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Certain Assessment of Using MWCNT Nps in Drilling Fluid to Mitigate Stick-Slip Problem during Drilling Operation System

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Abstract

Stick- slip is the continuous stopping& release of the Bit/BHA due to the irregular down-hole rotation prompted by the existing relationship between the friction torque and the torque applied from the surface to free the bit.

Friction coefficient between BHA and wellbore is the main player of stick slip amount, which can be mitigated by support a good lubricators as additives in drilling mud.

Mathematical (or empirical) solves should be done through adjusting all parameters which supposed to reduce stick- slip as low as possible using different models, one of the main parameters is drilling mud. As per Nanoparticles drilling fluid is a new technology that offers high performance it's necessary to find out the relationship between the use of Nano fluid and the minimum stick- slip vibration. In this study (multiwall carbon Nano tube) will be used as a Nanoparticles in Fresh water bentonite mud and polymer mud by five tests per each one to find out the coefficient of friction and used it in a special torque and drag software as a part of drilling vertical well simulation to calculate expected bottom hole torque within five different Nano concentration per each mud type. In fresh water bentonite mud torque reduction was from 4000 ft-lb to 3500 ft-lb, while in polymer mud torque failed and didn't reduce, so it raised from 2050.88 ft-lb to be around 2200 ft-lb.

Keywords: stick – slip problem, drilling mud, Nano particles fluids, MWCNT, drill string, BHA vibrations

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1- Introduction

Big amount of vibration during drilling formation frequently occurs, where in one drilling run all three main vibrations may occur together (torsional vibration, axial vibration and lateral vibration). Solutions in both of technologies and methodologies paths can be together a useful key in order to reduce down hole vibration. Unacceptable levels of vibration can cause drill string fatigue, poor directional tendencies, premature bit failure, stalling of the top drive or rotary table, hole enlargement, MWD tool failure and Bit /Stabilizer / tool joint wear, stick-slip vibration represent the torsional type and it the biggest trouble maker between the three down hole vibrations. [1], [2], [3]

Nowadays, directional drilling models are the most preferred for many reasons, therefore there are needs of using complex bottom hole assembly design (BHA), where this BHA will be longer than the normal one and includes very thin clearance in some parts, so this drilling operation will create high torque and vibrations, hence such like these operation should comply with make vibration monitoring and controlling a key in drilling optimization. A number of operator companies have become aware of the importance of controlling vibration and have created programs to raise awareness and generate control strategies.[4], [5]

2- Aim of this study

In this Study we work to find out direct drilling mud effects on torsional vibration(stick-slip) during drilling by finding relationship between the problem of stick slip during drilling and the adding of Nanoparticle materials (using multiwall carbon Nanotubes (MWCNTs)] to the drilling fluid within different concentrations.

3- Methodology

Carbon Nano tube (CNT) is one of the allotropic forms of carbon with cylindrical shape structure. It is consist of carbon atoms which are connected in hexagonal shapes. [6], [7], [8].

The main character of CNT that is the Length of CNT can be up to 132,000,000 times greater as compared to its diameter which is very high and attractive as compared to other materials. In additional to cylindrical structure, important properties of CNT are exceptionally improved such as unique electrical characteristics, mechanical strength and thermal conductivity [2].

CNT is one of the strongest materials in terms of tensile strength and elastic modulus [9].

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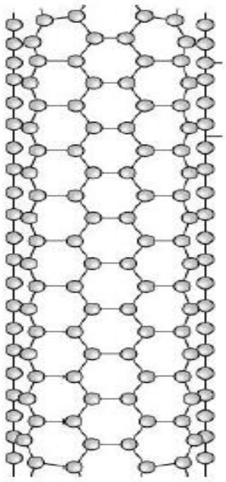

Fig. 1. Multiwall carbon Nanotube MWCNT [10]

Fig. 2. Single wall carbon Nanotube swcnt [10]

3.1. Diagnostic Test

a. The Lubricity tester

Lubricity tester is often used to assess and guess the influence made by a drilling mud additive with regards to friction force. The most common tester, the Fan or OFITE Model 212, is normally used in a laboratory setting (as shown in Fig. **3**).

This Extreme Pressure (EP) and Lubricity Tester is intended to simulate contact between a drill string and casing, it consists of a rotating ring and stationary block, which are submerged in the drilling fluid.

