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Experimental Study on using Nano-Gilsonite in Water-Based Drilling Fluids as a High-Performance Filtration Control Agent and Stuck Pipe Reducer in High-Pressure High-Temperature Wells

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Abstract

Nano-fluids are fluids containing nano-materials which, due to the unique physical/chemical properties, have special properties, and also offer undeniable potential in broad industries. However, there are still unstudied nano-materials that can be used to attain the most benefits of these types of materials in drilling industries. Recently, several researchers have studied the application of different nano-materials to formulate drilling fluids with enhanced properties to increase mud resistance in high-pressure and high-temperature (HPHT) in downhole conditions. Also, Gilsonite powder as a fluid loss controller and torque and drag reducer is a common drilling fluid agent in oil-based/water-based muds. In this paper, the effect of Nano-Gilsonite particles on properties of water-based drilling fluid such as rheological properties, API fluid loss, HPHT fluid loss, pH, and differential sticking is investigated and discussed. The results indicate that Nano-Gilsonite particles have a highly beneficial effect on water-based drilling fluid additive to conquer drilling problems such as differential sticking problems and high fluid loss problems in HPHT conditions. For instance, adding 2% wt/wt Nano-Gilsonite to a simple bentonite mud could diminish pipe sticking tendency by approximately 98.5%. The goal of this research is using and optimizing Nano-Gilsonite particles as an environmentally friendly water-based drilling fluid agent to minimize operational problems while drilling in HPHT zones.

1. Introduction

Most of the oil and gas wells suffer from the problems that occur during drilling or caused due to drilling, such as sand production [1], high torque and drag [2], dealing with high-pressure high-temperature situations, etc. In the oil/gas drilling industry, designing high-performance drilling fluids (muds) is an essential priority for drilling wells in minimum time and highest quality. Most of the mentioned problems can be prevented, if proper drilling fluid can be designed and applied, based on the well trajectory, formations types, and other drilling parameters [3].

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In past years (until 1970), oil-based drilling fluids were widely used across the world, and due to excellent shale recovery, filtration properties, and high resistance for chemical contaminations, there were so popular. However, by passing the time and appearing more considerations on environmental issues, water-based drilling fluids became more common throughout the world [4]. The high-performance drilling fluid needs to be environmentally acceptable, too. Therefore, water-based muds are at the center of attention for development, but these types of muds need special and tailored-made agents to qualify drilling fluids functions in the best manners. Mentioned functions are summarized as [4]:

- Carrying cuttings to the surface
- Cooling the bit
- Lubricating the bottom-hole assembly and bit
- Reducing unwanted torque and drag forces while drilling
- Preventing liquid/gas influx into the wellbore
- Stabilizing open boreholes/ problematic formations
- Control fluid loss by creating a thin filter cake on the wellbore surface

1.1. Nano-materials in the drilling industry

Nowadays, based on the significant usage of nanotechnology in different fields of science, applying nano-materials in oil and gas drilling is growing, too. Nano-particles are a perfect choice for drilling fluids agents because they have a special physio-chemical property. This property qualifies them for the high-performance drilling fluids requirements. Nano-sized particles have a high surface area to volume ratio in comparison with common agents in drilling fluids which are typically micron-sized, and this has led to enhancing drilling mud properties [5]. Researchers have been successfully used nano-materials in different types of drilling fluids to improve the mud cake structure, lower the fluid loss, and reduce unwanted torque forces in the drilling operations so far. Some of these research studies are summarized in Table 1.

