Effect of Multi-Walled Carbon Nanotubes on the Water-Based Drilling Muds

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ABSTRACT

This study aims to investigate of the effect of multi-walled carbon nanotubes (MWCNTs) that production by chemical vapor deposition (CVD) on the performance of water-based drilling muds (WBDM). MWCNT was added to WBDM at 0.001, 0.005, 0.01, 0.05 and 0.1 % w/v. The rheological properties of the MWCNTs added drilling fluid were determined according to the API standarts. The drilling muds at different ratios of MWCNTs addition are compared with each other, it is found that 0.1 % of MWCNTs added drilling mud has the best properties.
Multi-Walled Carbon Nanotubes, Water based drilling mud, Rheological properties
Keywords: Multi-Walled Carbon Nanotubes, Water based drilling mud, Rheological properties

Çok Duvarlı Karbon Nanotüplerin Su Bazlı Sondaj Çamurlarına Etkisi

ÖZ

Bu çalışmada, kimyasal buhar biriktirme yöntemi (CVD) ile üretilen çok-duvarlı karbon nanotüplerin (MWCNTs), su bazlı sondaj çamurlarının (WBDM) performansı üzerine etkisinin araştırılması amaçlanmıştır. 0.001, 0.005, 0.01, 0.05 and 0.1 % w/v oranında MWCNTs eklenmiş WBDM'lerin reolojik özellikleri API standartlarına göre tespit edilmiştir. Analiz sonuçları MWCNTs'nin iyi bir katkı maddesi olduğunu göstermiştir. Ayrıca farklı oranlarda MWCNTs eklemesi sonucu elde edilen WBDM'ler kendi içlerinde karşılaştırıldığında, en iyi katkılama oranının % 0.1 w/v olduğu görülmüştür.
Anahtar Kelimeler: Çok Duvarlı Karbon Nanotüp, Su Bazlı Sondaj Çamuru, Reolojik Özellikler

INTRODUCTION

Drilling fluid (also called "drilling mud") has many functions in drilling operations. Some of these are wellbore cleaning, cooling and lubricating of the bit and drill sting, formation of an impermeable cake, checking high formation pressures and corrosion protection. Drilling fluids are generally classify water-based, oil-based and air based drilling fluid [1]. The water-based drilling fluid is frequently used and consists of mainly water, bentonite, viscosifier, fluid loss reducer and lubricants [2]. Good drilling fluid makes drilling operation more comfortable. In recent times, important reports were performed about the properties of drilling fluids by using, polymers, nano-materials, at different compositions [3-11]. The ultrafine size and high surface area can solve drilling fluids problems [12-14]. Beg et al. [15], aims to evaluate the enhance the rheological properties, lubricity. Rheology is evaluated by AV, PV and GS variation for water-based muds (WBM). The SiO_2 NPs and TiO_2 NPs were used at various amounts. These properties were observed for the mud samples at static conditions. The titanium nanoparticles show optimal performance at a concentration of 0.60 % (w/w). The thermal properties of nanofluids at various carbon nanotubes were investigated. According to the results, CNTs-nanofluids reveal the higher performance. In addition, the thermal properties increase with temperature and concentration [16]. Alvi et al. [17], studied the effect of MWCNTs and functionalized MWCNTs with –OH and COOH groups such as bentonite, KCL and xanthan gum (XG). Hence, the addition of 0.0095wt % of MWCNTs, MWCNTs-OH and MWCNTs-COOH nanoparticles decreases the filtrate-loss. In xanthan gum drilling fluid, MWCNTs reduced the friction coefficient by 38 %. In the present study, the effects of MWCNTs as an additive on rheological properties, mud cake thickness and water loss of a WBDF were investigated. The filtration and the rheological properties such as apparent viscosity (AV), plastic viscosity (PV), yield point (YP), gel strengths (GS) of the plain WBDF and the MWCNTs added drilling mud were performed by American Petroleum Institute API RP 13B-1 [18] recommendations.

MATERIAL and METHOD

Synthesis of MWCNTs

MWCNTs were synthesized at 720 ^oC in the presence of $CaCO_3$. $CaCO_3$ was used for the catalyst. pH-value of the suspension was 7.0. The mixture was heated and dried at 120 ^oC overnight as MWCNTs [19].