Since particular load under wellbore conditions is hard to determine, classically fixed levels of contact forces are used. We can measure by this device lubricity factor or coefficient of friction (CoF), Mud torque reading and Mud cake friction (KF).

Fig. 3. Ofite Lubricity Tester [11]

There are some features make this model device is still up to date of measuring friction factor, the following features conclude them:

- The accuracy of reading data by Digital Control.
- The motor automatically maintains torque as a constant speed when force is applied to the ring and block. So no need to manual speed adjustments.
- Simple use instruction, makes testing quick and easy, i.e. manual speed control, pre-set speeds (60, 200, 600, and 1000 RPM) and torque zeroing.
- Has the ability of recording torque reading and temperature with respect to time in simple and clear monitor. [11]

3.2. Ultrasonic Actions

An ultrasonic treatment is the most common solution to disperse the nanoscale particles in liquid media. It used with/ without chemical dissolving agents. In typical dispersion operations, sonication required about (12-36) hrs. to ensure influence dispersion with appropriate solvent.

a. Sonication Organization

There are three major stages that Ultrasonic system working on it: Generator to transfer AC power energy (high voltage), Converter works as modifier of that energy into vibration and probe (Horn) enlarges and contracts longitudinal status. By changing the amplitude setting we can get a various cavitation fields.

During sonic operation the solution could get high temperatures, so it may need close observation [12], [13].

b. Ultra-Sonic Device (Elma E series) [14]

- **Sweep (cleaning)**: Safely clean metal, glass, electronic, and plastic parts
- **Degas(bubble remover)**: Rapidly remove gasses from liquids
- **Normal(dispersion)**: Dissolve, homogenize, disperse, mix and emulsify lab samples

Fig. 4. Elma ultrasonic device E series

The Elmasonic E series consists of 8 diverse unit dimensions with tank volumes alternating from 1.75 up to 28 litre.

They are formed with efficient 37 kHz ultrasonic power transducers of the latest generation. It is easy to work in lab condition and safe to be left alon to automatic switch-off after 12 hours for more safety.

3.3. (Stick-Slip) Software Assumption

Using some parameters of the real rig and by input the variable values of friction factors that got from the experimental work for 10 samples, this software will calculate a new torque values (ft-lb) per each sample result. In this research Rig IDC-56 is used to simulate drilling a vertical well, 12 1/4” section hole, WOB=(25 - 30 Klb. for polymer mud, and WOB =12 - 14 Klb. for FWB mud where it commonly used on shallow depth), RPM= 45 with fixed friction factor of 0.25 ft-lb between drilling string and 13 3/8” casing. The drilling Bit& BHA designed as follow:

Table 1. BHA design in software

Item	Description	(OD)	ID	(Weight)	Length	Cum. Length
#		(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
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"]Heavy wall drill pipe(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 workshop is prepared to develop the rheological characterize of drilling fluid. The increase of some rheological parameters above the desired limit can cause some issues such as stuck pipe, lost circulation etc. For example, the preferred drilling fluid has minimum plastic viscosity, and gel strength with a flat curve in order to reduce the required pump pressure to start circulation again.

To reach these aims of the study, ten experiments tests were directed in bottom hole conditions, where hot roll was used in order to heat and rotate the mud samples for four hours in around 250 degree Fahrenheit, Viscometer Model 800 was used to measure mud rheology, Benchtop meter to get PH, Filter press device to determine the water loss Multi-mixer Model 9B Fan to ensure mix mud in high efficient and quick minor, sonication system with solvent to disperse Nanoparticle in mud and Mud Lubricity Tester to catch the friction factor for each test sample.

4.1. Sample preparation

To insure good Nano-MWCNT Dispersion the following Procedure was conducted:

a. Mixing MWCNT powder in Distilled water and put it into Ultrasonic Bath.
b. Mixing Surfactant in water type Distilled to raise the efficiency of nanoparticles dispersion and put it into Ultrasonic Bath too.
c. Merge the two solutions were prepared in above and put them again in the Ultrasonic Bath for 7-8 hours.
d. Five samples (cups) were made, as per the first sample was blank then adding 0.35, 0.7, 1.05, 1.75 gm of MWCNT consequently to FWB and adding 0.1, 0.2, 0.3, 0.5 gm to polymer mud.
e. Nano-colloidal solution added to fluid system in Different concentrations as follow:
   1- 280.5 CC of polymer mud.
   2- 350 CC of FWB.

