

## **A Study of the Performance of Nanomaterials on Water Base Drilling Fluid**

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### **Abstract:**

This study is an attempt to investigate the effect of nanomaterials on the water base drilling mud properties. Two types of nano materials were investigated, are Multi Walled Carbon Nano Tube (MWCNT) and nano silicon oxide (SiO<sub>2</sub>). The investigated properties of drilling mud with the rheological properties (Plastic viscosity, yield point, Apparent viscosity and Gel strength), filtration, and lubricity test are investigated. In addition, effects of high temperature on these properties were studied. All tests are conducted according to API specification and proceed in Petroleum Research and Development Center (PRDC).

The experimental results show that a significant improvements in the lubricity test and the rheological properties such as yield point, filtration properties of the MWCNT and nano silicon oxide modified drilling fluid compared with the base drilling fluid. Also a significant improvement in the rheological properties at using combined of nanomaterials (MWCNT and nanoSiO<sub>2</sub>) and reduction of filter loss at using nanosilicon oxide compared with fluid loss reducer.

**Keywords:** Nanomaterials, MWCNT, nano SiO<sub>2</sub>, Plastic viscosity, yield point, Apparent viscosity, Gel strength, Drilling fluids.

### **Introduction:**

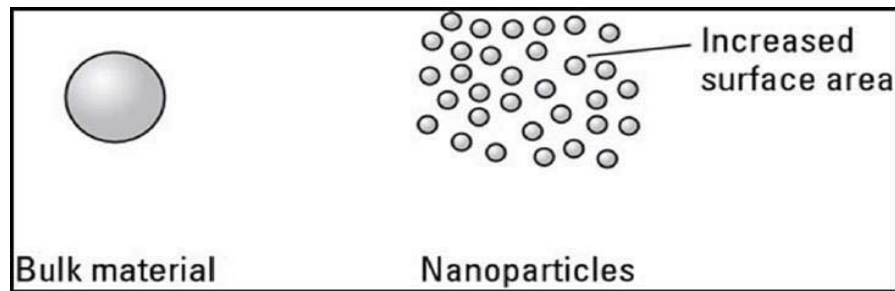
#### **Drilling Fluids:**

Drilling deeper, longer and challenges in wells have been made possible by improvements in drilling technologies, including more efficient and effective drilling fluids. Drilling fluids, also referred to as drilling mud, are added to the wellbore to facilitate the drilling process by suspending cuttings, controlling pressure, stabilizing exposed rock, providing buoyancy, and cooling and lubricating [1].

#### **Nano-Technology:**

Nanotechnology is becoming a widely popular in every aspect of science and technology. It involves using particles which are of 1–100 nm in size. It can play a major role in solving some of the most common problems encountered by drilling [2]. Amanullah and Al-Tahini [Amanullah and Al-Tahini, 2009] classified the nano-fluids as simple or advanced nano-fluids based on the nanoparticles concentration in the drilling fluid. Nano-particles can be customized for achieving single or multiple functionalities. Nano-particles have a very high surface area to volume ratio which increases the reactivity of the nanoparticles as shown in Figure (1). Due to this fact, the amount of nanoparticles required for any application is much less which reduces the cost to a great extent [3].

The smart fluid containing multifunctional nano-particles can be customized to form a thin layer of non-erodible and impermeable nanoparticle membrane around the wellbore which prevents some of the most common problems like shale swelling, spurt loss and mud loss due to lost circulation. This simple process eliminates the addition of fluid loss additives, shale inhibitors, rheology modifiers, formation strengthening materials etc. [4]. These nano-particle membranes are very useful during drilling application and can be removed easily during clean-up before the completion process. This is very helpful in deviated, horizontal and extended reach wells. The smart fluids can be used in reducing the torque and drag in the drilling process. The nano-particles form a continuous thin film around the drill-pipe, This provides lubrication and thus reduces the torque and drag problems. The same concept can be used to reduce the differential pipe sticking problem. [5].



**Fig. (1) The reactivity of the nanoparticles**

### **Effect of NANO FLUIDS on Drilling:**

Nanofluids can be designed by adding nanosized particles in low volumetric fractions to a fluid. The nanoparticles improve the fluid's rheological, mechanical, optical, and thermal properties. Suspensions of nanosized particles may provide the following advantages: (1) Nanosized particles can have enhanced stability against sedimentation since surface forces easily balance the gravity force, and (2) Thermal, optical, mechanical, electrical, rheological, and magnetic properties of nanoparticles, which depend significantly on size and shape, of these particles [6].

### **The Aim of The Study:**

The aim of this study is to investigate the effect of nanomaterial by adding with water base drilling fluids to examine the performance of this nano material on the rheological properties, filter loss and lubricity test of water base drilling fluids. In this work, the nanomaterial uses MWCNT (Multiwall Carbone Nanotube) and nano SiO<sub>2</sub> (silicon oxide).