Table 1. Summary of research studies conducted on using nanomaterials in different types of drilling fluids

Researcher(s)	Year	Studied Nano Particle	Improved property in drilling fluid
Mirzaei Paiaman and Al-Anazi.	2008	Nano-carbon black	decreasing probability of stuck pipe [6]
Jung et al.	2011	Nano-iron oxide	rheological and fluid loss control properties in HTHP wells [7]
Contreras et al. (a and b)	2014	Iron and Calcium Nano-particles	Fluid loss control and lubricity improvements of oil-based muds [8, 9]
Contreras et al.	2014	Iron-based and Calcium-based nano-particles	filtration loss reducers in oil-based drilling muds in LPLT and HPHT condition [9]
Taha and Lee	2015	Nano-graphene	lubricity, ROP enhancement, and retained permeability [10]
Salih and Bilgesu	2017	Nano-Silica, nano-Titania, and Nano-Alumina	enhance the mud cake structure reduce the filtration volume [11]
Karimi Rad and Mansouri	2018	Nano-Silica and Nano-Titania	API/HPHT fluid loss reducer and differential stuck pipe preventer [3]
Javeri et al.	2019	Silicon Nano-particles	reduces the thickness of the mud cake [12]

1.2. Gilsonite

One of the less-studied multifunctional agents used in drilling fluids is Gilsonite. Gilsonite is a naturally occurring bituminous asphalt [13]. Gilsonite varies in composition depending upon its origin, history of formation and the geographical region, and presence of other minerals such as Sulphur. Gilsonite has been used in the mining industry as an additive in oil drilling fluids or well [14]. The Gilsonite average molecular weight is significantly higher in comparison with other asphaltic additives used in the drilling fluid industry and other types of bitumen or resins. This high molecular weight makes Gilsonite a "semi-polymeric" material that can be used as a high-performance surface covering agent.

As water-based drilling fluids are mainly suitable for drilling in low-pressure, low-temperature (LPLT) conditions, while they may fail in high-pressure, high-temperature HPHT conditions, due to gelation or degradation of polymers [15, 16]. Therefore, adding Gilsonite can effectively improve water-based or oil-based drilling fluids performance in extreme temperatures in favor of its low cost. Some of the previous studies about using Gilsonite particles in drilling fluids are summarized in Table 2.

Table 2. Studies conducted on using Gilsonite particles in drilling fluids

Researcher(s)	Year	Improved property in drilling fluid
Davis and Tooman	1989	Hole stabilization [17]
Davis and Gilbreath	2002	Hole stabilization and shale drilling [18]
Gou et al.	2014	Mitigate lost circulation of oil-based muds in HPHT condition [19]
Samavati and Nurhafiza	2015	Gilsonite as thermal stabilizers to water-based drilling fluids in HPHT circumstances [20]

Based on research studies summarized in Table 2, Gilsonite provides so many benefits in water-based drilling muds as given in the following [17]:

- Improving filtration control
- Preventing seepage loss in permeable formations
- Shale Stabilization and protecting reactive shale surfaces
- Reducing pore pressure transmission and sealing mini-fractures (in shale and low-porosity sands)
- Strengthens the wellbore (Increase wellbore stability in loose formations and under-pressured zones)
- Minimizes differential pipe stuck
- Improves homogenous and low-invasion filter cake
- Applicable in HP/HT environments (more than 350 Fahrenheit degrees)

1.3. HPHT wells

According to the United States of America Department of Energy, the HPHT drilling process is defined as drilling a borehole whose temperature exceeds 300 °F and its pressure exceeds 20,000 psi [21].

In conclusion, in the following paper, Nano-Gilsonite effects in water-based drilling fluids are investigated to design a possible high-performance drilling fluid. Then, the concentration of Nano-Gilsonite usage in water-based drilling fluids was investigated and optimized. More specifically, this paper tries to discuss the effect of Nano-Gilsonite on the prevention of drilling tools sticking problems with an experimental prospect.

2. Materials and methods

2.1. Material description

The Gilsonite powder sample used in this study was provided by a mine located within a 15 km distance south of Kermanshah province in Iran. Then, it was crushed to nano-particles with a ball-mill method. Chemical analysis was performed on the obtained powder, as shown in Table 3.