4.2. Mixing Mud

a. Preparing polymer mud

Preparing was made based on Table **2**, the materials were mixed by multi mixer Fann (9B)

Table 2. polymer mud composition

Composition	Unit	Blank	Mixing Time
Distilled Water	CC	280.5	-
Sodium Chloride	gm	61.35	10 min
Potassium Chloride	gm	11.66	12 min
Caustic Soda	gm	1.05	12 min
Soda Ash	gm	1.55	12 min
Starch	gm	12.5	12 min
PAC LV	gm	1.04	12 min
Xanthan	gm	0.55	12 min
Limestone (50-75 μ)	gm	87.65	12 min

1- Using five individual samples of blank polymer mud Nano material were added in different concentration and mixed for 20 min.
2- By using Rotational Viscometer Model OFITE 800, viscosity Measured by at 120^{o}F
3- Put arranged mud in hotroll for assessing rheological properties in downhole circumstance at 250^o F amid 4 hrs.
4- Calculate the viscosity and gel strength at 120^{o}F by rotational viscometer type (OFITE 800)
5- Measure mud filtrate volume through API Filter Press type (Fan 300series) at laboratory temperature and pressure of 100 psi.
6- Appraise lubricity factor by using (EP/ Lubricity) tester

b. Prepare Bentonite Mud

Table 3. FWB mud composition

Composition	Unit	Blank Sample	Mixing Time
Distilled Water	CC	350.0	-
Bentonite	gm	22.50	25 min

The mud prepared based on Table **3** as follow:

1- Aging arranged mud in lab. Temperature within 16 hrs. to ensure
2- Nano material added to mud sample cups in certain concentrations and mixed at 20 min.
3- Viscosity & gel strength measured at 120^{o}F using rotational viscometer Model (OFITE 800).
4- Measure filtrate volume by API Filter Press model Fan 300series at room temperature and 100 psi pressure work.
5- Determine lubricity factor (CoF) by the use (EP/ Lubricity) tester.

c. Preparation of Nano Material

The following steps are concluding Preparing of MWCNT Nano Material for all tests:

5- Results and Discussion

5.1. Polymer Mud Test with MWCNT Additives

Table **4** is demonstrations the changes in Mud Rheology when we added MWCNT to 280.5 cc of polymer Mud by various concentrations respectively.

Table 4. Polymer mud rheology with mwcnt additives in two conditions

Rheology (120 °F)	Cup 1		Cup 2		Cup 3		Cup 4		Cup 5	
	BHR	AHR	BHR	AHR	BHR	AHR	BHR	AHR	BHR	BHR
AV	25	21.5	31.5	20.5	30	23.5	35.5	26.5	45	32.5
RPM 600	50	43	63	41	60	47	71	53	90	65
RPM 300	30	26	42	28	39	31	47	33	59	40
PV CP	20	17	21	13	21	16	24	20	39	25
YP lb/100 ft^2	10	9	21	15	18	15	23	13	20	15
RPM 200	22	19	32	21	30	23	32	25	46	30
RPM 100	14	12.5	22	13	21	14	24	15	30	19
RPM 6	3	3.5	5	3	5	3	5	4	7	4
RPM 3	2	2.5	4	2.5	4	2.5	4	2.5	6	3.5
GEL 10 s	3	3	6	2.5	4	3	5	3	7	4
GEL 10 min	4	4	8	4	7	5	7	5	9	5
pH	12.46	12.21	12.80	10.34	12.73	10.52	12.79	10.41	12.77	10.61
API FL, cc	-	2.2	-	3.8	-	3.5	-	3.2	-	3
Settlement	No	yes	No	No	No	No	No	No	No	No
Filter cake	-	1/32	-	1/32	-	1/32	-	1/32	-	1/32
Foam	No	No	No	No	No	No	No	No	No	No
Water Torque Reading	-	33.7	-	36.0	-	36.1	-	33.9	-	36.2
Mud Torque Reading	-	20.1	-	22.8	-	22.8	-	23	-	23.5
Lubricity Factor	-	0.2028	-	0.2153	-	0.215	-	0.2306	-	0.230
Torque Reduction	-	-	-	-	-	-	-	-	-	-
Mud Cake Friction (KF)	-	0.2046	-	0.1302	-	0.1302	-	0.1357	-	0.1396

