D.Mahmood
Petroleum Technology Department, University of Technology ,Baghdad, Iraq
dena_engineering@yahoo.com

N.S.AL-Zubaidi
Department of Petroleum Engineering, College of Engineering, University of Baghdad, Baghdad , Iraq

A.A.Alwasiti
Petroleum Technology Department, University of Technology,Baghdad, Iraq

Improving Drilling Fluid Properties by Using Nano-Additives

Abstract- *Nanotechnology is one of the most important techniques in recent days. Using Nano-additives to improve drilling fluids properties in order to meet the modern drilling process requirement is still being debated till date. In this study, three Nano-materials (magnesium oxide MgO, titanium dioxide TiO_2 and Graphene) were used to improve the rheological and filtration properties as well as Clay Yield. The weight of Nano-materials were (0.02, 0.05, 0.2, 0.5, 0.8) gm. The results showed that the rheological properties were the same with Graphene and TiO_2, while MgO gave the best results of rheological and filtration properties and with a higher values of yield point and gel strength. The higher value of Clay Yield obtained by0.2wt % (0.8 gm) of MgO was (173bbl/ton) while TiO_2 and Graphene gave the same values (124,126 bbl/ton) respectively.*

Keywords: *drilling fluid, Nano-material, Nano-technology.*

How to cite this article: D.Mahmood, N.S.AL-Zubaidi and A.A.Alwasiti., “Improving Drilling Fluid Properties by Using Nano-Additives,” *Engineering & Technology Journal*, Vol. 35, No. 10, pp. 1034-1041, 2017.

1.Introduction

It is well known that the most important step in oil exploration is the drilling process . Its importance lies in two parts; the first, is technical it is important to reach the desired goal with the most direct route and at the lowest incidents, the second, is economical it occupies about 60% of the total well cost [1].The drilling process changes and progresses since its beginning from simple vertical drilling with simple depth into inclined, horizontal to subsea and deep sea drilling. This progressing requires special drilling fluid to fulfill and meet the target.The progress and effectiveness of the drilling operations depend largely extent on the use of appropriate drilling fluid to the soil layers and the means of response excavated. Nowadays, drilling fluids is designed by using new technology to become more mechanically strong, physically small, chemical and thermal stable, biologically degradable, and environmentally friendly [2] .The most important technology that has emerged and inherently increased is Nanotechnology.

Like other industries, the oil industry takes an advantage of great benefit of this technology [3]. over the recent years with many researchers investigating its effect on drilling fluids. [4,5] studied the importance of nano-additives on lubricity, gelling characterization and drag reduction. [6] studied the effect of nano-particles on lost circulation. [7] showed the feasibility of using nano-graphene, carbon nano-tube and nano-silica to improve shale stability. [8] investigated the use of nano-local bentonite in drilling fluid and compared it with API bentonite. [9,3] studied the effect of carbon nano-tube and nano-additives on the rheological properties of drilling fluid at high pressure and high temperature conditions. Lastly, [10] proposed a solution to one of the most important challenges of drilling fluids in high temperature high pressure (HTHP) wells using Multi walled Carbon Nano-tubes (MWCNTs). In spite of the above researchers, more study should be conducted in this field. Hence, in this work, an attempt to improve commercial bentonite properties (which is used as a base for drilling fluid) using nano-technology will be made. Additionally, a comparison between using nano-materials at different concentrations to improve the drilling fluid of commercial bentonite will be mad.

2.Experimental work

I.The Materials

1. Commercial bentonite was equipped from South Oil Company (SOC). The clay was characterized using X-ray (fluorescence, diffraction) and AFM (Atomic Force Microscope).