### **Nano material properties:**

Good formulations of drilling fluid properties are required in drilling operations. Selection of suitable drilling fluid additives are important criterion in formulating drilling fluid. Nanomaterial selected in this study due to its extremely high surface area to volume ratio and high thermal conductivity. This research is focused on use the multi-walled carbon nanotubes (MWCNTs) and nanosilicon materials to investigate the effect

of these nano material on reohlogical properties, filter loss and lubricity test of water base drilling fluid.

### **Carbon nanotubes (CNTs):**

Carbon nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure. Nanotubes have been constructed with length-to-diameter ratio of up to 132,000,000:1, significantly larger than for any other material [7]. Nanotubes are categorized as single-walled nanotubes (SWNTs), and multi-walled nanotubes (MWNTs) [8].

Single-walled nanotubes (SWNTs) have a diameter of close to 1 nanometer, with a tube length that can be many millions of times longer. The structure of a SWNT can be conceptualized by wrapping an oneatom- thick layer of graphite called graphene into a seamless cylinder [9].

Multi-walled nanotubes (MWNTs) consist of multiple rolled layers (concentric tubes) of grapheme [10].

### **Nano silicon**

Silicon dioxide nanoparticles, also known as silica nanoparticles or nanosilica, are the basis for a great deal of biomedical research due to their stability, low toxicity and ability to be functionalized with a range of molecules and polymers [11].

**Physical Properties:** Silicon dioxide nanoparticles appear in the form of a white powder. Density is 2.4 g/cm<sup>3</sup> and molar mass is 59.96 g/mol.

**Chemical properties:** The chemical properties of silicon dioxide are Chemical symbol SiO<sub>2</sub>, Group (Silicon 14, Oxygen 16) and Chemical Composition (silicon 46.83, Oxygen 53.33).

**Thermal Properties:** The thermal properties of silicon dioxide nanoparticles are boling point2230°C, and Melting Point 59.96 g/mol.

### Experimental work and Apparatuses:

In order to evaluate and enhance mud performance, many tests carried out in laboratory to investigate the effect of nanomaterial on the rheology, filter loss and lubricity of drilling fluids.

The nano silicon dioxide ( $\text{SiO}_2$ ) and multiwalled carbon nano tube (MWCNT) as nano materials are used in this work.

### Materials

Before going into the experiments, a brief description of all chemicals and additives used in this study listed below:

### MWCNT (MULTI-WALLED CARBON NANOTUBES):

By generating better rheological properties in water-based drilling fluid Characterization of the MWCNT that use in this study are: Table (1)

**Table (1) Characterization of MWCNT**

<b>OD</b>	<b>13-18nm</b>
<b>Length</b>	<b>1-12um</b>
<b>Purity</b>	<b>&gt;99wt%</b>
<b>Ash</b>	<b>0wt%</b>
<b>Process gas</b>	<b>Argon</b>
<b>Primary functionality</b>	<b>None</b>
<b>Other functionalities</b>	<b>Atmospheric gas</b>
<b>Source material</b>	<b>CCVD MWNTS</b>
<b>Form supplied</b>	<b>Dry powder</b>

### Silicon Dioxide ( $\text{SiO}_2$ )

White powder used to improve the rheological properties and filter loss with OD >40nm.

Fig. (2).



**Fig. (2) Nano Silicon Oxide**

**The Laboratory Apparatus:**

**Viscometer:**



**Fig. (3) VG. METER**

**Low Pressure Filter Press:**



**Fig. (4) Low Pressure Filter Press**

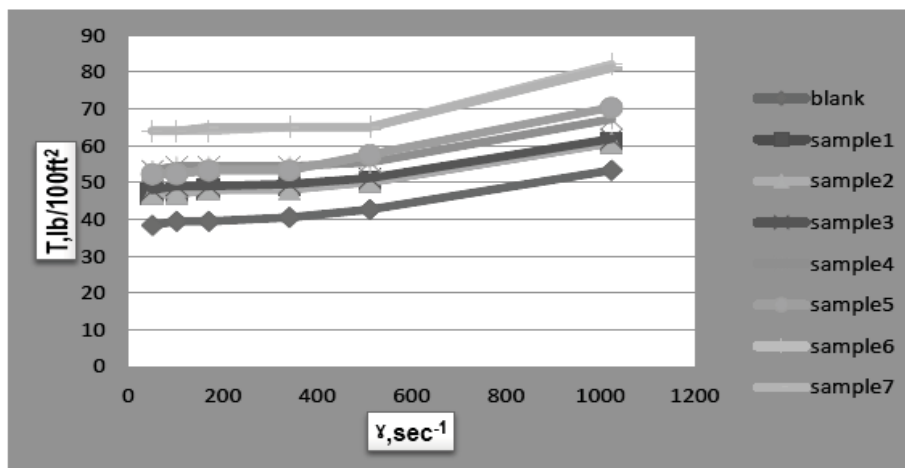
**Thermo Cup:****Fig. (5) Thermo Cup****Lubricity tester:****Fig. (6) Lubricity tester****Result and Discussion:**

In this work, the ideal rheological model is detected among six rheological models (Bingham plastic model, power law model, modified power law model, Robertson stiff model, modified Robertson stiff model, and cason model) by (AAPE) to determine the average absolute percentage error, AAPE value compares between the calculated shear stress values with the measured values obtained from Fann V.G. meter. The results showed that Bingham model is coincided with the tested samples in table (2) .as shown in table (2).