Table 5. Polymer mud rheology with MWCNT additives

Rheology (120	Blank	0.1 gm	0.2	0.3	0.4 gm
AV	21.5	20.5	23.	26.5	32.5
RPM 600	43	41	47	53	65
RPM 300	26	28	31	33	40
PV	17	13	16	20	25
YP	9	15	15	13	15
RPM 200	19	21	23	25	30
RPM 100	12.5	13	14	15	19
RPM 6	3.5	3	3	4	4
RPM 3	2.5	2.5	2.5	2.5	3.5
GEL 10 s	3	2.5	3	3	4
GEL 10 min	4	4	5	5	5
pH	12.21	10.34	10.5	10.4	10.61
API FL, cc	2.2	3.8	3.5	3.2	3
Settlement	yes	No	No	No	No
Filter cake	1/32	1/32	1/3	1/32	1/32
Foam	No	No	No	No	No
Water Torque	33.7	36.0	36.	33.9	36.2
Mud Torque	20.1	22.8	22.	23	23.5
Lubricity	0.202	0.2153	0.21	0.230	0.230
Torque	-	-	-	-	-
Mud Cake	0.204	0.13028	0.130	0.135	0.1396

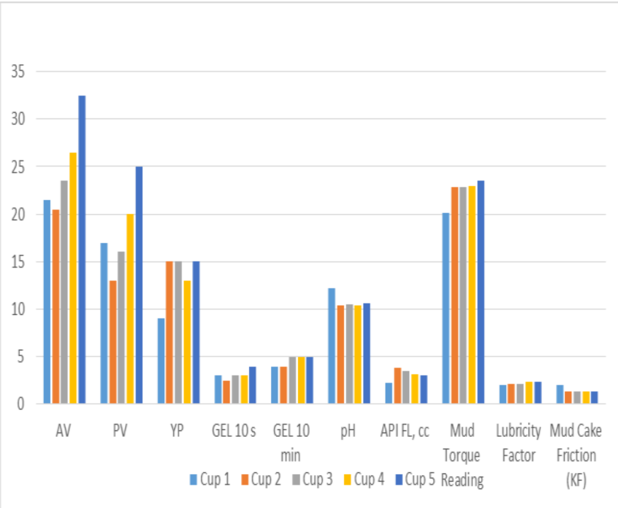

Fig. 5. plymer mud parametes with MWCNT (Lubricity Factor & Mudcake Friction*10)

In the graph 5 noticed that no big change in CoF with increasing Nano grams gradually per each test, with a little increase of CoF to improve that MWCNT doesn't enhance friction resistance when we add it to polymer mud and we have to try another Nanomaterial. It's also clear that MWCNT makes the problem of mud filtrate is bigger which leads to some other issues like formation damage or wall problems.

We can find that MWCNT is optimized lifting cutting and hole cleaning by increasing YP and 10 min gel, so this type of Nano material is valuable in fast drilling purpose especially in vertical wells, however we should avoid adding NWCNT to Polymer mud if stick- slip is the major expected problem.

It's also clear that MWCNT makes mud filtrate somewhat bigger than blank test which could leads to some other issues like formation contamination or wall problems.

We can find that MWCNT is optimized lifting cutting and hole cleaning by increasing YP and 10 min gel, so this type of Nano material is valuable in fast drilling purpose especially in vertical wells; however we may avoid adding MWCNT to Polymer mud if stick- slip is not the major expected problem.

