New Study of Mgo Nps in Drilling Fluid to Reduce Stick-Slip Vibration in Drilling System

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Abstract

Stick-slip is kind of vibration which associated with drilling operation in around the bottom hole assembly (BHA) due to the small clearance between drill string & the open hole and due to the eccentric rotating of string. This research presents results of specific experimental study that was run by using two types of drilling mud (Fresh water Bentonite & Polymer), with/without Nanoparticle size materials of MgO in various ratios and computes the rheological properties of mud for each concentration [Yield point, plastic viscosity, Av, PH, filter loss (30 min), filter cake, Mud Cake Friction, Friction Factor]. These results then were used to find a clear effects of Nanoparticle drilling mud rheology on stick - slip strength by several perspectives through a special "Torque and Drag" software which simulate the torque amount expected on BHA during drilling a vertical well in different conditions using real drilling string design that usually used in Iraqi oil fields. Thus to mitigate or to prevent stick–slip and cure the sequence events that could happen to both of drilling string and the well, i.e. Bit/BHA wear, pipe sticking, borehole instability and low Rate of penetration. Our study concluded that there are good reduction in the torque from (2031lb-ft) to (1823lb-ft) using polymer mud and torque reduction from (4000lb-ft) to (3450lb-ft) using Fresh Water Bentonite, these results do not include any breaking in the satisfactory range of other mud rheology.

1- Introduction

It is a usual routine that problems occur while drilling a well, even if we reviewed the well plan carefully. For example, in areas in which similar drilling practices are used hole problems may have been reported were no such problems existed previously in offset wells because formations are nonhomogeneous. Therefore, several wells near each other may have different geological conditions. [1], [2]

The failures of a drill string have increased obviously in the last 10 to 15 years due to the use of directional drilling modeling and complex models with expensive downhole tools which make vibration monitoring and controlling is a key of drilling optimization, and have become a serious issue resulting in substantial cost effective. Therefore, detection and control of drill string vibrations have become an area of considerable interest. [3]

Three main types of vibration frequently occur (individually or together) during drilling formation, (torsional vibration, axial vibration and lateral vibration). Over limited vibration can cause drill string failure, poor directional tendency, premature bit failure, stalling of the top drive or rotary table, hole enlargement, MWD tool failure, and Bit /Stabilizer / tool joint wear[4].

Torsional vibrations are often classified as one of the most damaging models of vibration when downhole tools called stick-slip Phenomenon [5], [6].

2- Aim of This Study

In this Study, anew work is acted to find out the relationship between the using of (Nano – MgO) materials in drilling mud and stick slip vibration during drilling in different concentrations.

To achieve real results the test has been ran in two major types of drilling mud; freshwater Bentonite (FWB) Mud and Polymer Mud, to cover the drilling muds for both of shallow and deep wells.

3- Methodology

MgO is usually manufactured by calcination of magnesium carbonates. In contrast to expansive additives, the reactivity of MgO is influenced by the manufacturing process. In comparison with other materials MgO exhibit a considerably higher free enthalpy, thus a higher reactivity, even in the dead-burnt state (manufacture at a temperature above 1600°C), while MgO nanoparticles are prepared by microwave-assisted synthesis using magnesium acetate, where MgO Nano-powders is synthesized using microwave plasma torch.[7]

It is clearly noticed that Nano fluids made by Nano MgO show specific properties such as a high tendency for adsorption, where MgO increases the effect of attraction forces in comparison with repulsion forces which results in fine fixation [8], [9].

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3.1. Sonication System

Ultrasonic system consists of 3 major components: Generator, Converter and probe (Horn).

The Generator transforms AC line power to electrical energy with high frequency by providing high voltage pulses of energy at a frequency of 20 kHz that drives a piezoelectric by Converter, the probe's tip expands and contracts longitudinally, this will lead to cavitation in the liquid and violent collapse of microscopic bubbles during rapid vibration. The collapse of many of cavitation bubbles releases a huge energy in the cavitation field. This feature is a keypad, which allows the user to adjust the sonication parameters as per test requirements [10].

3.2. Ultrasonic

Dispersion of nanoscale materials has become dependent on ultrasonic methods. Even with chemical dispersing agents, were to provide access to these agents onto material surfaces, ultrasonic is required.

In usual dispersion runs, sonication takes 12-36 hrs. in order to ensure a good dispersion in an appropriate solvent.