٢ .The Nano-materials

The chemical additives that are used in this work are graphene (black powder with an average diameter of 6–8 nm), titaniumoxide (TiO_2) (white powder with an average diameter of 10–30 nm) and magnesium oxide (MgO), (white powder with an average diameter of 20 nm). They were supplied by the SkySpring Nanomaterials, Inc.

https://doi.org/10.30684/etj.35.10A.10
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II. Experiments

The evaluates commercial bentonite at the concentrations of 3, 4. 5, 6 and7 wt%. In order to improve its performance, through taking a blank solution of 22.5 g of commercial bentonite and 350 ml of water and mixed it with nano-materials of Graphene, MgO and TiO_2 at concentrations (0.05,0.01, 0.05, 0.1, 0.2 and 0.4) wt%. The prepared drilling fluid was mixed using Hamilton Beach mixer for 30 min, whereas, the nano-particle solutions were first mixed using Hamilton Beach mixer and were continued to be mixed using Ultrasonic mixer for about 10 min. The rheological properties of each experiment were experimented using viscometer (Model 900) and according to API specifications, The apparent viscosities (AV), plastic viscosity (PV), yield point (YP) and gel strength were measured. The filtration test was conducted using a filtration device (API Filter press OFITE apparatus). To obtain results with better accuracy, each experiment was repeated three times and the average results were then calculated.

3.Results and Discussion

I. X-ray analysis

The X-ray fluorescence for commercial bentonite is shown in Table 1. Comparatively, the ratios of $\{(Na_2O+K_2O)/(CaO + MgO)\}$ for the types of bentonite was found to be 1.09% for commercial bentonite indicating commercial bentonite is of sodium type. And The X-ray diffraction analysis of the Iraqi clay and commercial bentonite is shown in Table 2. This table indicates that the main constituent of commercial are montmorillonite and Quartz.

II. Rheological properties

Five concentrations of commercial bentonite were used as drilling fluid and their rheological properties are shown in Table 3.The table shows that the apparent viscosity increased up to 33.3 cP after adding 7 wt% of commercial bentonite. The plastic viscosity increased slightly with increasing commercial bentonite up to 6 wt%. A high increase in yield point value (59.2 lb/100 ft^2) was obtained after increasing nanoparticle concentration up to 7%. Also there is a noticeable increase in gel strength at 5wt% with high thixotrobic behavior. In order to study the effect of nanoparticles on these rheological properties, nano- materials: graphene, TiO_2 and MgO were added at different concentrations. The results are illustrated in Table 4 and Figs. 1to3.

show that apparent viscosity and yield point increase as nano-particle concentrations increase. However, this increase shows the same trend for graphene and TiO_2 addition. According to the structure of montmorillonite bentonite type which is layer shaped, the nanoparticles move toward the surface of clay wall due to the Vander Walls and Foulombic forces between them [11] leading to the formation of a new surface that changes the properties of fluid. The nano-particles have a high surface area with small volume. This surface area plays an important role in increasing the interaction between nano-particles and the surface of bentonite that linked physically or through chemical bonds causes an increase in viscosity. The higher interaction or attractive forces is through the use of MgO at high concentrations. The structure of MgO nanoparticle is very porous [12] that makes it very active. This greater porous structure embedded on the clay surface enhances linkage and increases apparent viscosity.

On the other hand, the addition of nanoparticles decreases plastic viscosity. The figures also illustrate that the increase of nano-particle concentrations has no effect on plastic viscosity .

In drilling, yield point represents the ability of fluid to suspend the cutting. This value increases with the addition of nano-particles and the higher value of yield point was observed with MgO addition, however, it is very high and unacceptable value.[13] showed that small nano-particles yield higher values of viscosity and yield stress than larger nano-particles. However, this disagrees with our results in which viscosity value was not affected very much when using TiO_2 (average diameter 10–30 nm) and grapheme (average diameter 6–8 nm). The gel strength values are high and the highest values are in the addition of MgO at 0.1 wt% and 0.2 wt%, i.e. a very high thixotropic tendency.

III. Filtration test

The effect of nano-additives on the filtration property of commercial bentonite is shown in Fig. 5.We can deduce from this figure that grapheme addition shows a decrease in filter loss value from the blank solution (6.3 ml) but at the same time it shows irregular behavior in filter losses of increasing and decreasing as concentration increases, while the filter cake thickness increases with increasing solid concentrations Fig. 4. However, the TiO_2 and MgO addition give regular decrease with increasing nano-solid concentration which is acceptable and reasonable results as viscosity value increases. The lowest value of filter losses was obtained with adding (0.2%) MgO, at which the filter losses reduced by 34.92%.

