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Improving the Performance of Drilling Fluid Using Lignite Nano Particles

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Abstract—The effect of lignite on the filtration characteristics of water base mud was studied at low and high temperature. Recently, the nanoparticle additives are studied and investigated as alternative additives due to its stability during drilling even at high-temperature and high-pressure (HTHP) conditions. In this study the effect of nano particles size of Lignite on filtrate volume and mud cake thickness was investigated , at different weights (0.01, 0.05, 0.07, 0.1, and 0.2) gm, in (API WBM, Polymer mud, DURA THERM mud, and Saturated Salt Water mud) and different temperatures (35, 75, and 100) oC. The results show that most tests provided a very good filtration control for the used drilling fluids at 100 oC. Better performances were observed in polymer and Saturated Salt Water mud at 100 oC with Lignite concentration of 0.01 gm and 0.1 gm, and filtrate volume reduction 52.5 % and 60 % respectively.

Keywords— Drilling fluid, Nano particles, Fluid loss control, HTHP conditions.

1. Introduction

This Drilling fluids serve many objectives in a drilling operation, including cuttings lifting, bit lubricating, bit cooling, hole stability and preventing the inflow-outflow of fluids between the hole and the formation. However, with production increase from non-conventional reservoirs, the stability and effectiveness of the drilling muds under HTHP conditions have gain big concerns. Heat transfer, gel formation, drag reduction, binding ability for sand consolidation, wettability alteration, and corrosive control are a number of engaging features for applications of nano-fluids which recent investigation have shown that are of interest [3]. (Grace, et al., 2006)

Many researchers tried to improve the filtration behavior and rheological properties of drilling fluid under different conditions.

[5] Presented an approach to stabilize rheological properties of drilling fluid at HTHP condition by using (10-20 nm) size of Palygorskite NP (Pal NP). They found that using Pal NP in small additive concentration with Montmorillonite and water can be improved its rheological properties and stability at HTHP conditions.

[8] Present a new development of nano-fluid using nanographite and nanosilicon wires as additives. They concluded that the nano-fluids retain all the desired rheological properties at high temperatures (up to 90 ºC). Nano-fluid viscosity was higher than the traditional mud viscosity at all tested temperatures.

[4] Studied the impact of Multi Walled Carbon Nano Tubes (MWCNT) and metal oxides (titanium oxide TiO_2 NP, aluminum oxide Al2O3 NP and copper oxide CuO NP) on the rheological and filtration properties of WBM at different nano concentrations (0.001, 0.01, 0.1) gm and at room temperature and aging for 16 hours at 250 oF. The results showed that MWCNT concentration gave lower filtration loss while a metal oxides nano particle is good until 0.01 gm.

[9] Investigated the effect of the TiO2/polyacrylamide (PAM) nano composite on water-based fluid. They found that the nano-enhanced water based fluids (NWBF) improve the rheological properties. The increase of the concentration of the additive increases the shear thinning behavior of the drilling fluid.

[6] Evaluated the performance of drilling fluids containing Fe_2O_3 and SiO2NP by using different concentrations (up

to 2.5 wt. %), for minimizing hole damage at HTHP conditions. Aging tests was performed at 350 oF for 16 hours. They observed that the rheological properties of bentonite-based fluids containing iron oxide nano-particles remained stable with minor losses in gel structure.

[10] examined the effects of Tin oxide nano-particles (SnO_2 NP) on water-based mud properties. They found that SnO_2 NP additive enhances

The rheological, thermal, electrical conductivities, thixotropy and filtration properties. They found that increasing SnO_2 NP concentration leads in reduction of the flow behavior index (n) and in increase of the flow consistency index (K).

[2] Studied the effect of Al_2O_3 NP on the rheological properties of water-based mud. Adding Al_2O_3 NP provided thermal stabilization for the drilling fluid under high temperature conditions and maintaining the shear stresses of the fluid as temperature increases.