Table 6. CoF & Torque and drag software reading with MWCNT

Rheology	-------- gm	0.1 gm	0.2 gm	0.3 gm	0.4 gm
Lubricity Factor	0.2028	0.2153	0.2154	0.2306	0.2307
Torque reading	2050.88	2201.79	2201.79	2303.02	2303.02

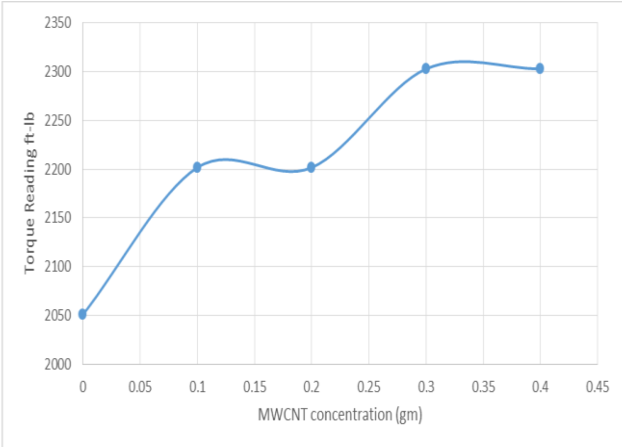

Fig. 6. Torque reading (polymer mud + MWCNT

Fig. **6** show that there is a little increase in Torque reading occurs in the test sample since MWCNT was added and it proportionally sensed to that Nanomaterial.

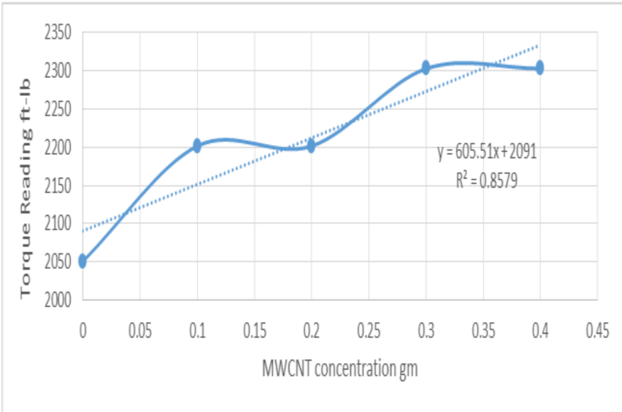

Fig. 7. (Polymer mud + MWCNT) torque reading with trend line

As shown in Fig. **7**, the relationship between Torque reading and MWCNT additives in polymer has acceptable trend line with (R^2=0.8579) within linear equation

Y= 605.51X +2091 as shown in Fig. **7**

That means using MWCNT as Nano material is purely a proportional relationship toward torque increasing, so to reduce downhole friction is unsuccessful in case we used mud type "polymer".

Polymer mud has lower CoF than FWB mud in wide range then polymer would certainly reduce friction positively, however in drilling high angle wells or horizontal well there is extra requirement of reducing torque as much as possible therefore we have to keep looking for another Nanomaterial to cover drilling requirements.

a. Fresh Water Bentonite Mud Test with MWCNT Additives

In this job's package, FWB mud was used with 350 ml. and adding MWCNT as (0.35, 0.70, 1.05, 1.75) gm. MWCNT per each test's cup respectively, in ratio configuration: (o%, 0.1%, 0.2%, 0.3%, 0.5%) % wt. The mud parameters recorded in table (7) for each amount of MWCNT individually in.

Table 7. Fwb mud rheology with mwcnt additives

Rheology (120 °F)	-------	0.35	0.70	1.05	1.75
AV	18.5	26.	30	36.5	43.
RPM 600	37	53	60	73	8
RPM 300	34	49	56	69	8
PV	3	4	4	4	2
YP	31	45	52	65	8
RPM 200	32	47	54	63	8
RPM 100	31	43	51	62	8
RPM 6	24	38	46	57	7
RPM 3	24	37	45	54	7
GEL 10 s	24	38	45	57	7
GEL 10 min	25	43	48	63	7
pH	9.18	9.2	9.19	9.38	9.4
API FL, cc	14.2	10.	8.2	7.8	6.
Settlement	No	No	No	No	N
Filter cake	5/32	4/3	4/32"	3/32	3/3
Foam	No	No	No	No	N
Water Torque	35.5	32.	35.8	36.0	35.
Mud Torque	45.9	40.	43.8	39.8	36.
Lubricity Factor	0.424	0.42	0.415	0.375	0.34
Torque Reduction	-	12.	4.57	13.2	21.
Mud Lubricity	0.69	0.06	0.073	0.06	0.0

