (600\ rpm) - \theta\ (300\ rpm)$

μp: Plastic viscosity (cp)

$\gamma p = \theta\ (300\ rpm) - \mu p$

γp: Yield Point (lbf /100ft2)

$\mu a = (\theta\ (600\ rpm))/2$

μa: Apparent viscosity (cp)

The filtration properties of solutions were also found in terms of the API-13 B1 standard [13] filter press equipment. 100 psi pressure was exerted to the fluid column for 30 minutes and filtrate loss as well as mud cake thickness were recorded. Mud cake thickness was measured in 1/32". Density of the mud was also measured using mud balance; consist of base and a balance arm with a cup for counterweight.

3. RESULTS AND DISCUSSION

3.1. Characterization of the Colemanite

Colemanite is commonly available in distinct transparent crystalline forms. It can also be thin, platy and brittle. Ground Colemanite is reddish-grey greyish white powder. The elemental nominal chemical composition of colemanite was determined using XRF that is given in Table 2.

Table 2. Chemical composition of colemanite

Composition (w%)		
B_2O_3	CaO	H_2O
50.9	27.2	21.9

3.2. Effect of the Colemanite Ratio on Rheological and Filtration Properties of Water Based Drilling Fluids

In the present study, 1, 2, 3, 4 and 5 %w/v of colemanite ratio as additives were mixed with the drilling fluid separately and their effects on rheological properties of water-based drilling mud were investigated (Table 3).

Table 3. Rheological results of the drilling fluids with colemanite

Parameters	Without colemanite	Colemanite added WBDF (w/v %)				
		1	2	3	4	5
PV (cp)	11.5	13.3	14	14.1	14.8	15
YP (lb/100 ft^2)	10	15	18	21	24	20
AV (cp)	16.5	22.5	24	25.5	27	25
10-second	3	10	13	15	15	20
10-minute	5	33	33	34	35	39
Filtration Loss (mL)	9.6	10	10.8	11.2	11.6	12.8
Cake thickness (mm)	0.20	0.25	0.32	0.42	0.48	0.50

As we said that the task of drilling fluid was to remove rock fragment from the wellbore, to implement necessary hydrostatic pressure, to cool and lubricate the all systems and to ensure the stability of the hole. According to Table 3, we can say to improve rheological properties of efficient drilling fluid.

The change of the apparent viscosity (AV) and the plastic viscosity (PV) versus the colemanite ratio were represented in the Figure 1. It was found that the cP ratio of the mud increased with 4% of colemanite concentration, after 4%, viscosities decreased. The result of analysis showed that the rheological properties of drilling mud containing 4% w/v colemanite increased. For example, 30.4% cP of apparent viscosity, 63.6% cP of plastic viscosity increased. It means that the addition of the colemanite up to 4% into the drilling fluid could provide the better flowability and reduce the possible problems such as surge, swab pressure, differential sticking and slow rate of penetration [14,15]. Yield point is also important for the selection of pump and pressure for flow, the mud from static positions [16]. Yield point of the drilling fluids increased slightly with colemanite concentration up to 4%, after 4%, it decreased (Figure 1). The addition of 5% of colemanite and more additions can not affect positively the rheological properties of drilling fluid (Table 3).

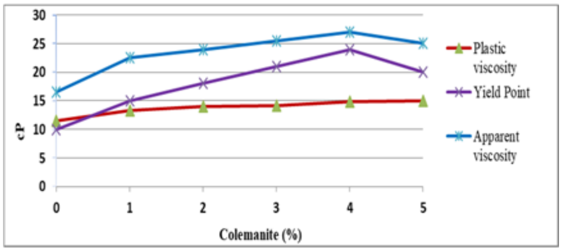

Figure 1. PV, AV and YP vs colemanite concentration

After the mud has been static for some time, the gel strength, which is indication of the pressure required to initiate flow, is shown in Figure 2. Gel strength increased with the colemanite concentration in the initial 10 second and 10 minute.

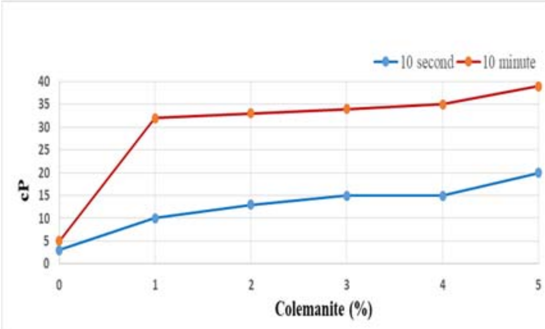

Figure 2. Gel strength vs colemanite concentration

Filtration loss and cake thickness depending on the colemanite ratio are presented in Figure 3 and Figure 4. When the results of liquid loss and cake thickness analysis are investigated, they increase proportionally with the colemanite amount (from 9.6 to 12.8 mL). Although the liquid loss increases with the colemanite amount, these results are in the reference value (10–15 mL). Because of this, they have no negative effect on drilling operation. Similarly, the cake thickness increases with the colemanite amount (0.2 to 0.5 mm) and these results are under the reference value (max 4 mm).