In most cases, when the cake is compacted on filter paper, small channels are formed inside the cake, allowing the filter to pass through and the best way of compacting ensures minimum amount of filter losses. Hence, the difference in filtration behavior between graphene, MgO and TiO_2 (as shown in fig. 6) can be attributed to both MgO and TiO_2 nano-particles that attract the bentonite particles and arranged them in a way that closes the porous in mud cake and reducing filter losses.

IV. Clay Yield

1.Clay Yield of Commercial Bentonite

Depending upon the rheological properties presented in Table 3, the data are used to calculate the Clay Yield of commercial bentonite. At different concentrations, the solids % by weight is plotted versus the apparent viscosity as shown in Figure 7 to find solids % by weight at 15 cP, according to API specification. The clay yield of commercial bentonite is **103.51 bbl/ton**.

2.Clay Yield of Commercial Bentonite with Nano-Additives

The clay yield of CB with different nano additives and at different wt% concentrations is shown in Figure 8. It is clear that adding MgO led to improve the clay yield of commercial bentonite to 167.74 and172.83 bbl/ton by adding 0.1 and 0.2 wt% of MgO to 6 wt% CB respectively. However, the addition of other nano- Graphene, and TiO_2 to improve clay yield is indistinct.

V. Rheological Models

Consistency curve (rheogram) which is a plot of shear stress versus shear rate is often used to graphically describe a rheological model. To understand fluid performance, a combination between rheological models and practical experience is made. The rheological model can be recommended using shear stress and shear rate data in Statistica 10 Program. The rheological model recommended is Herschel-Bulkley (H-B) model for most of the prepared fluids . The H-B model has three parameters (τy, k, and n) as shown in the following equation:

$\tau = \tau y + k\, \gamma^{n}$

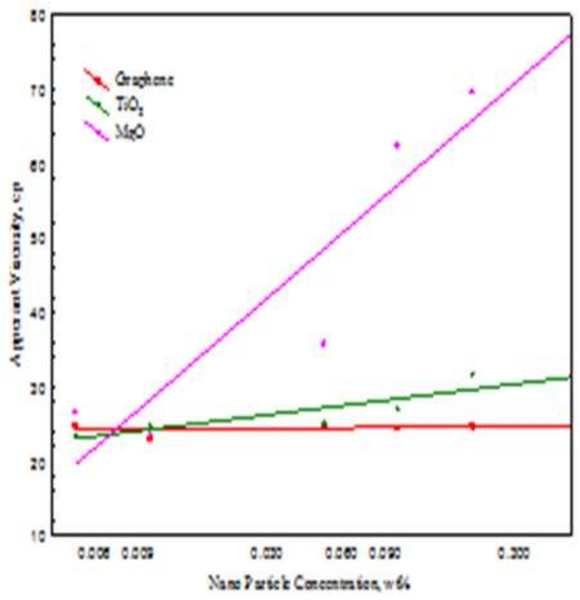

Figure 1: Apparent Viscosity Of Commercial Bentonite

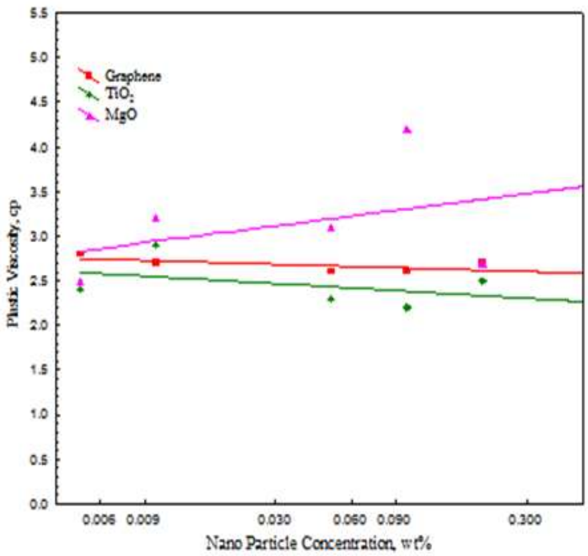

Figure 2: Plastic Viscosity Of Commercial Bentonite

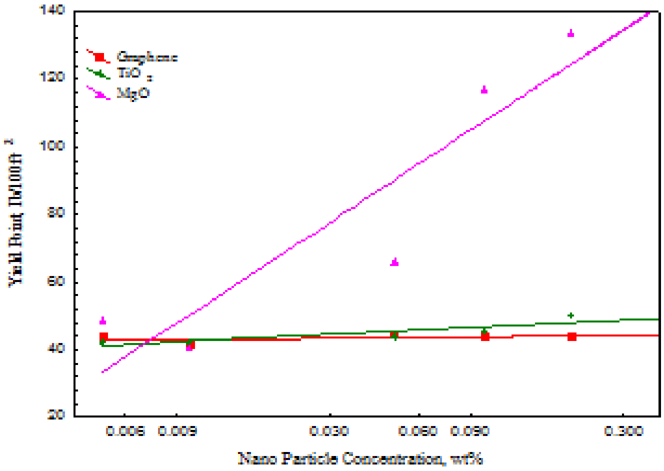

Figure 3: Yield point Of Commercial Bentonite With Different Nano-Additive Concentration

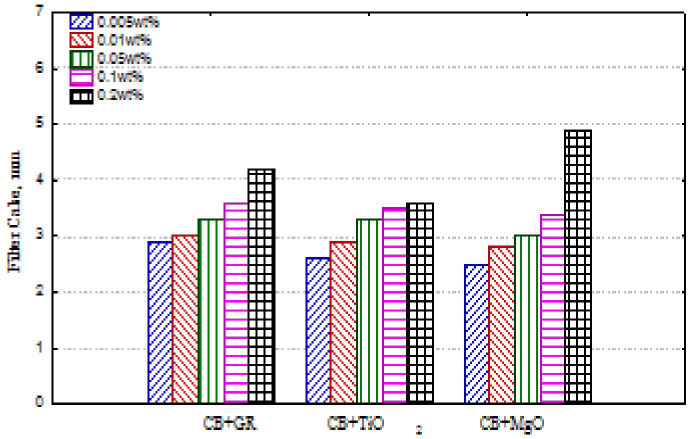

Figure 4: Mud cake thickness of Commercial Bentonite with Different Nano-Additives

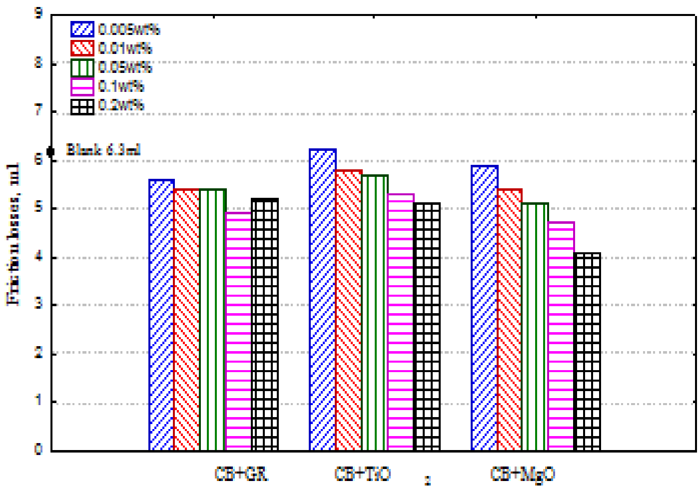

Figure 5 Filtrate Volume of Commercial Bentonite with Different Nano-Additives

Figure 6: Mud Cake of Filtration Tests of Commercial Bentonite with Different Nano-Additives