3.3. Ultra-Sonic Device (Elma)

Ultrasonic device made for multipurpose duties: remove chlorine from water, kill Bacterial cells, remove and recover ammonia from industrial waste water move and recover ammonia from industrial wastewater [10] as shown in Fig. **1** below:

Fig. 1. Elma ultrasonic device

3.4. Mud Lubricity Tester

In this study, generally use the lubricity meter to measure the COF or the coefficient of friction (Baroid lubricity coefficient) between the test ring and block [11].

The lubricity test represents (simulates) drill pipe rotation against downhole surfaces, using a constant load of 150 inch-pounds (600psi) is applied using a torque arm.

The lubricity tester is regularly used to evaluate and predict the impact made by a drilling fluid additive on friction.

The following coefficients are recognized as acceptable value:
1- CoF For water-based mud, a coefficient < 0.2
2- CoF For oil-based mud, a coefficient < 0.1
3- CoF For ester-based mud, a coefficient < 0.1

Fig. 2. Ofite EP and LUBRICITY TESTER

The OFITE EP and Lubricity tester is used to measure and evaluate the lubricating quality of drilling fluids, predict wear rates of mechanical parts in known fluid systems and provide data to assess the type and quantity of lubricating additives that may be required.

The following Calculations is required:
Correction Factor= $34\ Meter\ (32\ to\ 36)$

Lubricity Coefficient $=\dfrac{Meter\ Reading\ \times Correction\ Factor}{100}$

Percent of Torque Reduction= $\dfrac{A-B}{A}\times100$

Where: A= Torque reading of untreated mud, B= Torque reading of treated mud
And from viscometer:
Plastic viscosity

$(PV),\ cP= \theta600 – \theta300$ (1)

$Yeild\ Point\ (YP),\ Ib/100ft2= \theta300- PV$ (2)

$Apparent\ Viscosity\ (AV),\ cP= \theta600/2$ (3)

Gel strength, 10 second, Ib/100 ft2= the maximum dial deflection after 10 sec

Gel strength, 10 Minute, Ib/100 ft2= the maximum dial deflection after 10 Min.

3.5. Torque and Drag Software

Using the results of the lab test we took the friction factor and put it in a special Torque and drag software made by a global company to simulate a drilling job and find out Torque on the bit.

a. Torque and Drag Software assumption

The drilling model was build using parameters of IDC-56 to drill vertical well, 12 1/4" hole section, WOB=28 - 30 Klb. (WOB =12 Klb. For FWB mud where this mud used in shallow depth), RPM= 40 and fixed friction factor of 0.25 ft-lb between drilling string and 13 3/8" casing. The drilling Bit and BHA designed as follow:

Table 1. BHA Design

Item	Description	OD	ID	Weight	Length	Cum. Lengt
#		(in)	(in)	(lbpf)	(m)	(m)
1	PDC	8.000	3.500	138.52	0.44	0.44
2	Near-Bit Stabilizer with FV	8.000	3.000	147.22	2.31	2.75
3	MWD Directional + Gamma	8.000	4.000	128.48	9.90	12.65
4	1 x 8" Drill Collar	8.000	2.750	150.70	9.14	21.79
5	Integral Blade Stabilizer	8.000	3.000	147.22	2.16	23.95
6	PBL Circulating Sub	8.000	3.250	143.03	2.00	25.95
7	5 x 8" Drill Collar	8.000	2.750	150.70	45.70	71.65
8	8" Sledgehammer Jar	8.120	2.750	132.58	6.66	78.31
9	1 x 8" Drill Collar	8.000	2.750	150.70	9.14	87.45
10	X-Over Sub	8.000	2.875	149.18	0.78	88.23
11	2 x 6 3/4" Drill Collar	6.750	2.750	101.50	18.28	106.51
12	15 x 5" HWDP	5.000	3.000	49.30	140.70	247.21
13	5" DP	5.000	4.276	21.92	9.00	256.21

4- Experimental Work

This work aims to improve the rheological properties of drilling mud by reducing the friction of the mud with less filtration plus thin mud cake.

Drilling fluids have prepared with two major types of mud (FWB & Polymer mud) using varies Nano MgO ratio.

All experiments tests conducted under laboratory conditions, and then the mud hot rolled by heating for four hours in about 250 degree Fahrenheit and retested again.