Table 3. Chemical analysis of Nano-Gilsonite

Elements	Weight percentage
Carbon	80.1 %
Sulfur	4.1 %
Oxygen	1.7 %
Hydrogen	6%
Nitrogen	0.5%
Ash	7.1%

Properties of obtained powder are given in Table 4.

Table 4. Properties of Nano-Gilsonite

Properties	Range	Test Method
Specific Gravity	0.9-0.92	ASTM D D3289-17
Softening Point	130-145° C	ASTM D36
Moisture	0.25	-
Solubility in CS2	Approximately 95%	ASTM D482
Solubility in Trichloroethylene	Approximately 90%	ASTM D2042-15
Solubility in Carbon Tetrachloride	Approximately 85%	ASTM D3467
pH	7-7.5	ASTM 1512
Surface Area	75-85 m2/gr	ASTM 3037

In conclusion, physical and chemical characterization of used Nano-Gilsonite showed these specific properties:

- High-content of Asphaltene
- High molecular weight
- High solubility in organic solvents
- High purity of carbon molecules

Besides, the proposed Nano-Gilsonite was used in low concentrations and without requiring any special surfactant in the drilling fluid. Nano-Gilsonite disperses quickly and easily in water-based with only mild agitation.

2.2. Methodology

2.2.1. Step1: drilling fluids preparation

A simple polymeric mud was used for the initial formulation of blank fluid. It includes freshwater, salts, viscosifiers, and fluid loss controllers (mud sample1). After mixing required mud additives in the fluid phase, the mud's pH was adjusted to 9.5- 10.5 using NaOH to keep the mud in the alkaline range. This blank mud was used as a representative drilling fluid containing micron-sized particles for comparative evaluation of rheological, HPHT/API filtration, and mud filter cake properties of the nano-based fluids. The nano-fluids (mud samples 2 and 3) had the same formulation as mud sample 1 in addition to Nano-Gilsonite with concentrations of 0.5 and 1% wt./wt., respectively. The mentioned formulations are given in Table 5.

Table 5. Formulations of simple polymeric mud and nano-fluids for evaluating the nano-Gilsonite effect on mud properties

Composition	Unit	Mud Sample 1	Mud Sample 2	Mud Sample 3
Fresh Water	mL(%V/V)	242.6 (69%)	242.6 (69%)	242.6 (69%)
Sodium chloride	gr (lb/bbl)	56	56	56
Caustic Soda	gr (lb/bbl)	1	1	1
Soda Ash	gr (lb/bbl)	1.5	1.5	1.5
Starch	gr (lb/bbl)	12	12	12
Xanthan gum	gr (lb/bbl)	0.5	0.5	0.5
Limestone	gr (lb/bbl)	139.7	139.7	139.7
Nano-Gilsonite	gr (lb/bbl) [%wt/wt]	-	0.87 [0.5%]	1.75 [1%]

Also, a simple bentonite mud (mud sample 4) was used as a simple drilling fluid for comparing and evaluating of sticking pipe properties of the nano-based drilling fluids that are studied in this paper [3]. The nano-fluids (mud samples 5 to 7) had the same formulation as mud sample 4 in addition to Nano-Gilsonite with concentrations of 0.5, 1%, and 2% wt/wt, respectively. Using this type of blank fluid is because of its high fluid loss and high pipe sticking characteristic in high pressures [3]. The mentioned formulations are given in Table 6.

Table 6. Formulations of simple bentonite mud and nano-fluids for evaluating nano-Gilsonite effect on differential sticking tendency of drilling fluids

Composition	Unit	Mud Sample 4	Mud Sample 5	Mud Sample 6	Mud Sample 7
Drill Water	cc	350	350	350	350
Bentonite	gr (lb/bbl)	35	35	35	35
Nano Gilsonite	gr (lb/bbl) [%wt/wt]	-	0.87 [0.5%]	1.75 [1%]	3.5 [2%]

Each component for both test series was mixed for 15 minutes (based on the order given in Tables 5 and 6), and at the final stage, the mixture was mixed for 20 extra minutes to reach a homogenous fluid. It is worth mentioning, for simulating the drilling operations, fluids were rolled at 300° F for 8 hours in a roller oven.