**Table (2) Results of (AAPE) of MWCNT**

Rheological Models	Average Absolute Percentage Error(AAPE)						
Bingham plastic	1.5	1.41	1.23	1.39	1.17	1.27	1.30
Power law	2.33	1.87	1.91	1.78	1.70	1.69	1.91
Modified power law	50.73	56.48	53.52	55.24	54.71	56.58	55.96
Robertson Stiff	4.53	3.88	5.08	4.52	5.69	4.38	4.71
Modified Robertson Stiff	4.75	2.98	1.46	2.89	2.19	2.37	2.01
Casson	3.43	3.18	3.27	3.42	3.03	3.00	3.12

Also, according to figure of Rheogram The results showed that Bingham model is extremely identical with the tested samples as shown in fig. (7).

**Fig. (7) Rheogram of MWCNT**

### **1- Effect of Adding MWCNT and Nano SiO<sub>2</sub> to The water base mud:**

After the preparation of the samples and aging for 16 hr to hydration then take the measurements of viscosity, density, pH and filtration at laboratory condition and the results were as follows:



Table (3) Results of MWCNT

Rheological Properties	Blank	.05gm	0.1gm	0.3gm	0.5gm	0.7gm	0.9gm	1.1gm
R600/R300	50/40	57/47	57/47	58/48	63/52	66/54	77/61	76/61
R200/R100	38/37	46/45	45/45	46.5/46	51/51	50/50	61/60	61/61
R60/R30	37/36	44/44	44/44	46/45	51/50	49/49	60/60	60/60
R6/R3	30/29	42/41	40/39	42/41.5	47/46	46/46	55/55	56/56
AV,cp	25	28.5	28.5	29	31.5	33	38.5	38
PV,cp	10	10	10	10	11	12	16	15
YP,lb/ft <sup>2</sup>	30	37	37	37	41	42	45	46
YP/PV	3	3.7	3.7	3.7	3.72	3.5	2.8	3
Gel10sec/10m in lb/100 ft <sup>2</sup>	34/37	40/45	44/46	42/47	51/50	52/51	56/60	57/61
Mud weight	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
Filter loss,ml	12.4	12.2	12	12	11.8	11.8	11.6	11.6
pH	10	10	10	10	10	10	10	10

Table (4) Result of nano silicon oxide (SiO<sub>2</sub>)

Rheological Properties	Blank	0.1gm	0.3gm	0.5gm	0.7gm	0.9gm	1.1gm
R600/R300	50/40	56/43	59/44	68/49	70/50	74/53	74/53
R200/R100	38/37	41/39	43/40	43/39	46/43	46/42	47/43
R60/R30	37/36	38/38	38/37	38/37	42/40	41/40	42/41
R6/R3	30/29	35/35	34/34	33/32	38/37	36/35	37/36
AV,cp	25	28	29.5	34	35	37	37
PV,cp	10	13	15	19	20	21	21
YP, lb/100 ft <sup>2</sup>	30	30	30	29	30	30	32
YP/PV	3	2.6	2.2	1.4	2.1	2.1	2.1
Gel10sec/10min lb/100 ft <sup>2</sup>	34/37	35/44	35/48	35/49	36/50	40/50	40/50
Mud weight	1.03	1.03	1.03	1.03	1.03	1.03	1.03
Filter loss,ml	12.4	12	11.8	11.8	11.8	11.6	11.6
pH	10	10	10.1	10	10.2	10	10

The plastic viscosity of water based drilling fluid with MWCNT and nano SiO<sub>2</sub> were found slightly higher than conventional base fluids without nano particles. Nanoparticles consist of high surface areas per volume and increase the interaction of the nanoparticles

with the matrix and surrounding waterbased fluid. This surface area may serve as sites for bonding with functional groups can influence chain entanglement and thus can generate a different of properties in the matrix. Thus, the nanoparticles and base fluid may be linked together directly or through certain intermediate chemical linkages to improve the plastic viscosity of water based drilling fluid; each growth in the concentration of the particles would increase the viscosity of the suspension Figures (8, 9).