[1] tried to improve rheological and filtration properties of drilling fluid at varying temperatures (25 oC - 85 oC) by using functionalized carbon nanotubes and graphitized nanotubes, as well as soluble polymer such as acrylamide/2-Acrylamido-2-methylpropan sulfonic acid copolymer and acrylamide/2-Acrylamido-2-methylpropan sulfonic acid /NVinylpyrrolidone terpolymer. It is observed that the combination of 0.25 wt. % polymers with 0.25 wt. % nanoparticles improves the filtration properties by reducing the filtrate with thin filter cake for smooth drilling operations.

Instead of all above, more investigations on using new materials with low cost is still needed. In this research Lignite nano particles has been used to study its effect on filtration at different temperatures. Four types of water based fluid have been used (API WBM, Polymer mud, DURA THERM mud and Saturated Salt Water mud).

2. Experimental Work Sub-title

2.1 *Materials*

The lignite was supplied from Basra Oil Company (BOC) and a ceramic ball miller had been used to get nano particle size of (63 nm). Bentonite and other materials such as lignite, lignosoulfonate, PAC polymer and XC polymer were supplied from Iraqi Drilling Company (IDC). The copolymers (TS30LC and TS705) were equipped from SNF FLOERGER Company.

2.2 *Drilling Fluid*

In this study, four different mixtures of drilling fluids were studied. The first one **API WBM** (350 ml water, 22.5 gm bentonite), **Polymer mud** is the second, it consists of (350 ml water, 11.5 gm bentonite, 2 gm KCL, 0.5 gm KOH and 0.07 gm of TS30LC copolymer). Also, **DURA THERM mud** which is a water base fluid used mainly for drilling in HTHP conditions, as it is very stable in these environment due to the low percentage of the colloidal solids content and the chemicals that are very stable at HTHP. The contents of this mud are shown in **Table.1.** The last one is **Saturated Salt Water mud**, which is used mainly for the salt formations as it is designed to prevent wellbore enlargement. This enlargement results from the salt in the wellbore dissolving into the "unsaturated salt" water phase of the drilling fluid. The contents of this mud are shown in **Table.2**

Table 1: DURA THERM mud contents [7]

Materials	Weights (gm) / 350 ml of water	Primary function
Bentonite	1 - 10	Viscosity/ Gel Strength / Filter Cake and Fluid Loss Control
Barite	0 – 600	Increase Density
NaOH	0.5 – 1.5	Increase pH
$Ca(OH)_2$	0 - 2	Treat out CO_3 and pH
Lignite	15 - 20	Thinner and Fluid Loss Control
XC polymer	0.5 – 1.5	Viscosity / Gel Strength
Thermix	0 - 12	HTHP Fluid Loss Control
RESINEX	0 - 6	HTHP Fluid Loss Control

Table 2: Saturated Salt Water mud contents [7]

Materials	Weights (gm) / 350 ml of water	Primary function
Bentonite	10 - 30	Viscosity/Gel Strength / Filter Cake and Fluid Loss Control
Barite	0 - 550	Increase Density
NaOH	0.2 – 2.5	Increase pH
NaCL	110 - 125	Increase Chloride
$NaCO_3$	0.2 - 1	Control Calcium
Chrom-Lignosol-fonate	5 - 15	Thinner and Fluid Loss Control
PAC polymer	0.5 - 2	Stability and Fluid Loss Control
XC polymer	0.25 - 1	Low Shear Rate Viscosity

2.3 *Experiments*

1-Sample preparation

A specific amount of bentonite, related to each type mud, was added into 350 ml of water. The drilling fluid was hydrated overnight, after nearly 16 hours stirred by Hamilton Beach mixer for 2 minutes, starts with adding mud components with continuous blending, the specific amount of nano add into the mud mixture and stirring for 10 min with Hamilton Beach mixer and 10 min with ultra-sonic device.