Water based drilling mud (WBDM)

WBDM is the most used drilling mud in the petroleum industry [20]. Water is the continuous phase, providing the initial rheological properties of the drilling mud. In this study, firstly a WBDF system was prepared using fresh water, Na-bentonite (6 w/v %) (particle size lower than 75 µ and sodium type) according to API 13A [21]. The pH of the fluid was adjusted by sodium hydroxide (NaOH) (pH range of drilling mud 9.5 - 10). After preparation of the mud, the system was mixed for 30 minutes in total. This drilling mud was used as an arbitration specimen. Secondly, the same drilling mud was prepared and different amounts of MWCNTs (0.001, 0.005, 0.01, 0.05 and 0.1 w/v %) was added into it. The mixture was kept mixing for 3 minutes and then aged for 16 hours (average temperature 25 °C). Conventional WBDM and MWCNTs added WBDM formulations are given in Table 1.

Table 1. Formulations of conventional and MWCNTs added WBDM

Materials	WBDM	MWCNTs added WBDM (w/v %)				
		0.001	**0.005**	**0.01**	**0.05**	**0.1**
MWCNTs (g)	-	4.06×10^{-3}	2.03×10^{-2}	4.06×10^{-2}	2.03×10^{-1}	4.06×10^{-1}
Fresh water (g)	400	400	400	400	400	400
Na-Bentonite (w/v %)	6	6	6	6	6	6

The physical and chemical differences between the arbitration specimen and the MWCNTs added drilling mud were determined and compared with each other. The elemental compositions of the Na-bentonite was determined using XRF. The filtration and the rheological properties such as AV, PV, YP and GS the drilling muds were determined in line with the American Petroleum Institute API 13 – B1 recommendations. A FANN 35 viscometer was used to measure rheological properties of the drilling muds. The filtration properties (filtrate loss and mud cake thickness) of drilling muds was measured using an API filter press device.

RESULTS and DISCUSSION

Characterization of Na-bentonite

The elemental compositions of the Na-bentonite was determined by X-ray fluorescence (XRF)(ARL OPTIMX model) which are shown in Tables 2. As expected, the results showed that SiO_2 and Al_2O_3 are the main components in the structures and at the same time Na-bentonite of suitable for the API Specification 13A standard [20, 21].

Table 2. Formulations of conventional and MWCNTs added WBDM

Sample	Content of Oxides (wt %)							
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	Fe_2O_3
Na-Bentonite	2.48	2.44	20.9	65.85	0.75	1.44	0.29	5.85

Table 3. Rheological results of the drilling fluids

Parameters	WBDM	MWCNTs added WBDM (w/v %)				
		0.001	**0.005**	**0.01**	**0.05**	**0.1**
300 (rpm)	21.5	31	34	34.5	36	37
600 (rpm)	33	47	51	52	52	57
PV (cP)	11.5	16	17	17.5	19	20
YP (lb/100 ft^2)	10	15	17	17	17	17
AV (cP)	16.5	23.5	25.5	26	27.5	28.5
Gel at 10-second	4	4	4	4	4	5
Gel at 10-minute	6	7	7	7	8	8

Rheological Results

Flow characteristics (viscosity and gel strengths) of the drilling mud were determined with a FANN 35 viscometer by dial readings at 600 and 300 revolutions per min (rpm) in terms of shear rate and shear stress (the experimental results are given in Table 3). The viscosities, shear stress and shear rate are defined as follows:

PV = ϕ600 - ϕ300
AV = ½ ϕ600
YP = ϕ300 - PV

AV = cP
PV = cP
YP = lb/100 ft^2
ϕ = dial reading (value of revolutions per min (rpm))

According to Table 3, the PV and AV increases with the amount of MWCNTs. The values of PV are harmony with the study which was indicated that these values are in the range of 18–29 cP at room temperature for the mud after 0.05 % ratio [22]. In addition, the mud is effectively circulated without much pressure loss owing to friction. The reason of pressure loss is the increase of mud viscosities in contact with drilled cuttings. The change of the AV, the PV and YP versus the MWCNTs ratio were represented in the Figure 1.