The comparison of yield point (Y.P) of the conventional water-based mud and nano mud is investigated and shown in Figure (10). Generally, the yield points of MWCNT- based drilling fluids and nano SiO<sub>2</sub> are slightly higher than those of the conventional water-based fluids by increasing in the concentration of MWCNT and nano SiO<sub>2</sub> . The higher yield point of the nano-based fluid will provide better dynamic suspension of drilling cuttings. The results of this study are shown in Figure (11).

The amount of the filtrate of the conventional mud after 30 min (as defined by API filtration test method) was 12.4 cc; however, this value changed to 12.2 cc after adding 0.05 gm of the MWCNT to the mud and 12 cc after adding 0.1 gm of nano SiO<sub>2</sub> This means that amount of the filtrate decreases slightly by increasing of the amount of MWCNT and nano SiO<sub>2</sub>.

A phenomenon known as “**shear thinning**” occurs when the effective viscosity is high at low shear rates and low at high or increased shear rate, this obvious at Figures (13, 14) for both MWCNT & nano SiO<sub>2</sub>. The results of Tables (3, 4) were plotted as shown in Figures (8) through (12) below:

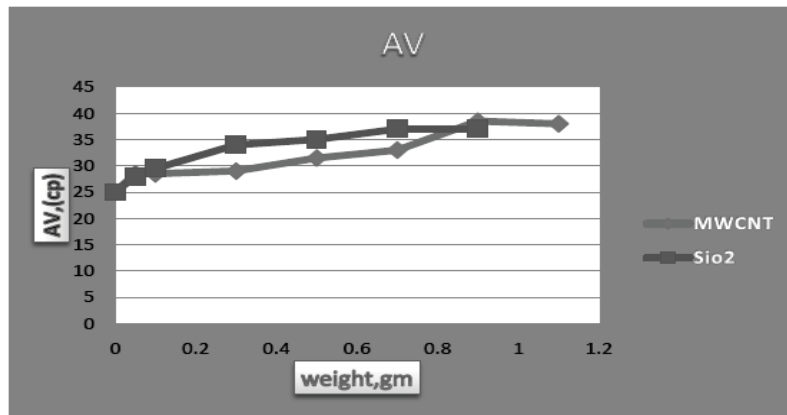


Fig. (8) Plot between apparent viscosity vs. weights of MWCNT and nano SiO<sub>2</sub>

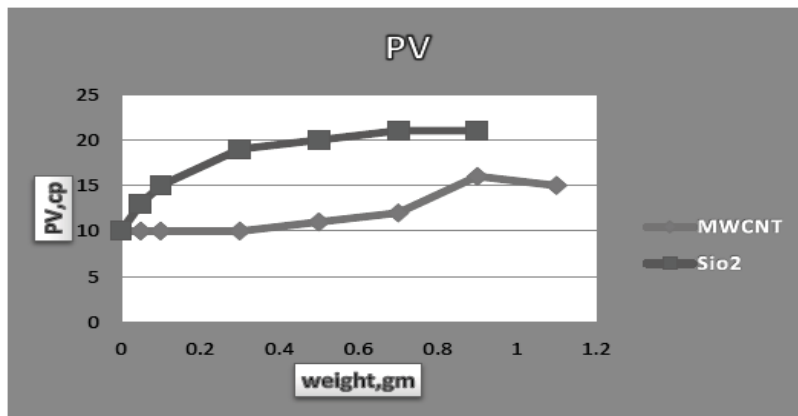


Fig. (9) Plot between plastic viscosity vs. weights of MWCNT and nano SiO<sub>2</sub>