2- Filtration properties measurements

Filtration properties (filtrate volume and mud cake thickness) were studied at different conditions, LTLP (room temperature and 100 psi) measured by OFITE filter press and HTHP (75 & 100°C and 500 psi) measured by OFITE HTHP filter press.

3. Results & Discussion

3.1 *Filtration Properties*

3.1.1 API WBM

The effect of Lignite NP on API WBM filtration properties is shown in **Fig.1 & Fig.2.**

It can be noticed that, at 35 °C filtrate volume is nearly stable with Lignite NP addition. While at 75 °C and 100 °C the filtrate volume decreased with small amount of Lignite NP. Where at 0.01gm of Lignite NP the filtrate volume decreased from 11.4 gm to 9.7 gm at 75 °C and decreased from 13.9 gm to 11 gm at 100 °C, but return increased as Lignite NP concentration increases.

From the above paragraph, it is concluded that using Lignite NP (thinner) with few concentrations will reduce filtrate volume due to the decrease in bentonite flocculation. However, by increasing the concentration of Lignite NP, the filtrate volume will increase due to the significant decrease in the API WBM viscosity.

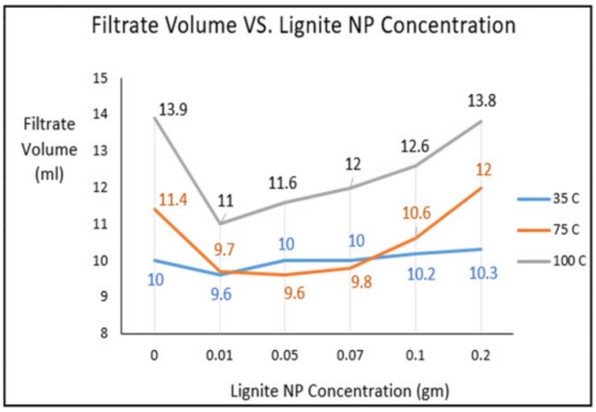

Figure 1: Effect of Lignite NP addition on filtrate volume of API WBM

API WBM mud cake thickness increases from 1.2 mm to 3.8 mm due to an increase in filtrate volume from10 ml to 13.9 ml at 35 °C to 100 °C temperature. Mud cake thickness at 35 °C is stable as filtrate volume stability. At 75 °C mud cake thickness nearly stable with small concentration of Lignite NP but after 0.07gm mud thickness increase until it reaches 3.8 mm at 0.2 gm of Lignite, while at 100°C mud thickness decreased about 10.5% at 0.01 gm Lignite NP.
It is concluded that, mud cake thickness is proportional to the volume of filtrate. Some unstable behavior is observed when nanomaterial is added to API WBM at different concentrations and temperature degrees, due to the effect of nano particles on mud cake permeability and effect of temperature on flocculation degree.

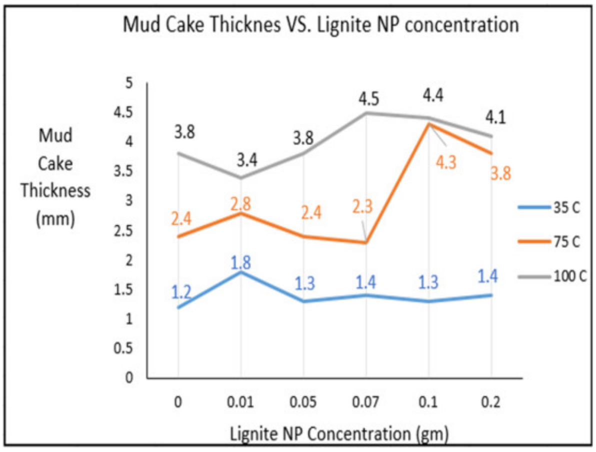

Figure 2: Effect of Lignite NP addition on mud cake thickness of API WBM

3.1.2 Polymer mud

Filtrate volume and mud cake thickness of polymer mud before adding Lignite NP increased from 6 ml to 8 ml and from 1 mm to 1.6 mm when temperature increased from 35 °C to 100 °C.