Table 2. Polymer Mud Materials

Composition	Unit	Blank	Mixing Time
Drill Water	cc	280.4	-
Sodium Chloride	gr	61.3	5 min
Potassium Chloride	gr	11.6	5 min
Caustic Soda	gr	1	5 min
Soda Ash	gr	1.5	5 min
Starch	gr	12	15 min
PAC LV	gr	1	15 min
Xanthan	gr	0.5	15 min
Limestone (50-75 μ)	gr	87.6	20 min

Table 3. FWB Mud Materials

Composition	Unit	Blank Sample	Mixing Time
Drill Water	cc	350	-
Bentonite	gr	22.5	20 in

4.1. Sample Preparation

a. Procedure of Nano-MgO dispersion

1- Nano MgO powder was mixed in Distilled water and subjected to Ultrasonic Bath.
2- Surfactant for efficient dispersion of nanoparticles was mixed in Distilled water and subjected to Ultrasonic Bath too.
3- In the end, both solutions were merged and put in the Ultrasonic Bath for 7-8 hours.
4- We made five samples (cups), the first cup without MgO (as a blank) then adding 0.3, 0.6, 0.9, 1.5 gm of MgO consequently.
5- Different concentrations of this Nano-colloidal solution added to the drilling fluid system as following:
   I. 280.4 CC of polymer mud.   II. 350 CC of FWB.

b. Prepare polymer mud

Preparing was made based on the following table and mixed them by multimixer Fann 9B:

Table 4. Composition of Polymer Mud

Composition	Unit	Blank	Mixing Time
Drill Water	Cc	280.4	-
Sodium Chloride	Gr	61.3	5 min
Potassium Chloride	Gr	11.6	5 min
Caustic Soda	Gr	1	5 min
Soda Ash	Gr	1.5	5 min
Starch	Gr	12	15 min
PAC LV	Gr	1	15 min
Xanthan	Gr	0.5	15 min
Limestone (50-75 μ)	Gr	87.6	20 min

1- Adding Nano material (different Concentration) to blank of polymer mud and mix for 20 min.
2- Measure viscosity by Rotational Viscometer Model OFITE 800 (Based on the attached procedure) at 120°F
3- Put prepared mud in hot roll for evaluating rheological properties in downhole situation at 250° F during 4 hrs.
4- After hot roll, measure viscosity at 120°F by rotational viscometer model OFITE 800
5- Measure filtrate volume by API Filter Press model Fan 300series (based on mentioned procedure) at room temperature and 100 psi pressure work.
6- Evaluate lubricity factor by EP/ Lubricity tester (based on mentioned procedure)

c. Preparing Bentonite Mud

The preparing was made based on the following table then aged in hot roll:

Table 5. FWB Mud Materials

Composition	Unit	Blank Sample	Mixing Time
Drill Water	cc	350	-
Bentonite	gr	22.5	20 min

1- Aging prepared mud in room temperature for 18 hrs.
2- Adding Nano material to prepared mud in the required concentration and mixing by a multi mixer at 20 min.
3- Measure viscosity at 120°F by rotational viscometer Model OFITE 800 (Based on the mentioned procedure)
4- Measure filtrate volume by API Filter Press model Fan 300series (based on the attached procedure) at room temperature and 100 psi pressure work.
5- Evaluate the lubricity factor by EP/ Lubricity tester (based on attached procedure).

d. Preparing Nano Material

Preparing Nano Material for all experimental work can be concluded as follow:
1. Add Nano material to water and disperse it in water by ultrasonic for 1 hour.
2. Add prepared Nano solution to surfactant and disperse them for 7 hrs by ultrasonic (this is final Nano solution)
3. Add final Nano solution to polymer mud in during mixing based on required concentration for 20 minutes.