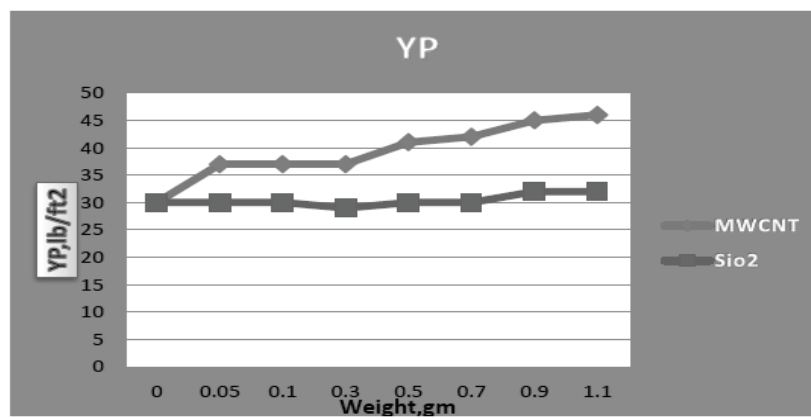


Fig. (10) Plot between yield point vs. weights of MWCNT and nano SiO<sub>2</sub>

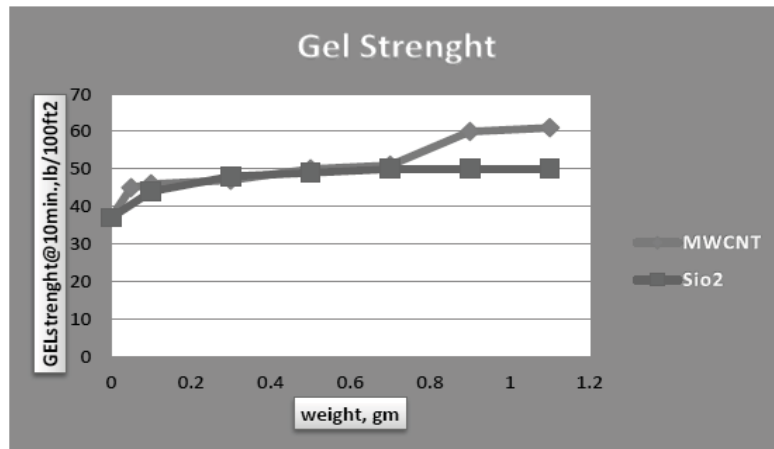


Fig. (11) Plot between gel strenth vs. weights of MWCNT and nano SiO<sub>2</sub>

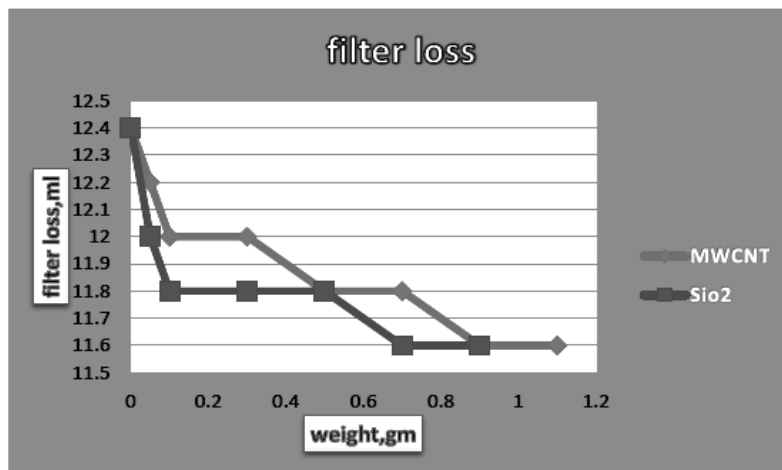


Fig. (12) Plot between filter loss vs. weights of MWCNT and nano SiO<sub>2</sub>



Fig. (13) Mud Cake

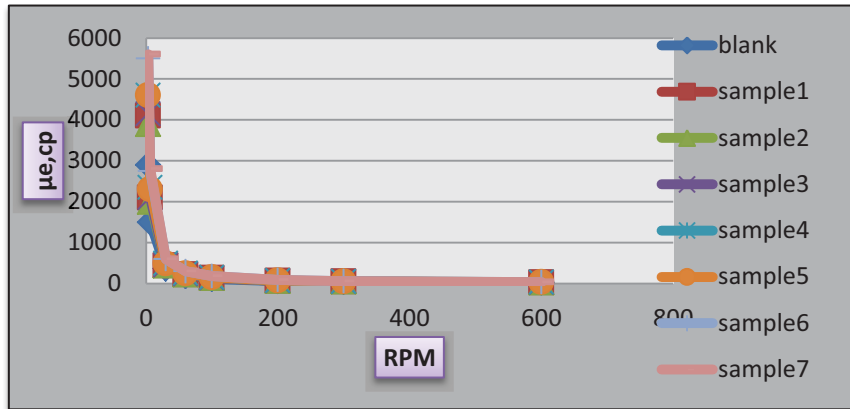


Fig. (14) Plot between effective viscosity vs. RPM of blank & MWCNT weights

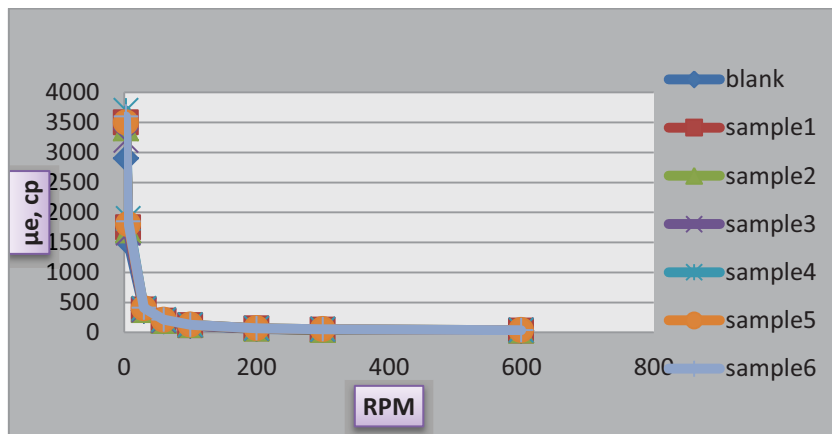


Fig. (15) Plot between effective viscosity vs. RPM of blank & nano SiO<sub>2</sub> weights