Flowchart of experiments for understanding Nano-Gilsonite effect on drilling fluids is given in Figure 1.

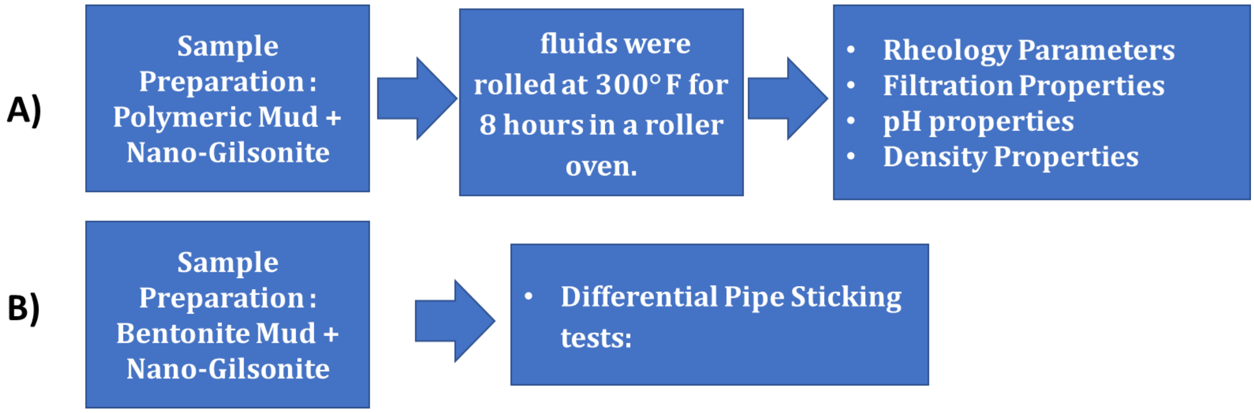

Figure 1. Flowchart of experiments for understanding Nano-Gilsonite effect on drilling fluids

2.2.2. Step 2: Characterization of Water-based Drilling Fluids

Essential parameters for evaluation are enlisted in the following:

Rheology Parameters:

Rheological measurement tests were run with Fann 35 Viscometer for each sample before hot rolling (BHR) and after hot rolling (AHR). Rheological parameters (plastic viscosity (PV), yield point (YP), and gel strength) were measured by Fann 35 Viscometer. Bingham plastic rheological parameters for viscoelastic fluid samples were calculated from direct-indicating viscometer readings and using Eq. (1) and Eq. (2).

$$Plastic\ Viscosity\ (PV)\ =\ 600\ rpm\ dial\ reading\ -\ 300\ rpm\ dial\ reading \tag{1}$$

$$Yield\ Point\ (YP)\ =\ 300\ rpm\ dial\ reading\ -\ Plastic\ Viscosity \tag{2}$$

where PV is in cP and YP is in $lb/100\ ft2$.

Gel strength was also directly read from the viscometer at 10 seconds and 10 minutes in the unit of lb/100 ft^2. All testing procedures were conducted according to API Recommended Practice 13-B.

Filtration Properties:

API Fluid Loss tests for each mud were performed at ambient temperature and the pressure of 100 psi with a multi-filter press, and the fluid loss volume gathered in 30 minutes was reported as an API fluid loss of fluid.

HPHT Fluid Loss tests for each mud were performed at 300° F and the pressure of 500 psi with a multi-filter press, and the fluid loss volume gathered in 30 minutes times two was reported as an API fluid loss of fluid.