5- Results and discussion

5.1. Polymer mud test with Nano MgO additives

Mud Rheology changes after adding Nano MgO to 280.4 cc of polymer Mud by various concentrations as shown in Table **6**

Table 6. Mud Rheology parameters

| Rheology	-------- gm	0.3 gm	0.6 gm	0.9 gm	1.5 gm
AV	21.5	24	24	35.5	36.5
RPM 600	43	48	48	71	73
RPM 300	26	30	28	43	46
PV	17	18	20	28	27
YP	9	12	8	15	19
RPM 200	19	22	21	31	33
RPM 100	12.5	13.5	13	19	20
RPM 6	3.5	3.5	3		5
RPM 3	2.5	3	2.5	5	4
GEL 10 s	3	4	3	4	5
GEL 10 min	4	5	4	5	6
pH	12.21	10.87	11.24	11.11	10.98
API FL, cc	2.2	2.7	2.3	3	2.8
Settlement	yes	No	No	No	No
Filter cake	1/32	1/32	1/32	1/32	1/32
Foam	No	No	No	No	No
Water Torque Reading	33.7	34.4	34.3	36.0	35.0
Mud Torque Reading	20.1	20.0	19.9	19.6	21.2
Lubricity Factor	0.2028	0.19767	0.1973	0.1851	0.2059
Torque Reduction	-	0.5	0.9	2.4	-
Mud Cake Friction (KF)	0.2046	0.2268	0.16578	0.18323	0.25303
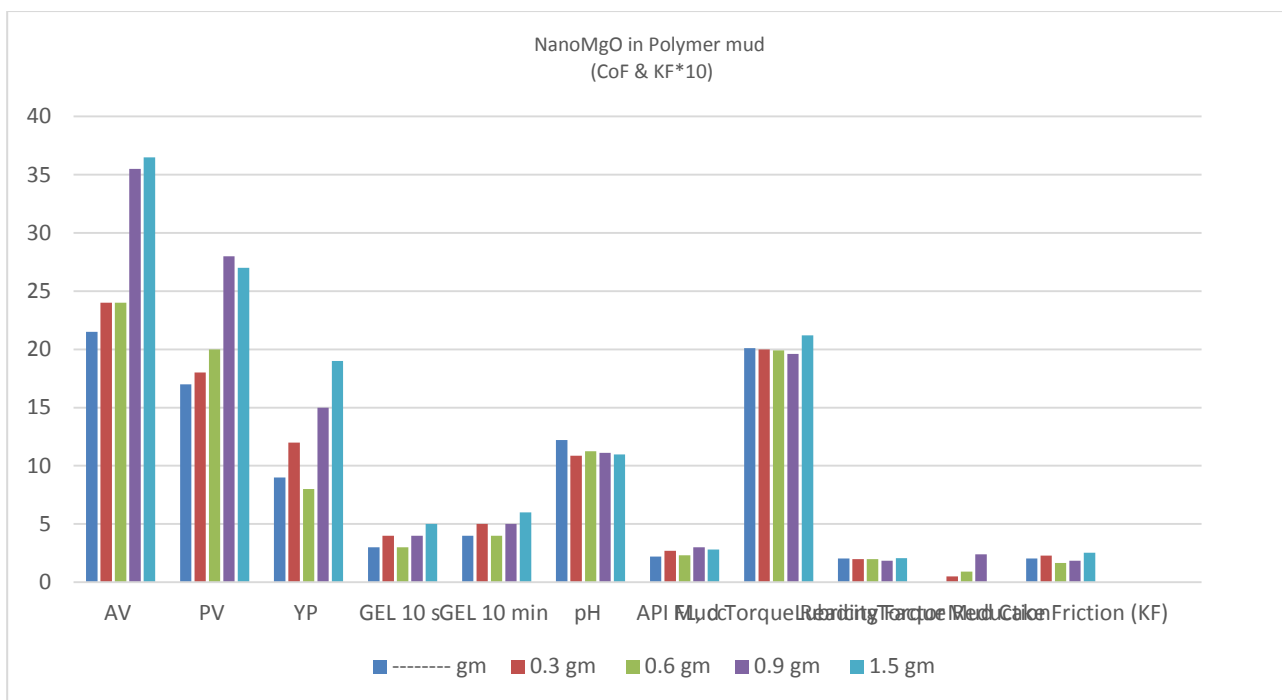
Fig. 3. Polymer mud with different MgO NPs concentrations

In Fig. **3**, both Mud cake friction and Lubricity factor multiplied by 10 to clarify the change for review because their amount is too small. The diagram of Test 7 illustrated that the MgO concentration of 0.9 gm in polymer mud is the most affected with regards to torque reduction with the amount "0.1851" of CoF. At the same time the test of 0.9 concentration has no significant changes in other mud rheology except PV which recorded (26) where its higher than the Pv at blank and (0.3 gm) tests, as per Nanomaterials are solid structure so higher PV is typical results.