**2- Effect of high temperature on water base drilling fluids:**

The weights of MWCNT (0.9 gm) and (0.5gm) nano SiO<sub>2</sub> almost gave the best results, the effect of high temperatures on the drilling fluid studied and the results were as follows:

**Table (5) Results of temperature on blank**

Rheological Properties	40 c°	50 c°	60 c°	70 c°
R600/R300	52/47	53/49	54/52	54/52
R200/R100	45/45	45/44	52/52	53/52
R60/R30	45/43	48/48	52/52	53/53
R6/R3	41/40	47/47	51/49	52/50
AV,cp	26	26.5	27	27
PV,cp	5	4	2	2
YP, lb/ ft2	42	45	50	50
YP/PV	8.4	11.25	25	25
Gel10sec/10min lb/100 ft2	38/41	38/41	38/41	41/43
Mud weight	1.03	-	-	-
Filter loss,ml	12.4	-	-	12.4
pH	10	10	10	10

**Table (6) Results of temperature by adding (0.5gm)of SiO<sub>2</sub>**

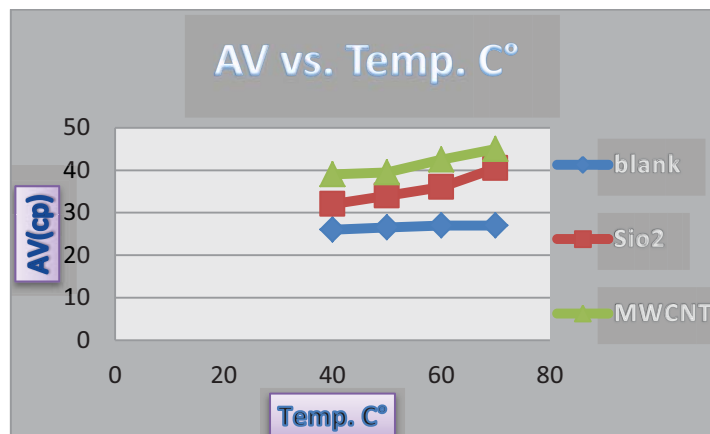
Rheological Properties	40 c°	50 c°	60 c°	70 c°
R600/R300	64/55	68/60	72/65	81/75
R200/R100	48/45	56/56	58/57	66/65
R60/R30	45/45	55/55	55/53	65/65
R6/R3	40/39	46/45	51/50	59/55
AV	32	34	36	40.5
PV	9	8	7	6
YP	46	53	62	61
YP/PV	5.1	6.2	8.8	10.1
Gel10sec/10min	45/50	46/55	50/60	52/65
Mud weight	1.03	-	-	-
Filter loss	11.8	-	-	-
pH	10	10	10	10

**Table (7) Results of temperature by adding(0.9 gm)of MWCNT**

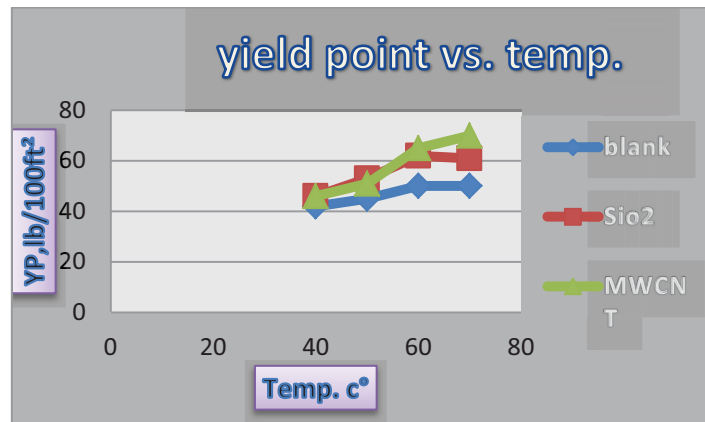
Rheological Properties	40 c°	50 c°	60 c°	70 c°
R600/R300	78/62	79/65	85/75	90/80
R200/R100	63/60	65/63	72/71	78/76
R60/R30	60/60	62/62	70/70	76/75
R6/R3	58/58	60/60	65/61	71/65
AV	39	39.5	42.5	45
PV	16	14	10	10
YP	46	51	65	70
YP/PV	2.8	3.6	6.5	7
Gel10sec/10min	58/60	63/66	65/71	68/80
Mud weight	1.03	-	-	-

Filter loss	11.8	-	-	-
pH	10	10	10	10



**Fig. (16) Plot show the effect HT on viscosity for Blank.sio2and MWCNT**



**Fig. (17) Plot show the effect HT on yield point for Blank.sio2and MWCNT**

It is obvious that adding of the nano SiO<sub>2</sub> and MWCNT to base drilling fluid compared with base drilling fluid without additive (blank) that increase in viscosity & gel strength. The HT and MWCNT are more effective than nano SiO<sub>2</sub> in HT as shown in Figures (16, 17).