Differential Pipe Sticking tests:

The tendency of mud to creating a borehole assembly (BHA) sticking problem and how the effectiveness of nano-material to prevent stuck pipe was determined by ''Differential Sticking Test'' which measures the ''Stuck Pipe Tendency Coefficient'' of mud. In this test, a torque plate will be put over the mud cake for 10 minutes, then with a spinner wrench, a rotational spinning force will be applied for moving a wrench on the surface of the mud cake. The more minor reading value for spinning force shows fewer torque problems of downhole tools and more efficiency of nano-fluids in decreasing unwanted torque. By knowing the dimension of cake that is formed during the test, the "Bulk Sticking Coefficient" is simply calculated by using Eq. (3). This coefficient takes into account friction/stickiness of the filter cake and also the thickness of the mud cake which can directly affect the stuck pipe tendency [22].

$$K_{sc} = \frac{T_u \times 0.001}{1 + 1.33 \times H} \tag{3}$$

where K_{sc} is Bulk Sticking Coefficient [22], T_u is the average of readings from the torque wrench in psi, and H is bed height which is formed on the top of above the surface of the mud cake in inches.

Density:

The mud balance was calibrated with distilled water, then cleaned and wiped dry. Then it was placed on a flat level surface and filled to the top with the mud sample. The lid was then placed on the cup, and mud was flowed out of the hole in the cup to ensure that any air bubble was moved out. The mud density was read at the rider's edge towards the mud cup after washing and drying the whole mud balance [23].

pH Value:

A digital pH meter was used to measure the concentration of hydrogen ions in an aqueous solution. The pH meter was calibrated using a sample of de-ionized water. Afterward, the sample was transferred to a beaker, and the pH meter probe was inserted into a mud sample. After waiting for 60 – 90 seconds for the reading to stabilize, the pH value was then recorded [23].

All laboratory equipment used in the following paper are listed as:

- Hamilton Beach Mixer Laboratory Scale
- Mud Balance
- Rheology: Fann 35 Viscometer

- HPHT Filtration: OFITE HTHP Filter Press
- Fann API Filter Press
- Fann Roller Oven
- pH Meter
- Lab Grade Ultrasonic Cleaners
- OFITE Differential Sticking Tester

3. Result and Discussion

3.1. Drilling Fluids Properties

Results of performed laboratory evaluations are given in Table 7.

Table 7. Rheology and filtration properties of samples 1, 2 and 3

Hot-rolling 8 hours in 300° F Rheological properties 120°F	Unit	Mud Sample 1		Mud Sample 2		Mud Sample 3	
		BHR	AHR	BHR	AHR	BHR	AHR
RPM 600		69	40	71	51	68	53
RPM 300		40	22	42	30	40	31
PV	cP	29	18	29	21	28	22
YP	$100lb/ft^2$	11	4	13	9	12	9
GEL 10 s	$100lb/ ft^2$	5	2	5	3	5	3
GEL 10 min	$100lb/ ft^2$	6	3	6	4	6	4
pH	-	9.38	8.16	9.41	8.09	9.45	8.12
API FL	cc	10.8		6.3		3.2	
HPHT FL	cc	21		9.2		4.9	
Filter cake thickness	Inch	3/32		2/32		2/32	
Foam	-	No	No	No	No	No	No
Settlement	-	No	No	No	No	No	No

Results of performed laboratory evaluations for differential sticking tests are given in Table 8.

Table 8. Differential sticking test results for muds 4,5,6 and 7

Differential Sticking Tester				
Parameters from Sticking Test	**Mud Sample 4**	**Mud Sample 5**	**Mud Sample 6**	**Mud Sample 7**
Torque Average	310	231	180	5
Thickness (H) (inch)	0.1	0.08	0.07	0.07
Ksc (Bulk Sticking Coefficient)	0.273	0.210	0.164	0.091
Sticking percent	100	76.9	60	1.5
Releasing Percent	0	23.1	40	98.5