We can also notice YP 0.9 gm test is higher than the previous two tests but still in the allowable range to raise cutting with no formation damage.

In Table **7** Friction Mud Rheology changes after adding Nano MgO to 280.4 cc of polymer Mud by various concentrations.

Table 7. CoF, KF with Torque Reduction

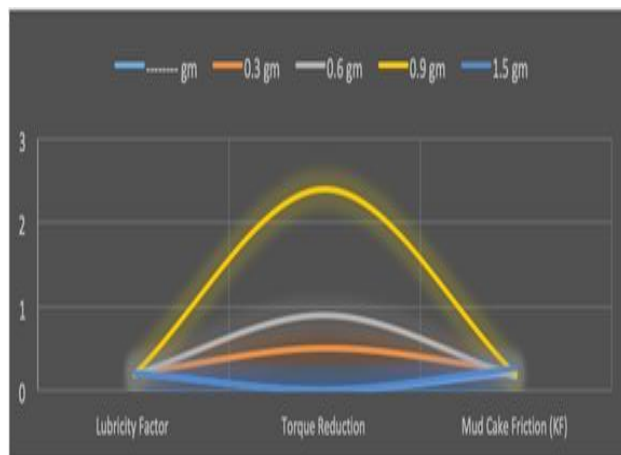| Rheology	-------- gm	0.3 gm	0.6 gm	0.9 gm	1.5 gm
Lubricity Factor	0.2028	0.19767	0.1973	0.1851	0.2059
Torque Reduction	-	0.5	0.9	2.4	-
Mud Cake Friction (KF)	0.2046	0.2268	0.16578	0.18323	0.25303

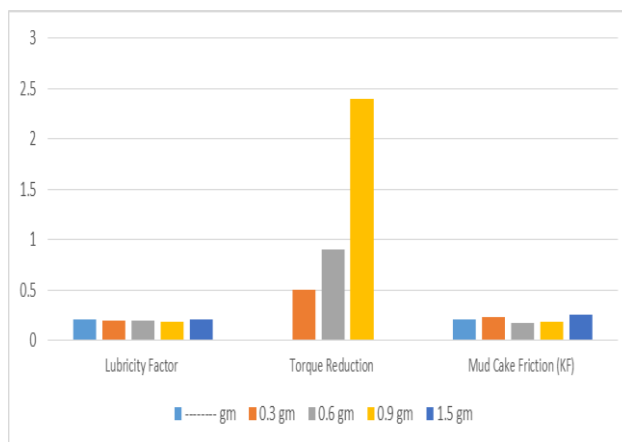Fig. 4. CoF, KF and TORQUE reduction with related to MgO NPs additives in polymer

Fig. 5. CoF & Torque reduction & KF of five tests in polymer

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Table 8. magnitude of CoF with MgO concentration

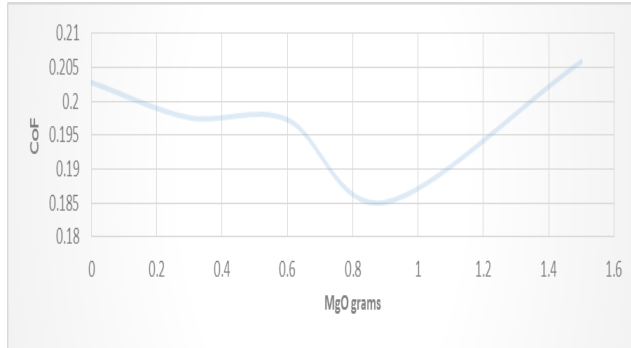| Rheology	--------gm	0.3 gm	0.6 gm	0.9 gm	1.5 gm
Lubricity Factor	0.2028	0.19767	0.1973	0.1851	0.2059

Fig. 6. MgO consentration&CoF in polymer

In Fig. **4**, Fig. **5** & Fig. **6**, it was clear that the 0.9 gm of Nano MgO had got the best CoF (lowest value) that led to decline in torque reading. However, the CoF and Lubricity factor had risen dramatically when the Nano concentration increased more than 0.9 gm. In addition, there is improvement in CoF between 0.6 to 0.9 gm but noticed stability in CoF in between 0.3 to 0.6 gm. in another hand although there was CoF decreasing when 0.3 gm added, but not as fall as the test of 0.9 gm MgO.