### **Combined effect of nano materials**

In this test it prepared three samples of nanomud by mixing nano silicon oxide with multi walled carbon nano tube ,the concentration of nanomud was (1.4gm) for sample1 and sample2 (3.5gm) from nanomaterial, with (21gm) of bentonite ,(1.05) gm of starch and (10.5) gm of barite these materials adding to 350 distilled water. The normal mud was prepared by mixing Bentonite, Barite and starch in the presence of (21gm), (1.05gm) and (10.5gm) respectively.

In all samples, the aging for 16 hours by taking the measurements of viscosity, density, pH and filtration of the laboratory condition and the results are shown in Table (8).

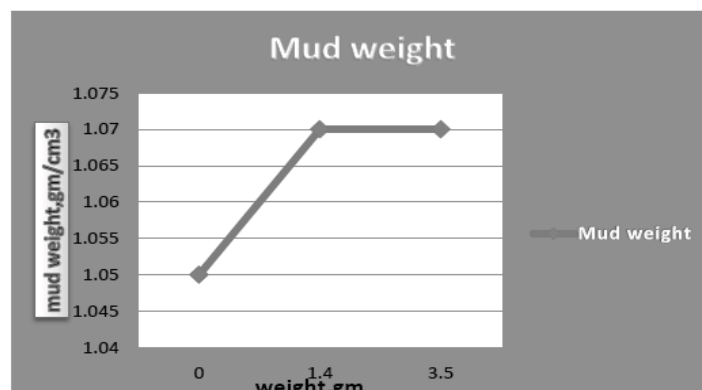


**Table (8) Results of Synthesis of Nanoparticles and Normal Drilling Mud**

Rheological Properties	Blank	1.4gm(nanomaterials)	3.5gm(nanomaterials)
R600/R300	62/52	67/52	86/68
R200/R100	47/44	46/40	61/55
R60/R30	43/43	39/37	47/45
R6/R3	40/40	32/30	38/38
AV	31	33	43
PV	10	15	18
YP	42	37	50
YP/PV	4.2	2.4	2.7
Gel10sec/10min	40/46	34/45	40/55
Mud weight	1.05	1.07	1.07
Filter loss	10	9.6	9
pH	10.3	10	10

In this work, it can be inferred that drilling mud after adding nanoparticles has better maintenance of the rheological properties. This experimental work shows that nano materials can be used for enhancing the properties of drilling fluids.

The results of Table (8) were plotted as shown in Figures (18) through (22) below:

**Fig. (18) Plot of mud weight combined nanomaterials**

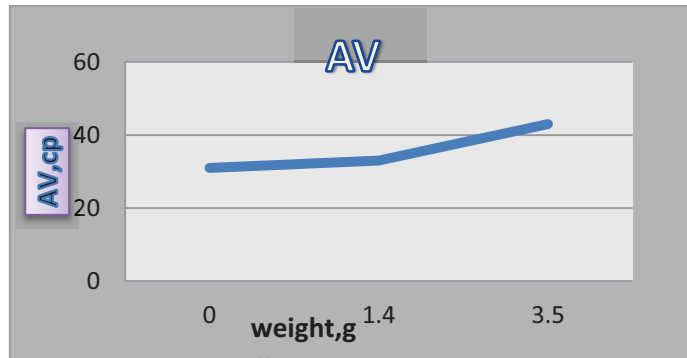


Fig. (19) Plot of apparent viscosity combined nanomaterials

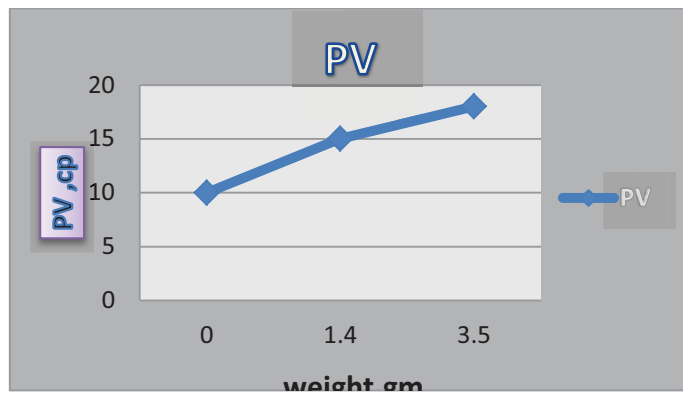


Fig. (20) Plot of plastic viscosity combined nanomaterials

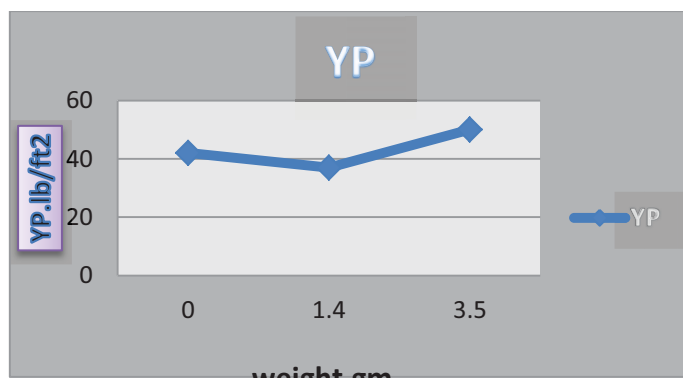
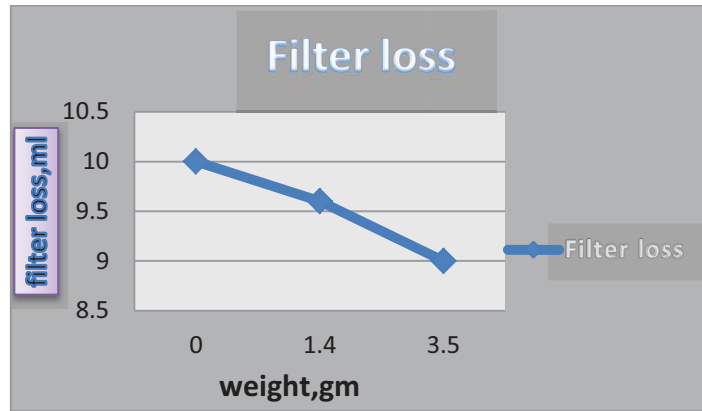


Fig. (21) Plot of yield point combined nanomaterials



**Fig. (22) Plot of filter loss**

**Effect of Nanosilicon oxide To Reduction Filter Loss:**

This work presents an experimental study showing how the Nano materials can reduce the filter loss. In this test, it was prepared three samples: initially performed on the base fluid (that it resemble the ones used and according to the daily mud report of the Iraqi Oil fields) to understand the nature of fluid loss of the prepared fluid without the addition of fluid loss reducers of nanoparticles. The sample two prepared by adding fluid loss reducer to base fluid and final sample using base fluid with adding nanoparticles (SiO<sub>2</sub>). The laboratory measurements included measuring mud weight, pH, viscosity, and standard API filter test at laboratory condition and the results were as follows:

**Table (9) Result Of base drilling fluid without the addition of fluid loss reducer or nanoparticles Sample 1.**

component	quantity	Rheological Properties	Sample1
Water	336	R600/R300	44/28
NAOH caustic soda	0.25	R200/R100	22/15
Soda ash	0.25	R60/R30	13/10
KCl	10.4	R6/R3	5/5
Xanthan gum	1.5	Gel10sec/10min	5/16
barite	27	Filter loss	12
Total weight	375.4	pH	10
		density	1.05

**Result of lubricity test:**

Lubricity test was designed to simulate the speed of rotation of the drill pipe and the pressure with the pipe bears against the wall of the bore hole. Table (10) shows the result of lubricity test on base drilling fluids (blank) and adding of SiO<sub>2</sub> and MWCNT.

**Table (10) Results of lubricity test**

Material	quantity	friction factor
Blank	22.5bent.+350water	0.51
MWCNT	1 gm	0.44
Sio2	1gm	0.43
MWCNT+Sio2	1gm+1gm	0.43

The nano-particles form a continuous thin film around the drill-pipe. This provides lubrication and thus reduces the torque and drag problems.

**Conclusion**

Based on this experimental study, several conclusions have been made:

- 1-An increase concentration in MWCNT and nano silicon oxide (SiO<sub>2</sub>) resulted in higher plastic viscosity, yield point and gel strength for water base drilling fluid.
- 2- An increase in temperature of nanofluids in comparison with conventional fluid increase of plastic viscosity, yield point and gel strength for water base drilling fluid.
- 3- An addition of nanoparticles (MWCNT and nano silicon oxide (SiO<sub>2</sub>)) into water base drilling fluid give better results because the fluid loss and the filter cake thickness were reduced.
- 4- The nanoparticles (SiO<sub>2</sub>) proved to be more effective in reducing the filtrate losses than conventional fluid loss reducer (PAC-LV).
- 5- An addition of nanoparticles (MWCNT and nano silicon oxide (SiO<sub>2</sub>)) into water base drilling fluid give better results by reducing the friction factor of drilling fluid compared with the conventional fluid.

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