At 0.01 gm of Lignite NP, the filtration reduction percentages were 18.33%, 29%, and 52.5% at 35 °C, 75 °C, and 100 °C respectively. As the concentration of Lignite NP increases, the filtrate volume value is unstable but still lower than the basic values at three different temperature degrees as shown in **Fig.3.**

Lignite NP addition causes instability in mud cake thickness due to the instability of filtrate volume at 75 °C and 100 °C, while at 35 °C the mud cake thickness decreases as Lignite NP concentration increases and is almost proportional to the filtrate volume as shown in **Fig.4**.

From above paragraph, it is concluded that at high concentrations of Lignite NP the filtrate volume and mud cake thickness is reduced specially at high temperature conditions.

3.1.3 DURA THERM mud

The effect of Lignite NP is observed when 0.05 gm is added, where the filtrate volume decreases as the concentration of Lignite NP increases until reduction percentage reaches 36% at 0.2gm and 100 °C where the filtrate volume decreased from 5 ml to 3.3 ml as shown in **Fig.5.**

In DURA THERM mud and at 35 °C the mud thickness decreased about 30% with addition 0.01 gm of Lignite NP but returned increase with higher concentrations, at 75 °C and 100 °C mud cake thickness was unstable behavior with lignite addition. As shown in **Fig.6.**

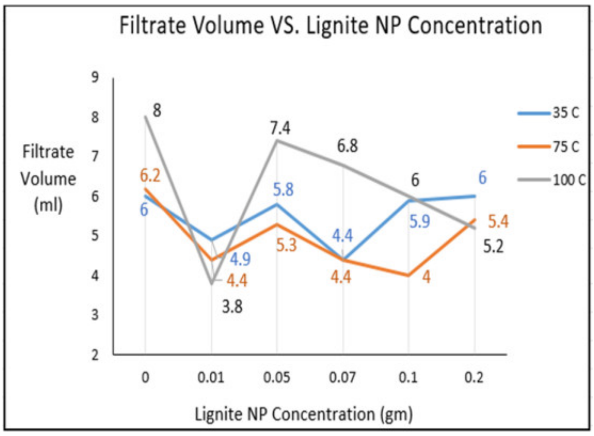

Figure 3: Effect of Lignite NP addition on filtrate volume of Polymer mud

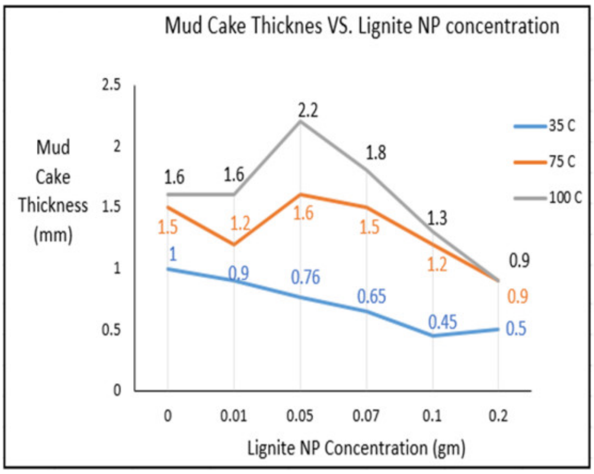

Figure 4: Effect of Lignite NP addition on mud cake thickness of Polymer mud

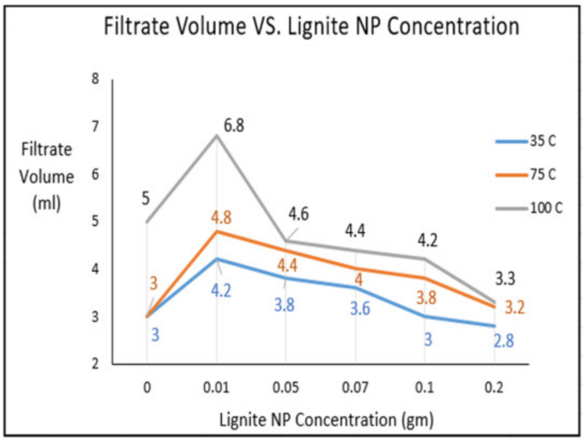

Figure 5: Effect of Lignite NP addition on filtrate volume of DURA THERM mud

From above paragraph, it is concluded that high concentration of Lignite NP has good effect on filtrate volume but DURATHERM mud has low values of mud cake thickness before any addition of nanomaterials.