In Table **9** the recorded data of torque software regarding Lubricity Factor changes with tests

Table 9. CoF and Torque reading data

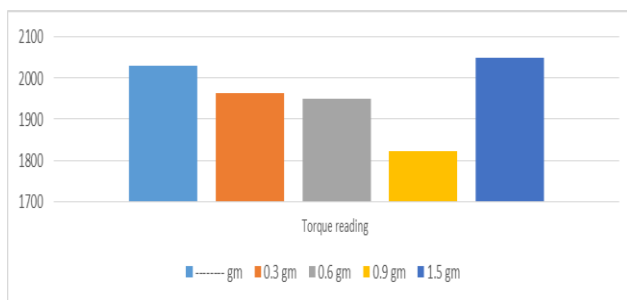| Rheology	--------gm	0.3 gm	0.6 gm	0.9 gm	1.5 gm
Lubricity Factor	0.2028	0.19767	0.1973	0.1851	0.2059
Torque reading	2031	1963	1950	1823	2050

Fig. 7. Polymer & MgO Torque software reading

From Fig. **8** & Fig. **9**, general in the blank test the software reads 4000 ft-lb and start decreasing by adding Nano MgO until getting its best amount in this lab tests, then refers back to 4000 in concentration Nano MgO of 1.5 gm. So using Nano - MgO more than (1) gm per 280.4 CC of polymer mud should be avoided because of it sharply higher the friction factor and mud torque amount.
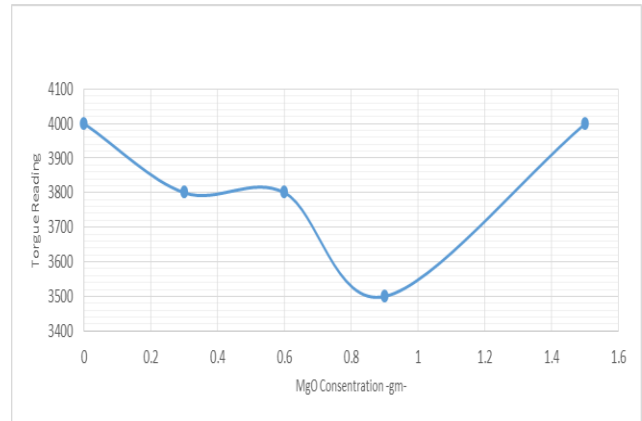

Fig. 8. Polymer& mgo torque reading on software

The best result recorded in the test was 0.9 gm MgO, however there was a little high AV and Pv (AV =35.5 & pv =28). And that due to the loos of other Nano benefits and maybe 0.9 gm or above cannot be used when plastic viscosity is restricted in certain drilling problems expected. Therefore, the same restriction with regards to the limitation of pump pressure and/or ECD (Equivalent Circulating Density) then lead to using low AV (where, AV= shear stress/shear rate),so it will require higher pressure.

5.2. Fresh Water Bentonite Mud Test With Nano Mgo Additives

Using five cup tests consist of FWB and Nano MgO in different concentrations we got the results in Table **10**.

Table 10. Mud Rheology changes after adding Nano MgO to 350 cc of FWB Mud by various concentrations

| Rheology@ 120 F	Blank	0.3 gm	0.6 gm	0.9 gm	1.5 gm
AV	19	20	21	33.5	42
RPM 600	38	40	42	67	84
RPM 300	35	35	39	62	79
PV	3	5	3	5	5
YP	32	30	36	57	74
RPM 200	33	37	38	62	76
RPM 100	30	35	37	59	72
RPM 6	25	33	34	56	66
RPM 3	24	33	33	55	65
GEL 10 s	24	35	35	46	61
GEL 10 min	25	37	38	52	66
pH	9.18	11.40	11.23	11.26	11.25
API FL, cc	14	14.3	16.4	17.0	15.2
Settlement	No	No	No	No	No
Filter cake	4/32"	4/32"	5/32"	5/32"	4/32"
Foam	No	No	No	No	No
Water Torque Reading	35.5	34.5	34.8	35.9	33.9
Mud Torque Reading	44.3	36.3	33.4	39.9	37.0
Lubricity Factor	0.4243	0.3577	0.3266	0.3779	0.3711
Torque Reduction	-	18.05	24.06	9.93	16.48
Mud Cake Friction (KF)	0. 69	0.0959	0.1483	0.1919	0.1745
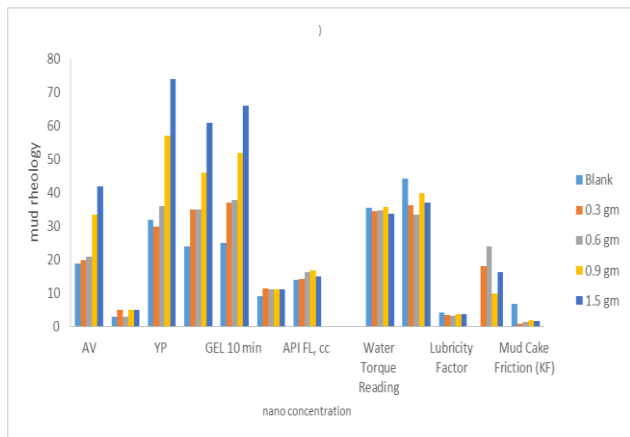
Fig. 9. Nano MgO in FWB (Lubricity Factor & Mudcake Friction*10)