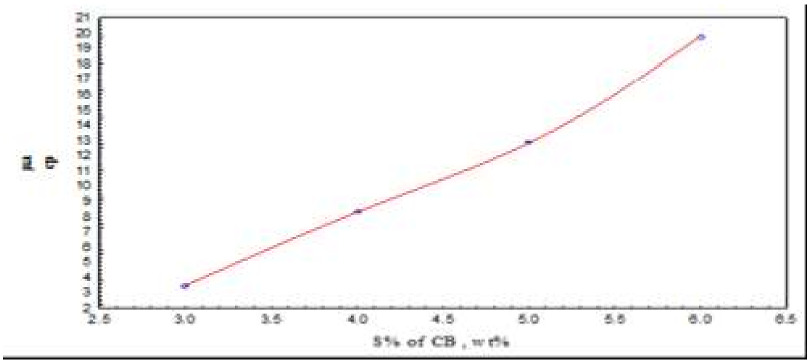

Figure 7: Solids % by Weight vs. Apparent Viscosity of Commercial Bentonite

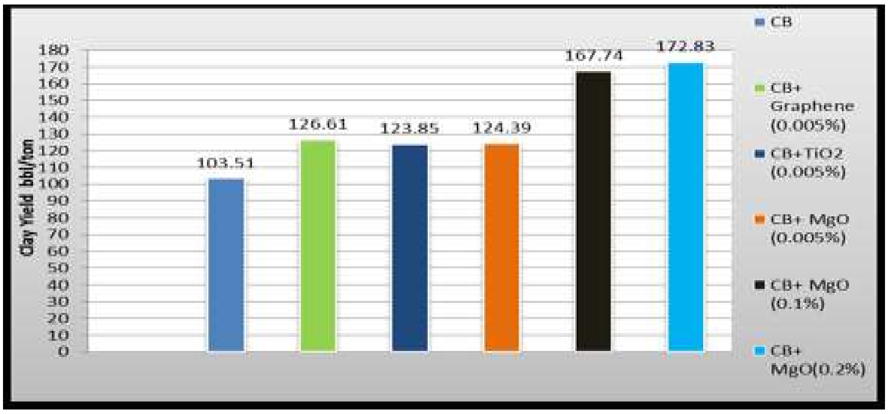

Figure 8: Clay Yield of Commercial Bentonite with Different Nano-Materials Additives