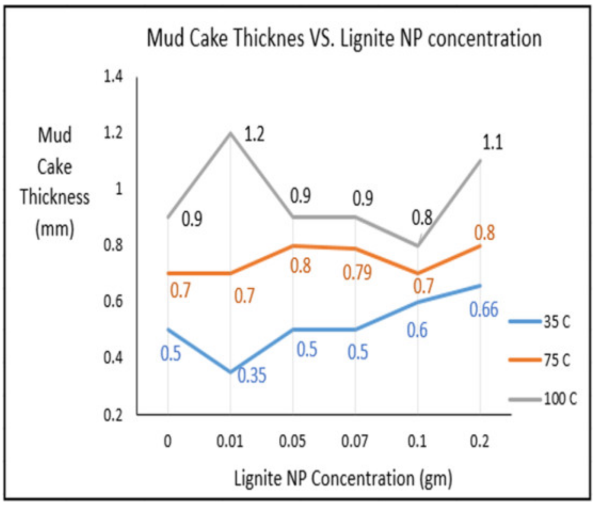

Figure 6: Effect of Lignite NP addition on mud cake thickness of DURA THERM mud

3.1.4 Saturated Salt Water mud

The effect of Lignite NP on the filtrate volume of this mud is shown in **Fig.7.**

It can be noticed that filtrate volume decreased with high concentration of Lignite NP at all temperature degrees. The filtrate volume nearly stables until (0.07 gm of Lignite at 35 ^{o}C) and (0.05 gm of Lignite at 75 ^{o}C), then they reduced to 2.5 mm and 1 mm at 0.2 gm of Lignite NP. At 100 ^{o}C the filtration reduction ratio is about 60% at 0.1 gm of Lignite NP.

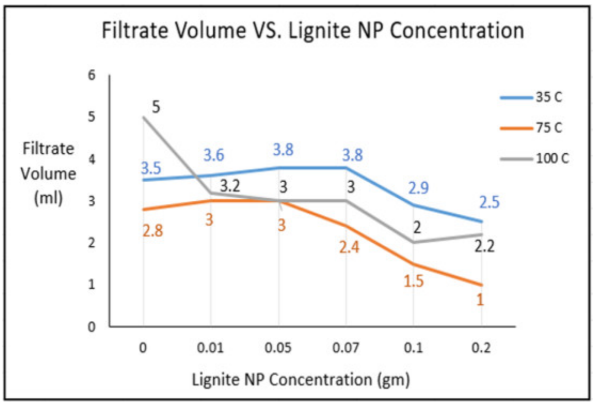

Figure 7: Effect of Lignite NP addition on filtrate volume Saturated Salt Water mud

At 35 ^{o}C and 100 ^{o}C mud cake thickness is increased with small concentration of lignite NP but it is returned decrease after adding 0.07 gm. While at 75 ^{o}C thickness of mud cake shows unstable behavior with Lignite NP weights, as shown in **Fig.8.**

From above paragraph, it is concluded that Lignite NP addition improved filtration properties of this mud especially at high concentrations and at all temperature conditions.