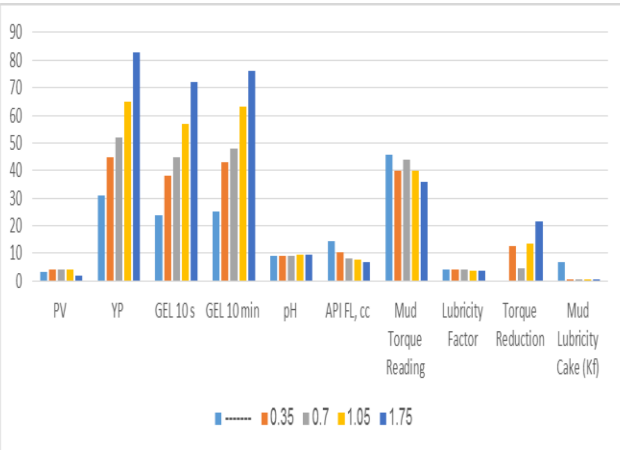

Fig. 8. FWB + MWCNT rheology with MWCNT (CoF & KF *10)

Table 8. CoF & Torque and drag software reading with MWCNT +FWB

Rheology	-------- gm	0.35 gm	0.7 gm	1.05 gm	1.75 gm
Lubricity Factor	0.4242	0.4260	0.4159	0.3758	0.3447
Torque reading	4068.67	4068.67	4018.17	3764.55	3400

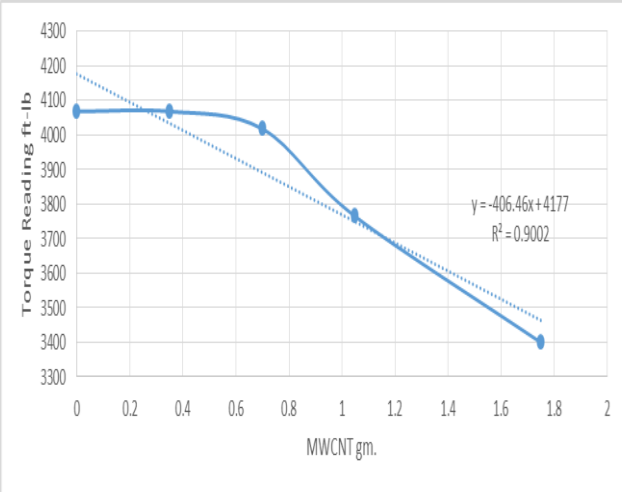

Fig. 9. (FWB + MWCNT) torque reading with trend line

By Fig. **9** MWCNT concentration of 1.75 gm is the lowest torque reading but it combined with too much high (YP=83), where the growth of yield point is come from high surface areas to the volume unite this will surge the interaction of the nanoparticles with the medium of the base fluid. YP is sensitive to MWCNT more than other Nano materials due to tubular structure of MWCNT, therefor the 0.105 gm has (YP=65) where it is acceptable. Also in same concentration (1.75 gm) found high gel strength comes from the high intensity of electrostatic force between nanoparticles which leads to the linkage between nanoparticles and base fluids to arrange like a rigid structure.

We can also see that in low Nano concentration there is no change in Torque until 0.6 gm, then there is dramatically drop in Torque 0.6 -1 gm to be slightly lower dropping after1 gm, so adding MWCNT more than 1.05 gm to the test sample is cost effective with relatively a little torque reduction so high amount of Nanoparticles economically failed to gain our goals.

In this test good results of less filtration, where the amount of filtrate was decreases a touch with increasing the concentration on nanoparticles of MWCNT.

Figure 9 shows also that the best linear equation is:

$$Y = -406.46X + 4177 \quad (1)$$

This equation ensures that MWCNT fraction reading have inversely relationship with torque, however this mixture does not match the optimum required for other mud rheology.

6- Conclusion and Recommendation

The following conclusions are captured from the research results:

- No big changes in CoF when we added MWCNT to polymer but there was CoF increasing from 0.2 to be 0.23 (which is bad indication) but without any side effect to other mud rheology.
- At high MWCNT Ratio in mud type FWB we got very low FF but we lost other important mud rheology like (YP= 74, Gel $_{0\ sec}$= 61).
- Using MWCNT with polymer mud gives negative effect on torque reduction, however MWCNT is enhanced lifting cutting and hole cleaning.
- High MWCNT Ratio in mud type FWB gives very low CoF but lost other important mud rheology like (YP= 74, Gel 0 sec= 61).
- The best MWCNT ratio to be really used in drilling field was 0.3% (1.05 gm in the test)[torque drop is (4068 – 3764) ft-lb] because if we add more a high shear rate and shear stress is required, thus more drilling risk expected.
- In general, Nano materials is very important enhances in mud rheology, therefor the petroleum Iraqi company need to ask all drilling contractors to use these technology to drill our wells with high performance and less problems.