In Fig. **9** Both Mud cake friction and Lubricity factor multiplied by 10 to make it clear for review because their amount are too small.
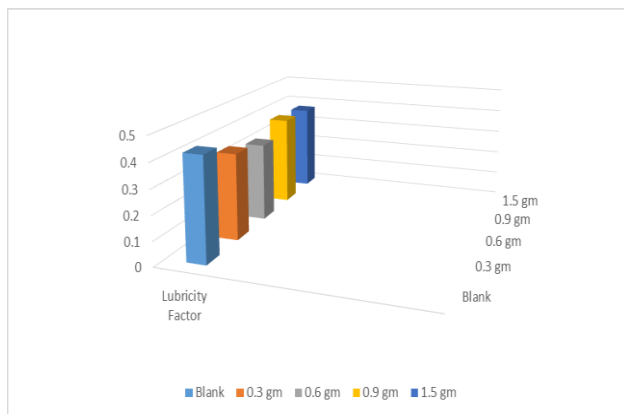

Fig. 10. Lubricity Factor (Nano MgO in FWB)

Table 11. CoF & Torque and drag software reading

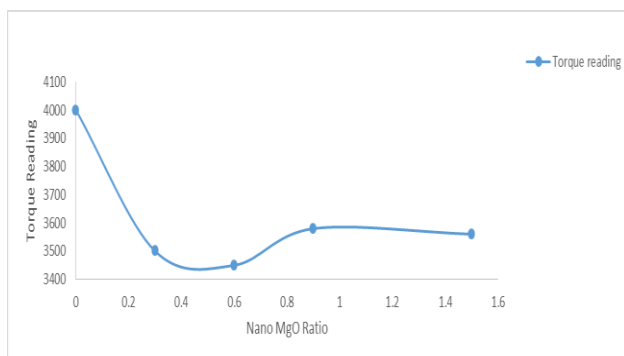| Rheology	--------gm	0.3 gm	0.6 gm	0.9 gm	1.5 gm
Lubricity Factor	0.4243	0.3577	0.3266	0.3779	0.3711
Torque reading	4000	3500	3450	3580	3560

Fig. 11. Sofy ware torque reading in FWB with MgO

By Fig. **11** we can find that Nano MgO additives reduced the expected downhole torque by more than 1500 ft-lb in the concentration of 0.6 gm. and noticed a clear curve retrograded since the first Nano MgO was added to explain the perfect acting of that Nanoparticles to FWB, then to records its best Torque reduction at concentration of 0.6 gm.

In MgO concentration between 0.6 – 0.9 Torque goes high but still lower than it amount before adding MgO, because of the nanoparticles of MgO has good effects on that mud lubricity . In the concentration of 1.5 gm there is a little drop in torque which may indicate that will continue drop with adding MgO proportionally, however it will be cost effect and will raise other mud rheology i.e. GEL and PV.