3.1.1. Rheological Properties Comparisons

Based on laboratory evaluations, the rheological properties (PV, YP, and gel strengths) before and after hot rolling were in the same range for mud samples 1 to 3. To be more specific, yield points were slightly increased due to adding solid particles (Nano-Gilsonite) to the drilling fluid. In conclusion, PV, YP, and gel strengths were not adversely affected by nano-particles, and no flocculation or high gelation was observed. Comparing the before hot rolling and after hot rolling data indicates that rheological properties for mud samples 2 and 3 experienced less reduction (because of rolling in high temperature) due to the effect of adding Nano-Gilsonite. This nano-additive will self-distorting/melting in temperatures above its softening point and help mud viscosifiers preserve the viscosity and gel strength of mud.

Based on Table 7, after hot rolling muds for 8 hours in 300 Fahrenheit degrees, PV and YP of mud sample 2 (containing 0.5% wt./wt. Nano-Gilsonite) were 16% and 125% more than mud sample1, respectively. Mentioned increments were at the level of 22% and 125% for mud sample 2 (containing 1% wt./wt. Nano-Gilsonite) comparing with mud sample1.

Also, 10sec gel strength parameters were 50% higher for mud samples 2 and 3 than mud sample 1. In comparing 10min gel strength, mud samples 2 and 3 had 33% higher values than mud sample 1. The self-distorting/melting of nano Gilsonite resulted in bonding between water and other additives to keep mud gel strength in better condition after rolling in high temperatures.

3.1.2. Filtration Properties

According to Figure 2, the API fluid loss (FL) was sufficiently controlled, which is less than 5 cc for mud sample 3, and it is very appropriate considering the hot-rolling process for 8 hours in 300° F. Adding 0.5% wt./wt. and 1% wt./wt. of Nano-Gilsonite to a simple polymeric mud reduced API fluid loss from 10.8 cc to 6.3 cc and 3.2 cc, respectively. In addition, the HPHT fluid loss test results revealed that Nano-Gilsonite could be used in harsh environments considering the moderate fluid loss in HPHT conditions. Adding 0.5% wt./wt. and 1% wt./wt. of Nano-Gilsonite to a simple polymeric mud reduced HPHT fluid loss from 21 cc to 9.2 cc (56% reduction) and 4.9 cc (76.5% reduction), respectively.

In conclusion, test results indicate that Nano-Gilsonite would invade into rock pores, micro-fractures, and bedding planes and form a coating thin layer that prevents drilling fluid enter to the rocks. Nano Gilsonite applies a physical mechanism to minimize fluid loss rather than a chemical mechanism. Gilsonite has superior performance to other asphaltic-type materials due to its low solubility in water and higher softening point.

Based on results, it was revealed that Nano-Gilsonite could be used as low invasion coring fluids to prevent core damages with minimizing filtrate invasion through the formation. The lower size of nano-particles covers much more space and consequently more ''pores sealing off'' and less filtration is encountered.

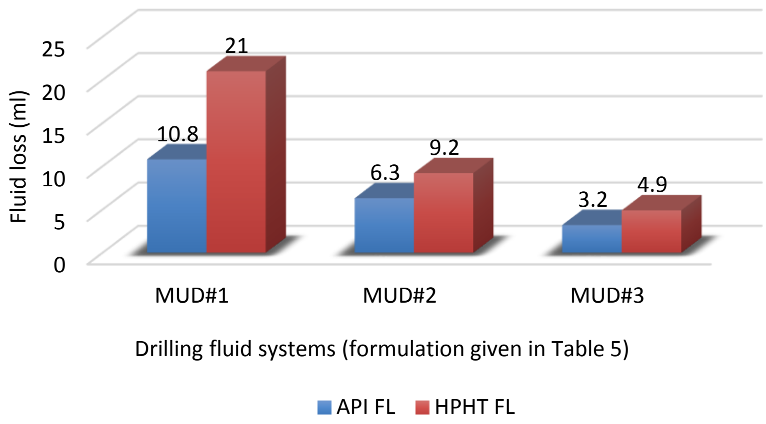

Figure 2. Comparing API fluid loss and HPHT fluid loss for mud samples 1, 2, and 3

3.1.3. pH Value

The pH of mud sample1 to 3 was at the same range between 9.38 to 9.45 instantly after mixing and range of 8.09-8.16 after 8 hours mixing. It means adding Nano-Gilsonite did not have a significant change in drilling fluids' pH.