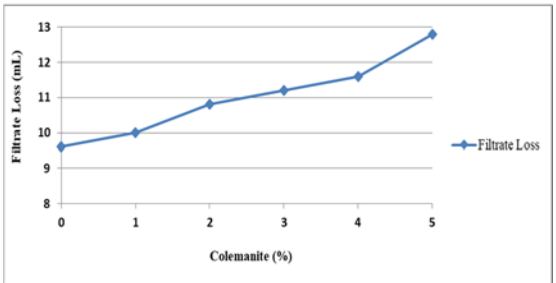

Figure 3. Filtrate loss vs colemanite concentration

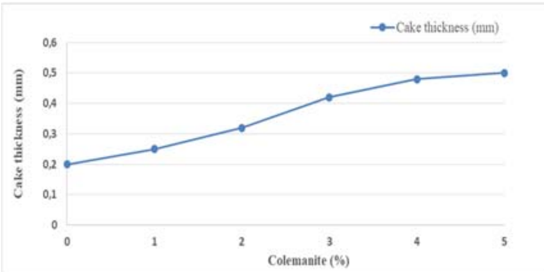

Figure 4. Filtrate cake thickness vs colemanite concentration

4. CONCLUSIONS

In this study, the effect of colemanite concentration on rheological and filtration properties of drilling fluid was experimentally investigated. The results showed that rheological properties such as plastic viscosity (PV) and apparent viscosity (AV) were slightly increasing up to 4% colemanite ratio in the drilling fluid after that the viscosities tend to decrease. Although the colemanite addition increases the fluid loss and cake thickness of the drilling mud, it has been determined that the results are within the reference values and do not constitute any obstacle using as drilling mud additive material. The data obtained as a result of this work will contribute positively to drilling operations. It will also be useful to examine the possible effects of colemanite addition of different particle sizes on the drilling mud.

5. REFERENCES

1. Abdo, J., Haneef, M., 2012. Nano-Enhanced Drilling Fluids: Pioneering Approach to Overcome Uncompromising Drilling Problems. J. Energy Resour. Technol., 134(1), p.014501.
2. Benchabone, A., Bekkour, K., 2006. Effect of Anionic Additives on the Rheological Behaviour of Aqueous Calcium Montmorillonite Suspensions. Rheol. Acta., 45(4), 425-434.
3. Amanullah, M., Arfaj, M.K., Abdullati, Z.A., 2011. Effect of CuO and ZnO Nanofluids in Xanthan Gum on Thermal, Electrical and High Pressure Rheology of Water-based Drilling fluids. J. Pet. Sci. Eng., 117, 1–9.
4. Zhong Qiu, Z., Huang, W., Cao, J., 2011. Shale Inhibitive Properties of Polyether Diamine in Water-based Drilling Fluid, Hanyi. J. Pet. Sci. Eng., 78, 510-515.
5. Amanullah, Md., Yu, L., 2005. Environment Friendly Fluid Loss Additives to Protect the Marine Environment from the Detrimental Effect of Mud Additives. J. Pet. Sci. Eng., 48, 199-208.
6. Gentzis, T., Deisman, N., Chalaturnyk, R.J., 2009. Effect of Drilling Fluids on Coal Permeability: Impact on Horizontal Wellbore Stability. Int. J. Coal Geol., 78, 177-191.
7. Wenga, J., Gonga, Z., Liaoa, L., Lva, G., Tanb, J., 2018. Comparison of Organo-sepiolite Modified by Different Surfactants and Their Rheological Behavior in Oil-based Drilling Fluids. Appl. Clay Sci., https://doi.org/10.1016/j.clay.2017.12.031, (in press)
8. Zhuanga, G., Zhanga, Z., Yang, H., Tan, J., 2018. Structures and Rheological Properties of Organo-sepiolite in Oil-based Drilling Fluids. Appl. Clay Sci., 154, 43–51.
9. Nabhani, N., Emami, M., 2012. The Potential Impact of Nano Materials in Oil Drilling Industry, NanoCon. 10, 23-25.
10. Al Yasiri, M., Al Sallami, W., 2015. How the Drilling Fluid Can be Made More Efficient by Using Nanomaterials. American Journal of Nano Research and Applications, 3(3), 41-45.
11. Eti Mine., 2014a. Kestelek Colemanite, Product catalogue, p. 2, Ankara, Eti Mine Works General Management Publishing.
12. Eti Mine., 2014b. Milled Colemanite, Product Catalogue, p. 3, Ankara, Eti Mine Works General Management Publishing.
13. API, 13B-1, 2003. Recommended Practice for Field Testing of Water-based Drilling Fluids. American Petroleum Institute. ANSI/API 13B-1/ISO 10414-1.
14. Falode, O.A., Ehinola, O.A., Nebeife, P.C., 2008. Evaluation of Local Bentonite Clay as Oil Well Drilling Fluid in Nigeria. Applied Clay Sci., 39(1-2), 19-27.
15. Xianhai, M., Yihe, Z., Paul, K.C., 2012. Effects of Carbon Ash on Rheological Properties of Water-based Drilling Fluids. J. Pet. Sci. Eng., 100, p.1-8.
16. Ahmaruzzaman, M., 2010. A Review on the Utilization of Fly Ash. Progress in Energy and Combustion Science, 36(3), 327-363.