And some points are recommended for future research:

- Using MWCNT with polymer mud is not recommended with respect to torque reduction, however MWCNT is enhanced lifting cutting and hole cleaning where YP & Gel$_{10\ min}$. are increased proportionally, thus this brand of Nano material is valued in fast drilling purpose particularly in vertical wells.
- Economically and for shallow depth using FWB with this Nano material is recommended.
- Re-assess the stability of the same Nanomaterials that we used, in HPHT circumstance, with taking in consideration keeping appropriate mud rheology.
- Start using Nanoparticle in the mud of oil fields to inspect the outcomes of stick-slip performance in wellbore conditions, in conventional well plan to clearly find out the torque reduction, when we compare that with offset well data.

Although MWCNT is still expensive, we used very low ratio, whereas average of 2.5 Kg of MWCNT is required to mix one cubic meter of mud, that's mean Nano is cheaper and safer even from using gas oil to increase lubrication, in additional of small amount is easy to handle and cheap transportation.

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Nomenclatures and Abbreviations

MWCNT:	multiwall carbon Nanotube
AV:	Apparent Viscosity cp.
CoF:	Coefficient of friction
FF:	Friction factor
hrs.:	hours
HWDP:	Heavy Wall Drill Pipe
IDC:	Iraqi drilling company (Rig number)
BHA:	Bottom Hole Assembly
NP:	Nano Particles
PV:	Plastic Viscosity, cp
ROP:	Rate of Penetration m/hr.
FW:	Fresh water Bentonite
YP:	Yield Point, Ib/100ft^2
CP:	cent poise
Γ:	Shear Rate, sec-1
T:	Shear Stress, Ib/100ft2
Mp:	Plastic Viscosity, cp

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تقييم خاص لتقنية اضافة MWCNT الى سائل الحفر لغرض التخفيف من مشكلة الالتصاق والانزلاق التي تحدث اثناء عملية الحفر

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الخلاصة

ظاهرة الالتصاق والانزلاق تعرف بانها توقف ثم انزلاق متعاقبين يحدثان بشكل ترددي في منظومة قاع البئر اثناء عمليةالحفر نتيجة للتباين في قيمتي جهد الاحتكاك الحاصل اثناء حفر القطع الصخرية وين الجهد المسلط في المنضدةالدوارة اورأس التدوير.

تقليل معامل الاحتكاك بين منظومة قعر لبئر وجدار البئر يمثل العامل الرئيسي لتقليل او منع حدوث هذه الظاهرة والتي تتم عمليا عن طريق توفير اضافات لسائل الحفر تزيد من انزلاقية الطين.

كلا التقنيات النظرية والتطبيقية تعمل سوية لتقليل تلك الاهتزازات وذلك لان تخطي الحد المسموح من الاهتزازات سيؤدي الى العديد من مشكال الحفر, احد اهم مفاتيح الحلول هو تطوير طين الحفر وكما هومعلوم فان استخدام المواد النانوية في اطيان الحفر تعد من التقنيات الحديثة حيث نجحت في تقديم نتائج مختبرية لاطيان ذات مواصفات عالية لذا تم استخدام مادة MWCNT في نوعين من الطين (FWB & polymer) بتراكيز مختلفة ومن ثم تحليل النتائج مختبرياً بعدها ادخلنا نتائجمعامل الاحتكاك لكل عينة في برنامج ذكي يعمل تمثيل لحفر بئر عمودي ليحتسب مقدار الاحتكاك المتوقع في قاع البئر.

نجحت المادة النانوية MWCNT قي تقليل مقدار الاحتكاك من 4000 ft–lb الى ft–lb3500 مع طين الحفر نوع Fresh Water Bentonite, بينما سببت ارتفاع طفيف في الاحتكاك (2050 – 2200) ft–lb في حالة الطين من نوع البوليمر.

الكلمات الدالة: مشكلة النزلاق, طين الحفر, سائل الجزيئات النانوية, سلسلة الحفر