3.1.4. Density

The density of mud samples 1 to 3 was at the same range (70 PCF) instantly after mixing and after 8 hours of mixing. It means adding Nano-Gilsonite does not affect drilling fluids' densities significantly.

3.1.5. Differential Pipe Sticking Tests

Laboratory tests showed that the proposed Nano-Gilsonite was able to reduce pipe sticking in common drilling fluids (mud sample 1) up to 98.5% by adding 2% w/w of nano-particles. Nano-Gilsonite changed the morphology and surface properties of mud cake on wellbore or casing surfaces. Nano-Gilsonite decreases the contact surface between metallic tools and borehole area, and decreases unwanted torque forces inside the well. The high surface area to volume ratio of Nano-Gilsonite provides a significant surface-covering capability which is applied between formations and drilling downhole equipment. Besides that, Nano-Gilsonite's addition to water-based drilling fluids helps reducing hole washout by strengthening permeable formations and sealing them while reducing torque and drag. On the other hand, The Nano-Gilsonite mitigates borehole erosion due to plugging microfractures and pore spaces and depositing a thin/smooth film on the borehole surface.

As is clear in Table 8, Nano-Gilsonite's addition effectively has brought down the probability of differential sticking in drilling operations. Addition of 0.5% and 1% wt./wt. of proposed nano-particles reduced stuck pipe in mentioned tests 23% (reducing sticking percentage from 100% to 76.9%) and 40% (reducing sticking percentage from 100% to 60%), respectively. Although for almost complete reduction of differential sticking probability, 2% wt./wt. of Nano-Gilsonite was needed.

3.1.6. Filter Cake Properties

The high thickness of mud cake soars the possibility of stuck pipe while drilling. The main reason for thick mud formation is the high fluid loss in drilling fluid or settlement of cutting on mud cake while drilling or tripping. The mentioned phenomenon is shown schematically in Figure 3. Most stuck pipe problems are caused by excessive differential pressures in front of permeable zones with low pressure [24].

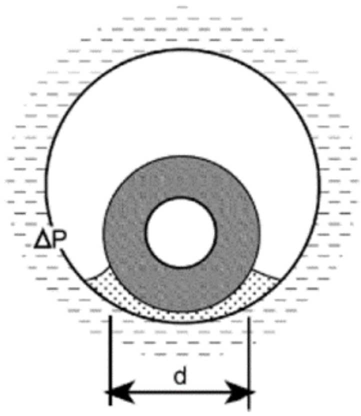

Figure 3. Differential stuck pipe because of high mud thickness [22]

Filter cake of nano-fluids (mud samples 2 and 3) were 2/32 inch, i.e. 33% thinner than filter cake of mud sample 1 which is formed in filtration test. More so, the smooth/compacted filter cakes of mud samples 2 and 3 helped in preventing the tendency to borehole assembly stuck, which will originate other incidents.

While drilling operation is performing, Nano-Gilsonite particles forms a self-distorting/melting, and consequently sealing off micro-fractures within drilling fluid cake formation and surface coating the wellbore surface- helped to create a less-permeable/homogenous filter cake in comparison with conventional muds. In fact, lowering fluid loss will lower the deposition of solids on the wellbore and consequently reduce mud cake thickness.

Based on previous research studies, dynamic fluid filtration is mainly controlled by forming mud cake at the early stage of contacting drilling fluid and rocks, and also, changes in thickness and permeability of mud cakes are not considered with passing the time [24].