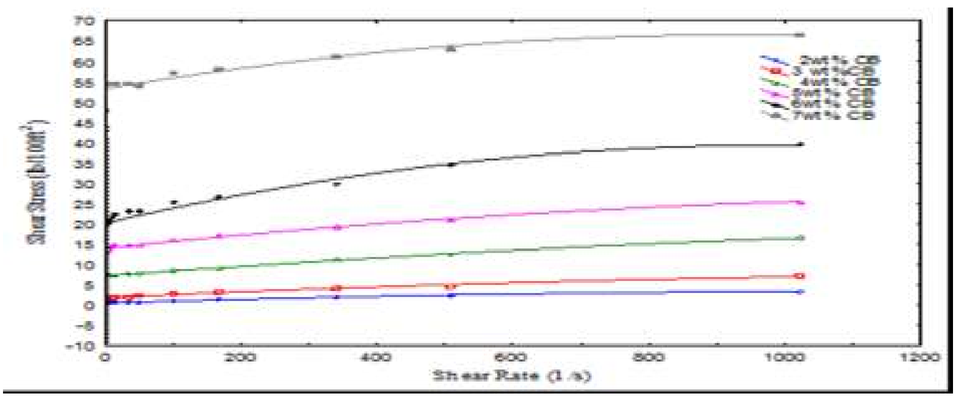

Figure 9: Consistency Curves of CB Fluid

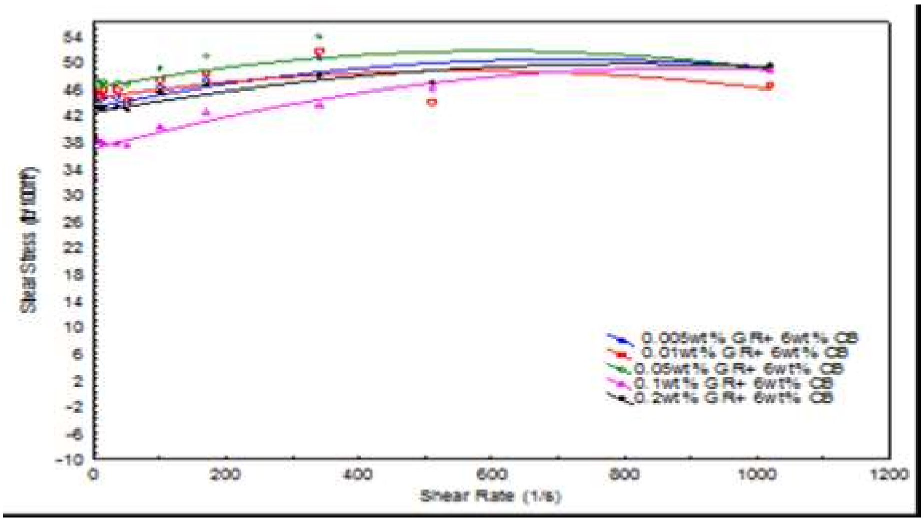

Figure 10: Consistency Curves Of CB with different GR concentration

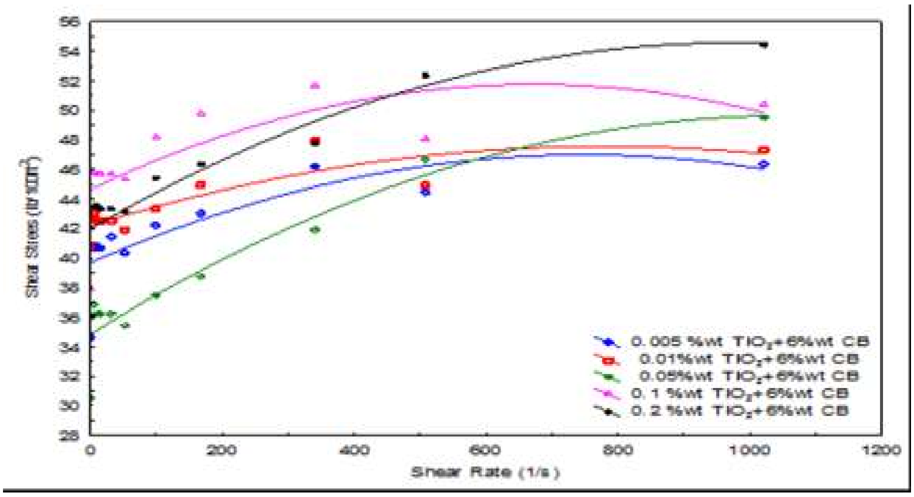

Figure 11: Consistency Curves Of CB with different TiO_2 concentration

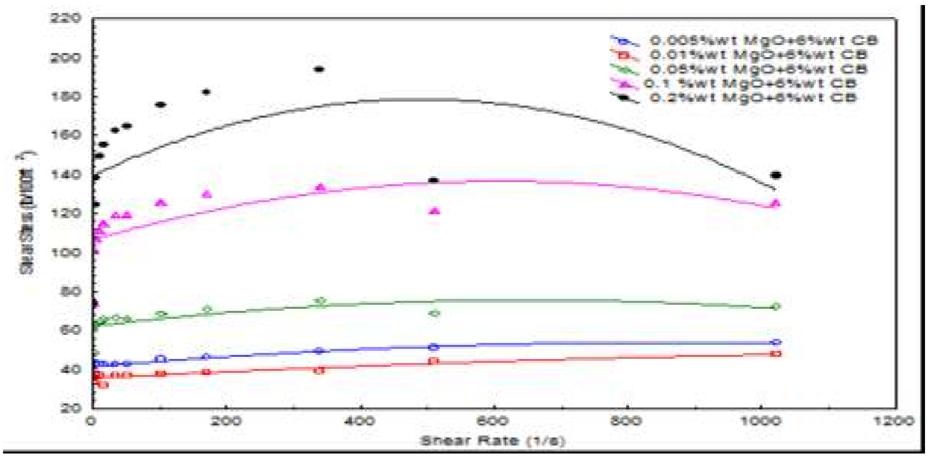

Figure 12: Consistency Curves Of CB with different MgO concentration

Table 1: The X-ray fluorescence for commercial bentonite

Constituent	SiO_2	Al_2O_3	CaO	Na_2O	MgO	K_2O
Commercial Bentonite	64.97	12.59	1.03	2.75	2.49	1.12

Table 2: The X-ray diffraction analysis of commercial bentonite.