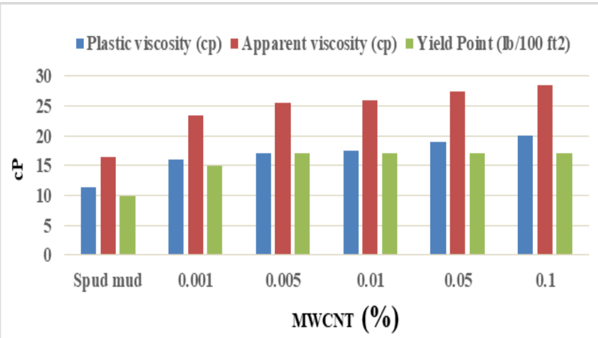

Figure 1. PV, AV and YP vs Colemanite Concentration

The values of YP increased with the amount of MWCNTs up to 0.005 %. After that, it remained stable. Figure 1 was formed by the calculated shear stress and shear rate by viscosities measurements. It is shown that the rheological properties in terms of PV and AV, which are important for good cuttings suspension characteristics when drilling is stopped, was improved with addition of the MWCNTs. The maximum value was recorded for 0.1 % w/v MWCNTs added into the drilling mud (Figure 1). In addition, the gel strengths (GS) versus the MWCNTs concentration graph is given in Figure 2. When the drilling is suspended or paused, the GS reacts to the mud behavior [23]. Higher GS has higher hydraulic power to restart the mud circulation. This is a problem of drilling operation [24]. The values of 10s and 10min increased with MWCNTs and WBDM was added.

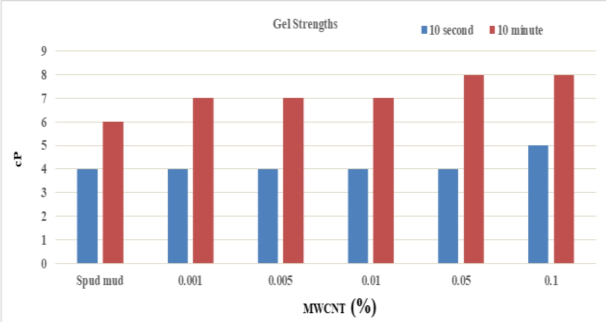

Figure 2. Gel strength vs MWCNTs concentration

Filtration Results

Filtration is important for hole durability. Low filtration is highly desired for water based drilling muds which contributes to wellbore durability. Figure 3 shows the filtration loss characteristics of the prepared drilling mud systems.

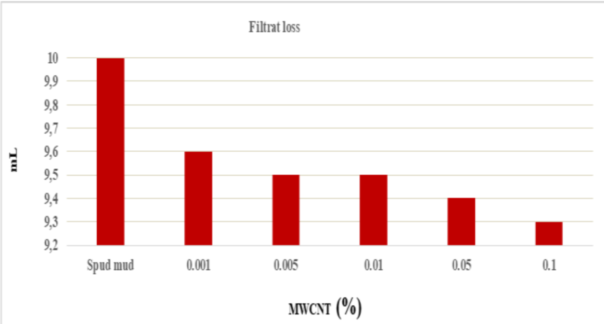

Figure 3. Filtrate loss vs MWCNTs concentration

Minimum filtration loss was obtained at the addition of the 0.1 % w/v MWCNTs. It was also found that the MWCNTs addition decreases the filtrate loss of drilling mud by about 7 %. The loss of filtration resulting from naturally fractured, crevices and channels [14] is important in terms of the cost and the required time for the drilling to reach the target depth. The cake thickness versus the MWCNTs concentration in the drilling mud is plotted in Figure 4, indicating that the cake thickness increased with increasing MWCNTs dosage [25].

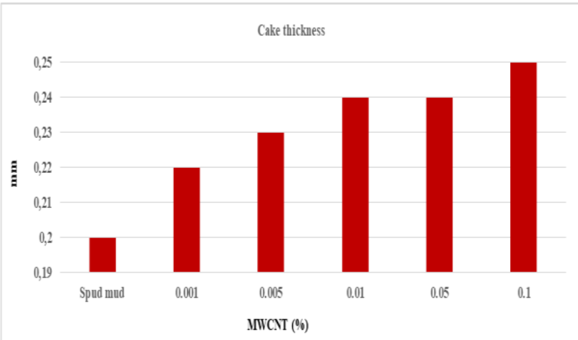

Figure 4. Cake thickness vs MWCNTs concentration in the drilling mud

Tight borehole along with increased cake thickness and the damage to the rig pump resulting from pressure increase cause the undesirable situations such as high cost and long rig time [26]. A thick mud cake is not favorable for drilling operation, however a lower filtration loss can decrease the cost of drilling operation.

CONCLUSION

Effects of MWCNTs on rheological and filtration properties of WBDM were investigated. The experimental results showed that MWCNTs is a promising additive for improvement of the rheological properties and filtration properties of the drilling muds. The results showed that the MWCNTs was a well applicant as a drilling mud additive owing to the increasing PV 74 %, AV 73 %, YP 70 %, GS (10-second 25 % and 10-minute 33 %) and the reduction in the loss of filtrate 7 % when compared to the water based drilling muds prepared without any addition. According to the results, the optimal ratio of the MWCNTs addition on drilling mud was obtained with 0.1 % of MWCNTs.

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