6- Conclusion & Recommendations

The following are concludes the experimental results overall:

1- In polymer mud lubricity factor dropped from 0.2 to be 0.185 when we increased Nano MgO from zero to 0.9 gm gradually by the tests then CoF starts increasing again with more Nano MgO.
2- Even though it was a minimal decrease in CoF with Nano additives, but it succeeds to change torque reading from 2031lb-ft… to 1823lb-ft…. which lead to avoid 12.5% of stick-slip vibration probability.
3- No changes were noticed in the other mud rheology except increasing in plastic viscosity due to Nano particles, so we highly recommend using Nano MgO as additives in drilling companies working in Iraq, especially in forecast projects no more vertical wells as much as deviated and horizontal wells which stick and slip as commonly occurs.
4- Nano MgO performs better rheology results with FWB mud where CoF dropped (0.42 ➝ 0.32), with a clear drop in Torque reading (4000 ➝ 3450).
5- The other rheology parameters were normal and acceptable to be used, therefore we recommend using Nano MgO in drilling fluid to mitigate stick-slip phenomenon, in Nano ratio of 1.73 kg per one cubic meter of mud.

Finally some of the important recommendations supposed to be in mined by future researchers:

1- Re-run the experimental work using different MgO Nano concentrations of the same Nanomaterials to detect any sensitive in mud rheology.
2- Choose another type of drilling muds like oil-based mud, salt mud, emulsion mud and KCL mud that used in oil fields to explore the Nano-particles effects.
3- Making a special device (similar to a drilling rig in small scale) consist of a small Bit, BHA and source of WOB with rotating advanced by torque sensors, to simulate drilling a hole and evaluate the real stick – slip vibration changes with regards to adding different Nanoparticles types & weight ratio.

Nomenclatures & Abbreviations

AV	Apparent Viscosity
CoF	Coefficient of friction
FF	Friction factor
hrs.	hours
IDC	Iraqi drilling company (Rig number)
BHA	Bottom Hole Assembly
NP	Nano Particle
NPs	Nano Particles
PV	Plastic Viscosity, cp
ROP	Rate of Penetration
FW	Fresh water Bentonite
YP	Yield Point, Ib/100ft2
CP	cent poise
γ	Shear Rate, sec-1
τ	Shear Stress, Ib/100ft2
μp	Plastic Viscosity, cp
τ_0	Shear Stress at Yield Point, Ib/100ft2
τ_1	Shear stress at lower shear rate
$\tau 2$	Shear stress at higher shear rate

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دراسة حديثة عن تأثيراضافة مادة النانو MgO الى طين الحفر لتقليل ظاهرة الالتصاق والانزلاق(stick-slip) خلال عملية حفر الابار.

الخلاصة

ظاهرة الالتصاق والانزلاق هي احد انواع الاهتزازات التي تحدث اثناء عمليات الحفر حول مجموعة رأس البئر نتيجة لصغر الفراغ الحلقي بين التجويف المفتوح ومجموعة رأس البئر وكذلك بسبب الدوران اللامركزي لخيط الحفر اثناء الحفر.

في هذا البحث استعراض لنتائج مختبرية باستخدام نوعين رئيسيين من طين الحفر وذلك باضافة النانو MgO بتراكيز مختلفة لمعرفة مدى تأثيرها على خواص طين الحفر بشكل عام ولتحديد قيم معمل الاحتكاك بشكل خاص, ثم ادخال قيم معامل الاحتكاك المستحصلة من التجارب في برنامج خاص (سوفتوير) لتحديد قيم الاحتكاكات من نوع stick-slip المتوقعة حول مجموعة قعر البئرمن خلال عمل ممارسة فعلية في البرنامج لحفر بئر عمودي بالاستفادة من بعض التصاميم الفعلية لخيط الحفر والمستخدمة في الحفر الابار لاحد الحقول العراقية.

ان الهدف من هذا العمل هو للحصول على نماذج طين حفر تقلل او تمنع حدوث ظاهرة الالتصاق والانزلاق التي يؤدي حدوثها الى مشاكل حفر عديدة كـ : تلف الحافرة وملحقاتها, التصاق الانابيب, عدم استقرار جدار البئر , انخفاض معدل الاختراق.

نجحت دراستنا في ايجاد تراكيز من النانو MgO حققت انخفاض في جهد الاحتكاك (Torque) كالاتي:

- 2031 – 1823 في طين الحفر نوع polymer.
- 4000 – 3450 في طين حفر نوع Fresh Water Bentonite.

علما ان النتائج اعلاه كانت متزامنة مع مواصفات طين الحفر ضمن المدى المقبول لتحقيق اهداف سائل الحفر كرفع القطع الصخرية المحفورة وتعليقها عند التوقف وغيرها من مهام طين الحفر.