Constituents	**Commercial Bentonite**
Major	Montmorillonite , Quartz
Minor	Gypsum, Calcite

Table 3: Rheological properties of Commercial bentonite

S% wt%	wt. gm	μ_a cP	PV cP	YP lb/100ft^2	YP/PV	Gel strength lb/100ft^2	
3%	10.5	3.55	2.3	2.5	1.08	10sec=3.2	10min=4.8
4%	15	8.25	3.8	8.9	2.3	10 sec=6.5	10min=9.1
5%	19	12.8	4.6	16.4	3.6	10 sec=36.47	10min=45.22
6%(Blank)	22.5	19.75	4.9	29.7	6.1	10 sec=38.55	10min=50.22
7%	27	33.3	3.7	59.2	16	10 sec=46.47	10min=61.69

Table 4: Rheological properties of CB with nano materials

S%	Wt. gm	density ppg	μa cP	PV cP	YP lb/100ft^2	YP/PV	Gel strength lb/100ft^2 10 sec	10 min
6% (Blank)	22.5	8.59	19.75	4.9	29.7	6.1	38.55	50.22
				CB+GR				
0.005	0.02	8.57	24.8	2.8	44	15.71	42.8	51.9
0.01	0.05	8.56	23.3	2.7	41.2	15.26	40.8	53.4
0.05	0.2	8.55	24.8	2.6	44.4	17.08	42.6	50.9
0.1	0.5	8.55	24.45	2.6	43.7	16.81	41.7	54.5
0.2	0.8	8.53	24.75	2.7	44.1	16.33	43	55.1
				CB+TiO_2				
0.005	0.02	8.6	23.15	1.9	42.5	22.36	٣٨.٧	٤٦.٦
0.01	0.05	8.6	23.65	2.4	42.5	17.70	39.9	52.6
0.05	0.2	8.61	24.75	2.9	43.7	15.06	43.05	55.7
0.1	0.5	8.61	25.2	2.3	45.8	19.91	41.9	52.2
0.2	0.8	8.62	27.25	2.2	50.1	22.77	42.8	48.9
				CB+MgO				
0.005	0.02	8.6	26.8	2.5	48.6	19.44	41.8	49.4
0.01	0.05	8.61	23.75	3.2	41.1	12.84	36.4	47.1
0.05	0.2	8.61	36.15	3.1	66.1	21.32	51.7	56
0.1	0.5	8.63	62.75	4.2	117.1	27.88	86.1	86.8
0.2	0.8	8.64	69.7	2.7	134	49.63	89	96.6

4.Conclusion

1.MgO nano additives give the best rheological and filtrationproperties results in comparison with Graphene and TiO_2.

2.The high concentration values of MgO nano additives are not suitable as an additive for drilling fluid since it gives a very high values of rheological properties Generally, the values of plastic viscosity decreased as nano additives concentrations increased.

3.The volume of filtrate is reduced when nano-materials are added, and the effect is clear at high concentrations of these

materials especially MgO. The mud cake thickness is increased when nano- materials are added at different concentrations. The highest value of mud cake thickness is obtained with higher concentration of MgO.

4. It is clear that by adding low concentration of different nano-materials causes noticeable increase of Clay Yield, especially MgO at high concentrations.

5. The addition of low nano additive concentrations causes a noticeable improving in rheological properties that gives high rate of penetration. Hence, it reduced the solids concentration of drilling fluid.

6. The prepared fluid are Herschel-Bulkley Model

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