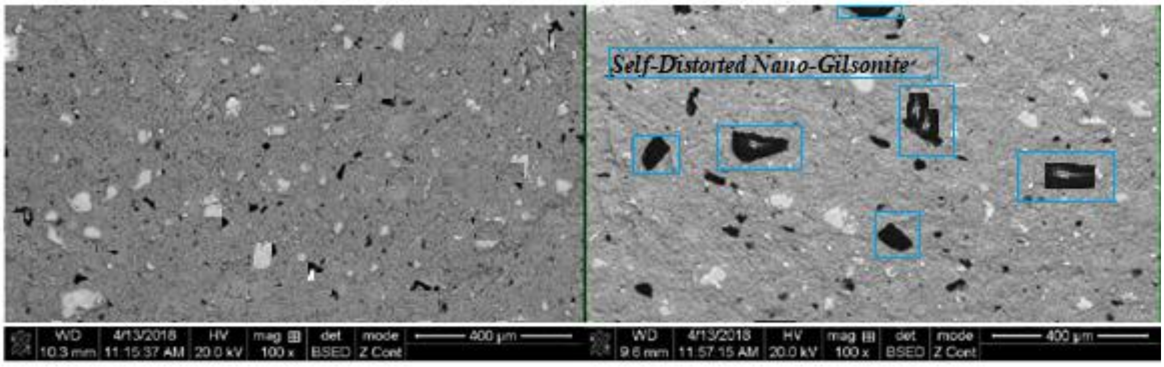

Figure 4. SEM images of filter cakes of tested drilling fluids (blank fluid (mud sample 1) in the left and nano-fluid (mud sample 4) in the right)

Figure 4 explains the physio-chemical mechanism of pore plugging for Nano-Gilsonite particles. The broad particle size distribution of applied nano-Gilsonite, and self-distorting/melting properties of Nano-Gilsonite in high temperature make them an ideal additive for filling out the pores on wellbore walls. Black areas in Figure 4 (the right side) are the self-distorted Nano-Gilsonite particles on an HPHT filter cake.

4. Conclusions

In the current study, Nano-Gilsonite effects in water-based drilling fluids were investigated. In previous studies, the effect of Nano-Gilsonite in improving filtration, filter cake thickness, and lubricity properties of muds were claimed [9,10]. The effect of Nano-Gilsonite on the prevention of drilling tools sticking problems with an experimental prospect has resulted in this paper. Also, most of the previous studies had been performed in oil-based muds, while the focus of the current study is fully on water-based mud systems.

- Proposed Nano-Gilsonite can enhance the properties of high-performance water-based muds with low effect on the rheological properties in low temperatures. Nano-Gilsonite improves the rheological properties of drilling fluid in high temperatures due to the self-distorting/melting of Nano-Gilsonite.
- Using the proposed Nano-Gilsonite eliminates the possibility of unwanted incidents such as high fluid loss in HPHT conditions, differential pipe sticking, and excessive-high torques while drilling.
- Proposed Nano-Gilsonite can decrease differential pipe sticking by forming a homogenous thin cake on the borehole surface due to the self-distorting/melting properties.
- Gilsonite is an effective additive to use for borehole stability. Proposed particles mostly fill the micropores and nano-pores on the formations and filter cake with a physical effect.
- Laboratory tests indicate that Nano-Gilsonite can improve drilling fluid performance with a minimum concentration value of 0.5 %wt./wt. In formations with the high possibility of differential pipe sticking, a concentration of 2% is recommended based on results. To be more specific, the proposed Nano-Gilsonite reduced pipe sticking up to 98.5% in the concentration of 2% w/w.

- Filter cake of fluids with Nano-Gilsonite was 2/32 inch, i.e. 33% thinner than conventional mud's filter cakes formed in filtration tests. More so, the smooth/compacted filter cake of fluids with Nano-Gilsonite helps prevent the stuck BHA/pipe incidents.

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