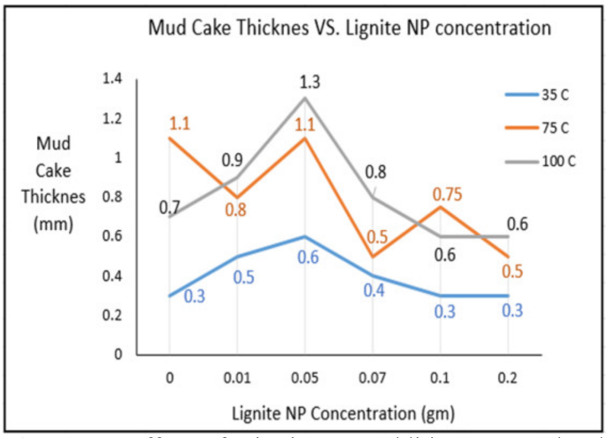

Figure 8: Effect of Lignite NP addition on mud cake thickness of Saturated Salt Water mud

4. CONCLUSION

1. Adding ***Lignite NP*** with few concentrations to the ***API WBM*** reduces filtrate volume, where at 75 °C temperature and 0.05 gm the filtrate reduction percentage of 15.8 %. Also at 100 °C the addition of 0.01 gm Lignite NP exhibits the same behavior as 75°C, filtrate volume decreases with percentage reduction reaches 20.9 %.
2. ***Lignite NP*** effect on ***Saturated Salt Water mud*** decreases filtrate volume at 0.2 gm concentration with reduction percentage of 28.6 % and 64.3 % at 35 °C and 75 °C respectively. While reduction percentage reaches 60 % with 0.1 gm at 100 °C.
3. ***Lignite NP*** is more effective on ***Polymer mud,*** especially at low concentrations and at 75 °C and 100 °C.
4. The effect of ***Lignite NP*** addition to ***DURATHERM mud*** is unstable and ineffective at 35 °C and 75 °C but their effect is more significant at 100 °C. Where at 100 °C the filtrate volume reduction percentage reaches 36% with 0.2gm Lignite NP addition.

Abbreviations

Symbol	Definition
API	American Petroleum Institute
BOC	Basra Oil Company
HTHP	High Temperature High pressure
IDC	Iraqi Drilling Company
LTLP	Low Temperature Low pressure
MWCNT	Multi Walled Carbon Nano Tubes
NP	Nano Particle
NWBF	Nano enhanced Water-Based Fluid
PAC	Poly-anionic Cellulose
Pal	Palygorskite
PAM	Polyacrylamide
WBM	Water Base Mud
XC	Xanthan gum

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تحسين ادائية سوائل الحفر باستخدام دقائق اللكنايت النانوية

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نشر في: 31 آذار 2019

الخلاصة – تاثير اللكنايت على خواص الترشيح لموائع الحفر مائية القاعدة تم دراسته من قبل باحثين عند درجات حرارة واطئة وعالية. وحديثا تم التوصل الى استخدام الجزيئات النانوية كاضافات بديلة بسبب استقراريتها عند عملية الحفر حتى عند درجة الحرارة و الضغط العاليين. وفي دراستنا سوف نستخدم جزيئات اللكانيت النانوية بتراكيز مختلفة 0.2 ,0.1 , 0.07 ,0.05 ,0.01)gm) لدراسة تاثيرها على خواص الترشيح لموائع الحفر التالية (API WBM, Polymer mud, DURA THERM mud and Saturated Salt Water MUD) وبثلاث درجات حراية مئوية (100, 75, 35). اما بالنسبة للنتائج فقد تم التوصل الى ان اغلب العينات المدروسة اعطت نتائج جيده عند التعرض للحرارة العالية 100 درجة مئوية , وافضل النتائج كانت في Polymer mud عند تركيز اللكنايت النانوية gm0.01 و في Saturated Salt Water mud عند تركيز gm 0.1 عند درجة الحرارة العالية 100 درجة مئوية, حيث ان نسبة التحسين في تقليل حجم الراشح كانت 52.5% و 60 % على التوالي .

الكلمات الرئيسية – سائل الحفر ، الجزيئات النانوية، السيطرة على خسائر الراشح، ظروف درجات الحرارة والضغط العالية.